FINAL REPORT

Results of the Estuary Interface Pilot Study, 1996-1999

A Technical Report
of the Sources Pathways and Loadings Work Group

San Francisco Estuary Regional Monitoring Program
for Trace Substances

Jon E. Leatherbarrow, Rainer Hoenicke, and Lester J. McKee
San Francisco Estuary Institute

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Acknowledgments

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1. Introduction

1.1. Background

Results from previous monitoring efforts in the San Francisco Estuary revealed that the Estuary margins tend to have higher concentrations of several contaminants of concern compared to the deeper channels (Flegal *et al.* 1994, Hunt *et al.* 1998a). The Estuary receives contaminant loads from a variety of external pathways, including urban runoff, agricultural drainage, atmospheric deposition, and wastewater effluent discharges (Davis *et al*. 1999). To gain a better understanding of the general sources and pathways of contaminants, the San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) began to address these issues through focused workgroups and pilot studies.

1.2. Objectives

The Estuary Interface Pilot Study (EIP Study) was initiated in 1996 with the general goal of characterizing contaminant contributions from the Guadalupe River and Coyote Creek watersheds to better understand the influence of local urbanized watersheds on receiving waters in the San Francisco Estuary. To achieve this goal, two stations were monitored at the watershed-estuary interface in the Santa Clara Basin along with routine monitoring of the RMP Status and Trends Program (RMP S&T) (Figure 1). In 1996, monitoring began at a station near Standish Dam (BW10), in the upper end of the intertidal zone of the Coyote Creek. The following year, a second monitoring station was included within the tidally influenced Alviso Slough, near the mouth of the Guadalupe River (BW15). The overall objectives of this study remained consistent throughout the four-year duration of monitoring:

- Relate contaminant patterns in the Estuary with those in adjacent watersheds to determine if runoff and sediment taken at the lower end of the Coyote Creek and Guadalupe River differ from water and sediment in the Lower South San Francisco Bay (Lower South Bay).
- Explore what kinds of ancillary water quality parameters and watershed characteristics should be measured or described to explain patterns, improve sampling design, and fine-tune sampling methodology.

1.3. Questions

The initial scope and direction of the Pilot Study were driven by several questions raised by an *ad hoc* committee of local agency and public representatives in 1996 (Daum and Hoenicke 1998). The following questions address relevant issues of potential sources, pathways, transport, effects, and management actions needed to control contaminant contributions from small tributaries in the San Francisco Estuary.

Sources and Pathways
- Are there significant differences in contaminant concentrations between watershed stations and receiving waters?
- Are contaminants entering the Bay through stormwater runoff originating in lower urbanized watershed segments or upper non-urbanized watershed segments?

Transport
- Can we estimate contaminant loads to the receiving waters in the Bay?
- What methods can be used to differentiate between loadings from urban sources (non-point and point) and those of natural origin (*e.g.* erosion, atmospheric)?
- To what degree does urban runoff contribute to contaminant loading to the Bay?
- How do contaminant signatures in suspended sediments in runoff compare to Bay suspended and bottom sediments?
- How do physico-chemical processes affect contaminant speciation and fate as freshwater meets the saline waters of the Bay?
- What are the fates of contaminants of concern in the Bay?

Effects
- What are the effects of contaminant loads from tributaries on aquatic and benthic organisms in the Bay?
- What methods can be used to determine the bioavailability of contaminants to aquatic and biotic organisms?
- What is the relationship of toxicity to loading events?

Management actions
- For which contaminants should there be a high priority to focus efforts of control measures and pollution prevention?
- Which contaminants can be managed more cost-effectively by non-point source pollution prevention than by point source controls?
- How can we make connections between implementation of control measures and protection of beneficial uses?
- How do we quantify contaminant reductions due to non-point source control measures?

This report addresses issues of potential sources, pathways and loadings of contaminants from the watersheds and provides recommendations for managing water quality in the San Francisco Estuary. For this purpose, contaminant data collected from the EIP stations were analyzed in comparison to contaminant concentrations in other regions of the Estuary. As part of the general data analysis, a methodology for approximating baseline concentrations of metals in sediment was applied to RMP sediment data to estimate the extent to which sediment at the EIP stations was contaminated relative to baseline conditions in the Estuary. Contaminant concentrations in EIP water samples were also used in combination with local hydrologic data to derive rough estimates of potential contaminant loads from the watersheds and compare these estimates to loads estimated for other pathways of contamination to the Bay. Finally, EIP sediment concentrations were compared to data collected during previous sediment studies in the watersheds to evaluate differences in concentrations between potential upstream sources and RMP stations at the Estuary Interface and the Lower South Bay.

Results from the Pilot Study have been used by the San Francisco Bay Regional Water Quality Control Board (Regional Board) in developing an approach for restoring beneficial uses impaired by mercury and in prioritizing management actions in watersheds that appear to contribute PCBs from historic and current watershed sources. Furthermore, results have been used in developing appropriate monitoring elements for the Copper and Nickel Action Plans in Lower South Bay. While several focusing questions could not be addressed through the current EIP Study design, Study findings and recommendations will be considered in designing a new tributary monitoring component of the RMP to meet the RMP objective of determining general sources, pathways, and loadings of contaminants to the Estuary.

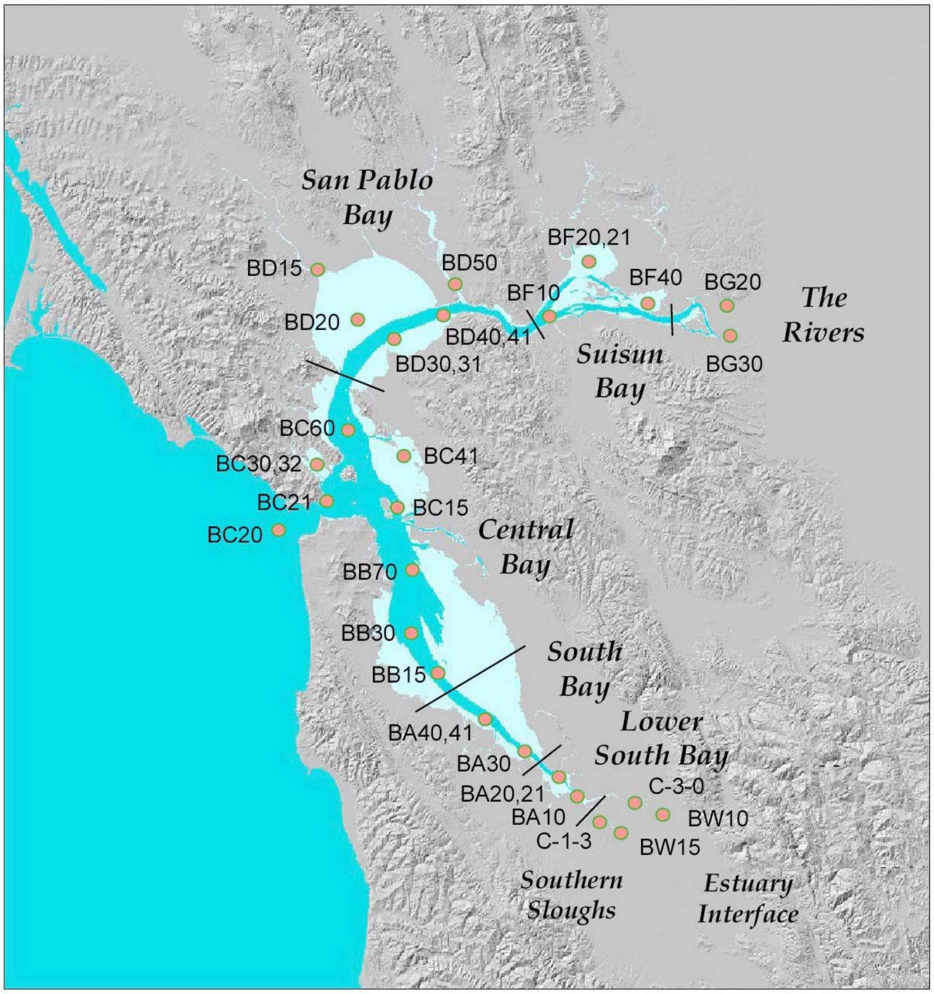

Figure 1. Map of RMP and EIP monitoring locations, 1996-1999. Monitoring stations are categorized by Bay segment: Rivers, Suisun Bay, San Pablo Bay, Central Bay, South Bay, Lower South Bay, Southern Sloughs, and the Estuary Interface. Segments were based on proposed segmentation of the Estuary developed by the RMP Design Integration Workgroup and scheduled for implementation in 2002.

2. Watershed Characteristics

Contaminant distribution and transport within a watershed are heavily influenced by characteristics such as land use patterns, geology, and hydrology. In particular, urban development typically increases impervious surface cover, which tends to accelerate runoff, alter patterns of erosion and deposition, and change patterns of water flow. EIP Study results were evaluated in consideration of land use and hydrologic factors that may have influenced water and sediment quality at the EIP stations.

2.1. Study Area

The Guadalupe River and Coyote Creek watersheds lie within the Santa Clara Basin, which includes the Lower South Bay (south of the Dumbarton Bridge) and the drainage area bounded by the Diablo and Santa Cruz mountain ranges (Figure 2). Both mountain ranges lie within the Coast Ranges, which are rich in ultramafic rocks and serpentinite soils that typically contain high concentrations of nickel and chromium (Andersen 1998, Bradford *et al.* 1996). The combined drainage area of both watersheds covers over half of the drainage area of the entire Santa Clara Basin and about 20% of the total area of watersheds tributary to the Bay in the nine Bay Area Counties.

The Guadalupe River sampling station (BW15) is located at the Alviso Yacht Club in the tidal reach of the River known as Alviso Slough. The Guadalupe River watershed encompasses approximately 170 square miles with its headwaters originating in the Santa Cruz Mountains. The Standish Dam sampling station (BW10) is located near the mouth of Coyote Creek, close to Dixon Landing Road and Highway 880 and just downstream of Standish Dam. The Coyote Creek watershed encompasses approximately 320 square miles with headwaters in the Diablo Mountains. Standish Dam (BW10) is also located upstream from the Local Effects Monitoring (LEM) station, San Jose (C-3-0), maintained by the San Jose-Santa Clara Water Pollution Control Plant and routinely monitored by the RMP for contaminants in water and sediment.

2.2. Land Use

The Coyote Creek watershed has historically been dominated by agricultural land use and still contains the largest contiguous area of agricultural land in the Santa Clara Basin (SCBWMI 2000). The Guadalupe River watershed contains several historic mercury-mining sites, most notably, the New Almaden mining district, which was the largest producer of mercury in North America. As rapid urban development and industrialization occurred in the twentieth century, land use in both watersheds converted to high-density urbanized land use in downstream areas. According to data compiled by the Santa Clara Basin Watershed Management Initiative (SCBWMI 2000), the Guadalupe River watershed is comprised of approximately 43% urban land uses, compared to 12% urban land use coverage in the Coyote Creek watershed. Of all the urban landscape in the Santa Clara Basin, the watersheds of the Guadalupe River and Coyote Creek comprise 25% and 15%, respectively.

2.3. Precipitation and Streamflow

Precipitation and streamflow data from the closest gaging stations were evaluated in relation to EIP sampling dates (Figure 3). Rainfall data were collected by the City of San Jose, station 131 (Alert ID 1453), which is maintained by the Santa Clara Valley Water District (SCVWD). Streamflow in Alviso Slough was estimated using data from the USGS station at Guadalupe River at San Jose (11169000), located approximately 11 km from the sampling station (BW15) (USGS 2001). Beginning in January 1999, the USGS began monitoring streamflow near the mouth of the Coyote Creek above Highway 237 in Milpitas (11172175). Before then, streamflow near Standish Dam (BW10) was estimated by combining flow data from SCVWD gauges on Coyote Creek at Edenvale (Station 58) and Upper Penitencia Creek (Station 83) provided by SCVWD (D. Daves, SCVWD, pers. comm.).

2.4. Reservoirs

Water flow in the Guadalupe River and Coyote Creek is heavily regulated by the SCVWD through the use of several reservoirs in the watersheds. Coyote and Anderson Reservoirs lie in the upper watershed of the Coyote Creek, with drainage areas of approximately 121 square miles and 193 square miles, respectively (SCBWMI 2000). Five major reservoirs exist in the Guadalupe River watershed with a combined drainage area of 63 square miles (USACE and SCVWD 2001). Of the drainage area not regulated by the upstream reservoirs above the USGS gaging station at San Jose (81 square miles), approximately 89% is heavily urbanized (USACE and SCVWD 2001).

Although water supply and use is regulated on Coyote Creek and Guadalupe River, contaminants associated with suspended sediment and retained by reservoirs may be released and transported to the Bay during spillway overflows. Almaden Reservoir, which drains into Alamitos Creek upstream from the Guadalupe River, reached capacity during winter sampling in 1997 and 1998. However, excess water is usually directed from Almaden Reservoir to Calero Reservoir during storm events. The prolonged wet period in early 1998 did, however, cause Calero Reservoir to overflow from February 3rd to February 24th, which coincided with wet-season sampling (E. Olson, SCVWD, pers. comm.). Therefore, samples collected at Guadalupe River (BW15) on February 4th and 5th, 1998 may have been influenced by the water quality of overflow from the Calero Reservoir.

Figure 2. Map of Guadalupe River and Coyote Creek watersheds. The map shows the locations of the EIP stations at Guadalupe River (BW15) and Standish Dam (BW10), RMP stations at South Bay (BA20,21) and Coyote Creek (BA10), and the Local Effects Monitoring stations at San Jose (C-3-0) and Sunnyvale (C-1-3). Santa Clara Valley Water District (SCVWD) stream gauges are located at Upper Penitencia Creek (station #83) and Coyote Creek (#58). The SCVWD rain gauge is located in the City of San Jose (station 131). USGS stream gauges are located at Coyote Creek above highway 237 (11172175) and Guadalupe River at San Jose (11169000).

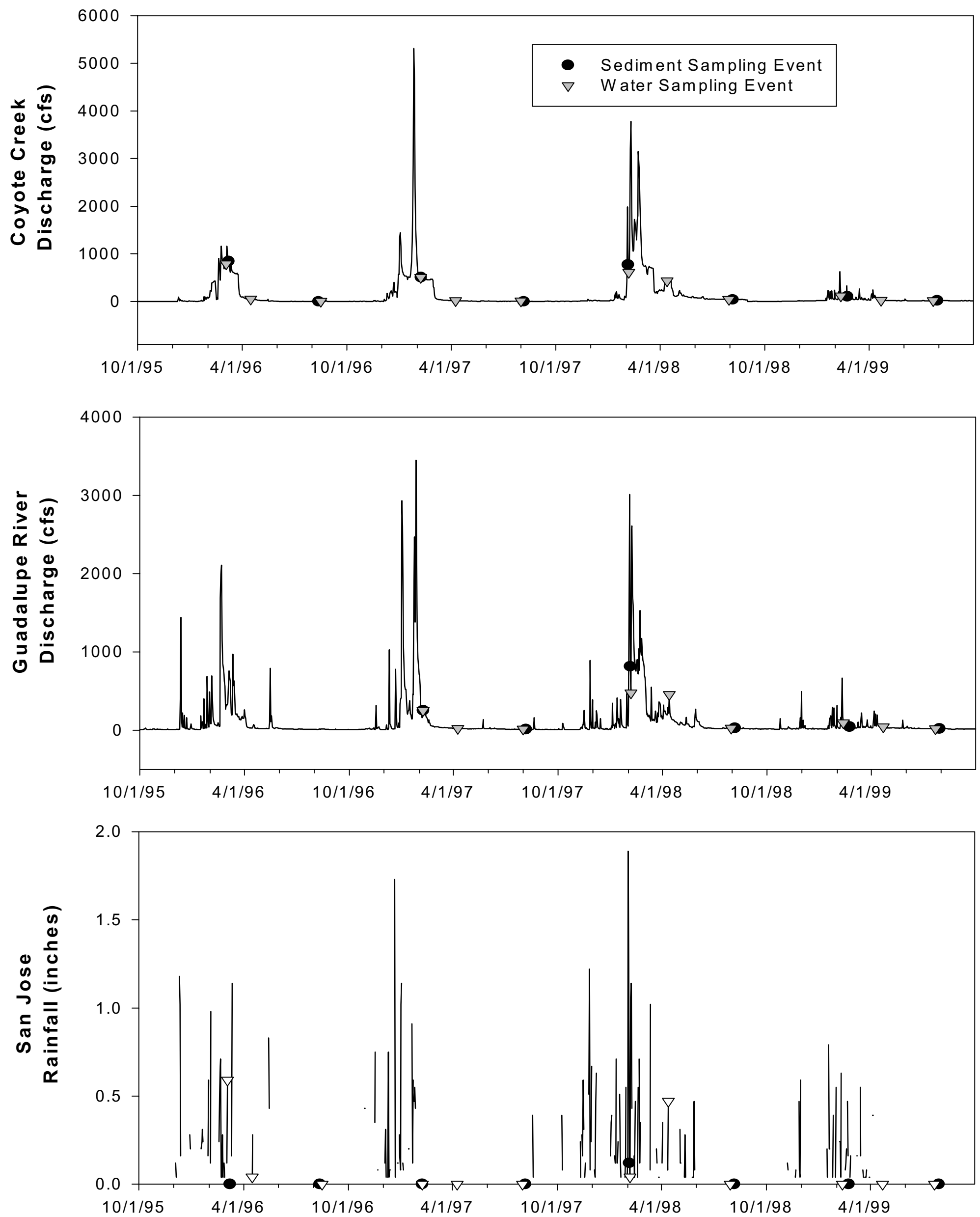

Figure 3. Streamflow and rainfall near the EIP stations on Coyote Creek and Guadalupe River. EIP water (∇) and sediment (•) sampling dates are marked on the hydrographs and hyetograph. Coyote Creek discharge from 1996-1998 was calculated by combining flow data from SCVWD gauges on Coyote Creek at Edenvale (Station 58) and Upper Penitencia Creek (Station 83). Discharge data from 1999 was obtained from USGS station Coyote Creek above Highway 237 at Milpitas (11172175). Guadalupe River discharge data from 1996-1999 was obtained from USGS station Guadalupe River at San Jose (11169000). Daily rainfall was measured at station 131 in the City of San Jose, maintained by SCVWD.

3. Methods of Sampling and Analysis

3.1. Sampling Design

EIP sampling was performed in conjunction with the RMP Status and Trends Program (S&T) and followed sampling protocols described in the Field Sampling Manual for the Regional Monitoring Program for Trace Substances (David *et al.* 2001). Detailed information for all sampling events exists in various RMP cruise reports maintained by Applied Marine Sciences, with recent sampling cruises available on their website (AMS 2002).

Water was sampled three times a year, during the wet season (January-February), the transitional season of receding Delta outflow (April), and the dry season (July-August). Sediment sampling occurred only twice a year, during the wet and dry seasons. The monitoring design was originally designed for sampling to occur on the out-going tide. However, both EIP stations were sampled on the same day for each monitoring event, which often prevented collecting samples on the same tidal cycle. Sampling information and site locations for all RMP stations are provided in Appendix A, Table A.1.

3.2. Laboratory Analysis

Laboratory analysis, quality control procedures, and compliance with data quality objectives (DQOs) were conducted in accordance with the 1999 Quality Assurance Project Plan for the Regional Monitoring Program for Trace Substances (QAPP) (Lowe *et al.* 1999). Specific quality assurance and control summaries for analyses of water and sediment samples from 1996 through 1999 are available in the various RMP Annual Reports (*e.g*., SFEI 2000). Parameters measured in water and sediment by the RMP are provided in Appendix A, Table A.2. Of the two Southern Slough stations, only San Jose (C-3-0) was monitored for organic contaminants in water.

3.3. Data Evaluation

Bay Segmentation

For comparisons between the EIP stations and different regions of the Bay, the S&T stations were grouped into seven larger sub-regions or ‘segments’ that represent similar hydrodynamic conditions (Table 1). RMP stations have historically been divided into segments based on segmentation outlined by the Regional Board’s Basin Plan (CRWQCBSFB1995). The RMP Design Integration Workgroup (DIWG) has recently developed a modified segmentation scheme based on similarities in hydrodynamic characteristics. The segments used in the EIP study were based on the modified segments recommended by the RMP DIWG.

Temporal Comparisons

RMP data were collected on an annual and seasonal basis to evaluate temporal variation in water and sediment quality. Although data from 1989 (a critically dry year) were available for several contaminants at S&T stations, EIP Study years have all been classified as wetter than average (Roos 1999). Therefore, only data from 1996-1999 were included in comparisons between EIP stations and S&T stations grouped by segment.

Water quality data collected from the EIP stations and streamflow data collected from nearby stream gauges were used to categorize water-sampling dates as either wet- or dry-season conditions (Table 2). Wet-season water samples were characterized by samples with salinity less than 0.5 ‰ and a conductivity range of approximately 320-680 µmho at Guadalupe River (BW15) and 340-550 µmho at Standish Dam (BW10). The water sample collected from Standish Dam (BW10) on March 4, 1996 was not included in the statistical analyses because sampling occurred approximately one month later than monitoring of other RMP stations. On EIP wet-season water sampling dates, mean daily discharge ranged from approximately 93-480 cfs in the Guadalupe River and 110-620 cfs in Coyote Creek. Dry-season water samples generally had higher concentrations of salinity and conductivity.

3.4. Data Analysis

General Data Analysis

All results for the Pilot Study were reviewed for quality assurance and control in accordance with the RMP QAPP and considered final as reported by the RMP (http://www.sfei.org/rmp/data.htm). Consequently, no outliers were identified or removed before statistical analysis of data. Analytical results reported below detection for trace elements were changed to a value equal to ½ the method detection limit. Results reported below detection for organic contaminants were replaced with a value of zero. Adding numerous individual congeners found below the detection limit would artificially inflate the total PCB or PAH concentrations calculated as the sum of those analytes.

Comparison to Guidelines

To evaluate the conditions of the sampling locations in terms of relevant water and sediment quality guidelines, contaminant concentrations measured by the RMP were compared to various guidelines and objectives (Appendix B, Table B.1). Concentrations of dissolved trace elements and total organic contaminants (dissolved + particulate) in water were compared to water quality guidelines from the U.S. Environmental Protection Agency's California Toxics Rule (CTR) (USEPA 2000). Concentrations of total trace elements in water were compared to hardness-dependent objectives calculated using procedures specified in the CTR. A criterion for diazinon is not included in the CTR, but RMP data were compared to the guideline of 40,000 pg/L developed by the California Department Fish and Game (Menconi and Fox 1994). Furthermore, a criterion for chlorpyrifos is not listed in the CTR, but EPA does have a recommended criterion of 56,000 pg/L (USEPA 1999).

In the absence of regulatory criteria for sediment contaminant concentrations in the San Francisco Estuary, RMP data have historically been compared to a variety of sediment quality guidelines (Appendix B, Table B.2). Effects range-low (ERL) and effects range-median (ERM) concentrations were developed by Long and Morgan (1990) and Long *et al.* (1995) to represent concentrations above which organisms "occasionally" or "frequently" exhibit adverse effects, respectively. For more region-specific comparisons of sediment data, the Regional Board developed "ambient sediment concentrations" (ASC) based on the 85^{th} percentile of ambient concentrations collected by the RMP and the Bay Protection Toxic Cleanup Program Reference Site Study (Hunt *et al.* 1998b) from 1991-1996 (Gandesbery 1998). These concentrations were developed to represent an approximation of contemporary ambient conditions of sediment contamination in the Bay, to which contaminant concentrations in RMP sediment samples were compared for assessment of potential sediment "degradation." The guidelines provide only an informal screening tool for evaluating whether contaminant concentrations in sediment may warrant further investigation. To assess whether potential effects on organisms may actually occur, this information must be used in conjunction with appropriate methods for determining the existence or extent of site-specific toxicity.

EIP samples were characterized by variable salinity (0 - 4.5‰), indicative of estuarine influence, and muddy sediments (> 40% fines) [defined by the percentage of fine-grained material (% fines) less than 63 µm in diameter]. Therefore, water-monitoring results were compared to water quality objectives on a freshwater basis (Table B.1), while sediment data were compared to ERL and ERM guidelines, as well as ASC concentrations for muddy sampling locations (> 40% fines) (Table B.2).

Statistical Analysis

Comparisons of contaminant concentrations in water were made on a seasonal basis by grouping wet- and dry-season results for each segment. Contaminant concentrations in sediment from both seasons were pooled together and grouped by Bay segment for comparison to EIP data. Differences in contaminant concentrations between EIP stations and other segments of the Bay were evaluated using the nonparametric Kruskal-Wallis analyses of variance at a significance level (α) of 0.05. In this study, the null hypothesis stated that no significant difference in contaminant concentrations existed between compared groups. For tests in which the null hypothesis was rejected, statistical tests of one-way ANOVA on the ranks of data were performed using Tukey-Kramer multiple comparison tests to determine which groups had significantly different concentrations. Descriptive statistics and results from the Kruskal-Wallis and Tukey-Kramer tests are listed in Appendix C, Tables C.1-C.6.

Table 1. RMP monitoring stations and Estuary segments. Segments were based on proposed segmentation of the Estuary developed by the Design Integration Workgroup of the RMP and scheduled for implementation in 2002. Different station codes represent slightly different station locations between water and sediment sampling. NS = not sampled.

Station Code		RMP	Bay	Segment
water	sediment	Station	Segment	Code
BW10	BW10	Standish Dam	Estuary Interface	EIP
BW15	BW15	Guadalupe River		
C-3-0	C-3-0	San Jose	Southern Sloughs	SS
C-1-3	C-1-3	Sunnyvale		
BA10	BA10	Coyote Creek	Lower South Bay	LSB
BA20	BA21	South Bay		
BA30	BA30	Dumbarton Bridge	South Bay	SB
BA40	BA41	Redwood Creek		
BB15	BB15	San Bruno Shoal	Central Bay	CB
BB30	BB30	Oyster Point		
BB70	BB70	Alameda		
BC11	BC11	Yerba Buena Island		
BC20	NS	Golden Gate		
NS	BC21	Horseshoe Bay		
BC30	BC32	Richardson Bay		
BC41	BC41	Point Isabel		
BC60	BC60	Red Rock		
BD15	BD15	Petaluma River	San Pablo Bay	SPB
BD20	BD22	San Pablo Bay		
BD30	BD31	Pinole Point		
BD40	BD41	Davis Point		
BD50	BD50	Napa River		
BF10	BF10	Pacheco Creek	Suisun Bay	SUB
BF20	BF21	Grizzly Bay		
BF40	BF40	Honker Bay		
BG20	BG20	Sacramento River	Rivers	Riv
BG30	BG30	San Joaquin River		

Table 2. Water quality and streamflow data at the Estuary Interface. Salinity, temperature and conductivity were measured at Standish Dam (BW10) and Guadalupe River (BW15). Coyote Creek discharge from 1996-1998 was calculated by combining flow data from SCVWD gauges on Coyote Creek at Edenvale (Station 58) and Upper Penitencia Creek (Station 83). Discharge data from 1999 were obtained from USGS station Coyote Creek above Highway 237 at Milpitas (11172175). Guadalupe River discharge data from 1996-1999 was obtained from USGS station Guadalupe River at San Jose (11169000). Wet-season water sampling dates appear in bold italics. NA = not available. NS = not sampled. . = no data.

Sampling Date	Sample Type	Coyote Creek				Guadalupe River			
		Discharge (cfs)	Conductivity (µmho)	Temperature (°C)	Salinity (o/oo)	Discharge (cfs)	Conductivity (µmho)	Temperature (°C)	Salinity (o/oo)
3/4/96	wat	789	2,500	14	0.00	NS	.	.	.
3/8/96	sed	846	.	.	.	NS	.	.	.
4/16/96	wat	52	1,030	18	0.80	NS	.	.	.
8/12/96	sed	2	.	.	.	NS	.	.	.
8/16/96	wat	3	7,800	26	3.10	NS	.	.	.
2/7/97	***wat, sed***	***509***	***340***	***12***	***0.02***	***253***	***490***	***14***	***0.09***
4/9/97	wat	18	NA	18	4.50	23	NA	17.1	2
8/1/97	wat	10	1,123	24	0.00	12	4,580	23	2.30
8/7/97	sed	5	.	.	.	11	.	.	.
2/4/98	sed	770	.	.	.	816	.	.	.
2/5/98	***wat***	***615***	***533***	***12***	***0.09***	***478***	***466***	***13***	***0.14***
4/13/98	***wat***	***432***	***422***	***14***	***0.13***	***456***	***317***	***14***	***0.02***
7/30/98	wat	44	1,250	21	0.50	26	1,200	22	0.50
8/6/98	sed	41	.	.	.	26	.	.	.
2/11/99	***wat***	***113***	***553***	***8***	***0.00***	***93***	***683***	***12***	***0.10***
2/18/99	sed	98	.	.	.	94	.	.	.
4/22/99	wat	29	1,240	17	0.40	41	1,170	18	0.30
7/22/99	wat	17	1,436	19	0.70	18	1,304	21	0.50
7/28/99	sed	17	.	.	.	20	.	.	.

4. Results

4.1. Water Monitoring Results

Based on salinity, conductivity, and streamflow data, wet-season EIP water samples were consistently characterized as freshwater, which suggests that the samples were primarily comprised of runoff from the watersheds. Conversely, dry-season water samples had higher salinity and conductivity, indicative of mixing of Bay waters. To focus on the potential influence of surface runoff from the watersheds on conditions at the EIP stations and Lower South Bay, wet-season water monitoring results are emphasized in this section and the discussion that follows. Descriptive statistics for water monitoring results and results from Kruskal-Wallis and Tukey-Kramer tests are given in Appendix C (Tables C.1-C.4).

Contaminant concentrations measured in water at the EIP stations were compared to pooled concentrations from other Bay segments on a seasonal basis for trace elements (Figure 4) and organic contaminants (Figure 5). In addition, concentrations of individual samples were compared to freshwater quality guidelines to determine the extent to which designated uses may be impaired at each EIP station by trace elements (Table 3) and organic contaminants (Table 4). Based on these comparisons, several contaminants were identified as potential contaminants of concern.

Trace Elements in Water

Mercury – Wet-season concentrations of total mercury in water ranged from 0.06 µg/L to 0.73 µg/L at Guadalupe River (BW15) (median = 0.077 µg /L) and from 0.022 µg/L to 0.064 µg/L at Standish Dam (BW10). Maximum concentrations measured in Guadalupe River samples from both seasons were at least three times higher than concentrations measured at any other RMP station. All of the water samples collected from Guadalupe River (BW15) and 58% of the samples from Standish Dam (BW10) exceeded the Basin Plan freshwater guideline of 0.012 µg/L for total-recoverable mercury in freshwater. Total mercury concentrations measured in wet-season water samples from Guadalupe River (BW15) were significantly higher than concentrations in the Lower South Bay, South Bay, Central Bay, Suisun Bay, and the Rivers ($p < 0.0001$).

Selenium – The highest concentrations of total and dissolved selenium were measured in Guadalupe River (BW15) water (7.22 µg/L and 6.42 µg/L, respectively). Approximately 44 % of the samples collected from Guadalupe River had concentrations higher than the CTR freshwater objective of 5 µg/L. Dissolved selenium concentrations, which comprise most of the measured selenium, were significantly higher in wet-season samples from Guadalupe River (BW15) and Standish Dam (BW10) than all segments north of South Bay (i..e. Central Bay, San Pablo Bay, Suisun Bay, and the Rivers) ($p < 0.0001$).

Organic Contaminants in Water

Polychlorinated Biphenyls (PCBs) – Total (dissolved + particulate) concentrations of PCBs in water at Guadalupe River (BW15) ranged from approximately 3,600 pg/L to 6,100 pg/L during the wet season (median = 5,350 pg/L) and from 2,100 pg/L to 7,200 pg/L during the dry season (median = 3,000 pg/L). Therefore, all samples collected at Guadalupe River exceeded the CTR freshwater objective of 170 pg/L for total PCBs. Total and dissolved PCB concentrations were significantly higher in wet-season water samples from Guadalupe River (BW15) compared to segments north of the South Bay ($p < 0.0001$).

Total PCB concentrations in Standish Dam (BW10) water samples ranged from 1,100 pg/L to 7,000 pg/L during the wet season (median = 3,900 pg/L) and from 1,400 pg/L to 4,000 pg/L during the dry season (median = 2,400 pg/L). All samples from Standish Dam also exceeded the objective of 170 pg/L. Similar to Guadalupe River (BW15), wet-season concentrations of total PCBs in Standish Dam (BW10) water were also significantly higher than concentrations measured in segments north of the South Bay ($p < 0.0001$).

Polycyclic Aromatic Hydrocarbons (PAHs) – The median dry-season concentration of total PAHs (250 ng/L) was approximately twice as high as the median wet-season concentration (123 ng/L) in Guadalupe River (BW15) water. PAH concentrations were generally lower in samples from Standish Dam (BW10), which ranged from 59-69 ng/L in the wet season and 10-313 ng/L in the dry season. High-molecular weight PAHs (HPAHs) comprised a large portion of the total PAH concentrations in all water samples from Guadalupe River (BW15), with most measured concentrations exceeding fresh water quality criteria for benz(a)anthracene, chrysene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-cd)pyrene (Table 4). Total PAH concentrations in wet-season water samples from Guadalupe River (BW15) were significantly higher than concentrations in segments north of the South Bay ($p < 0.0001$).

DDTs – The highest median wet-season concentrations of total DDT were measured at Standish Dam (BW10) (6,600 pg/L), Guadalupe River (BW15) (3,000 pg/L) and San Jose (C-3-0) (3,100 pg/L). Concentrations of total DDT in 86% of Standish Dam (BW10) water samples and 100% of Guadalupe River (BW15) water samples exceeded the CTR freshwater objective of 590 pg/L. Wet-season total DDT concentrations were significantly higher at Standish Dam (BW10) and Guadalupe River (BW15) than concentrations measured in the Central Bay ($p < 0.0001$).

Chlordane – Similar to DDT, the highest median concentrations of total chlordane were measured at Standish Dam (1,500 pg/L), Guadalupe River (1,300 pg/L), and San Jose (C-3-0) (840 pg/L) in the wet season. Approximately 78 % of the samples from Standish Dam (BW10) and 82% of Guadalupe River (BW15) samples exceeded the CTR freshwater objective of 570 pg/L. Wet-season concentrations of total chlordanes at Standish Dam (BW10) and Guadalupe River (BW15) were significantly higher than concentrations in segments north of the South Bay ($p < 0.0001$).

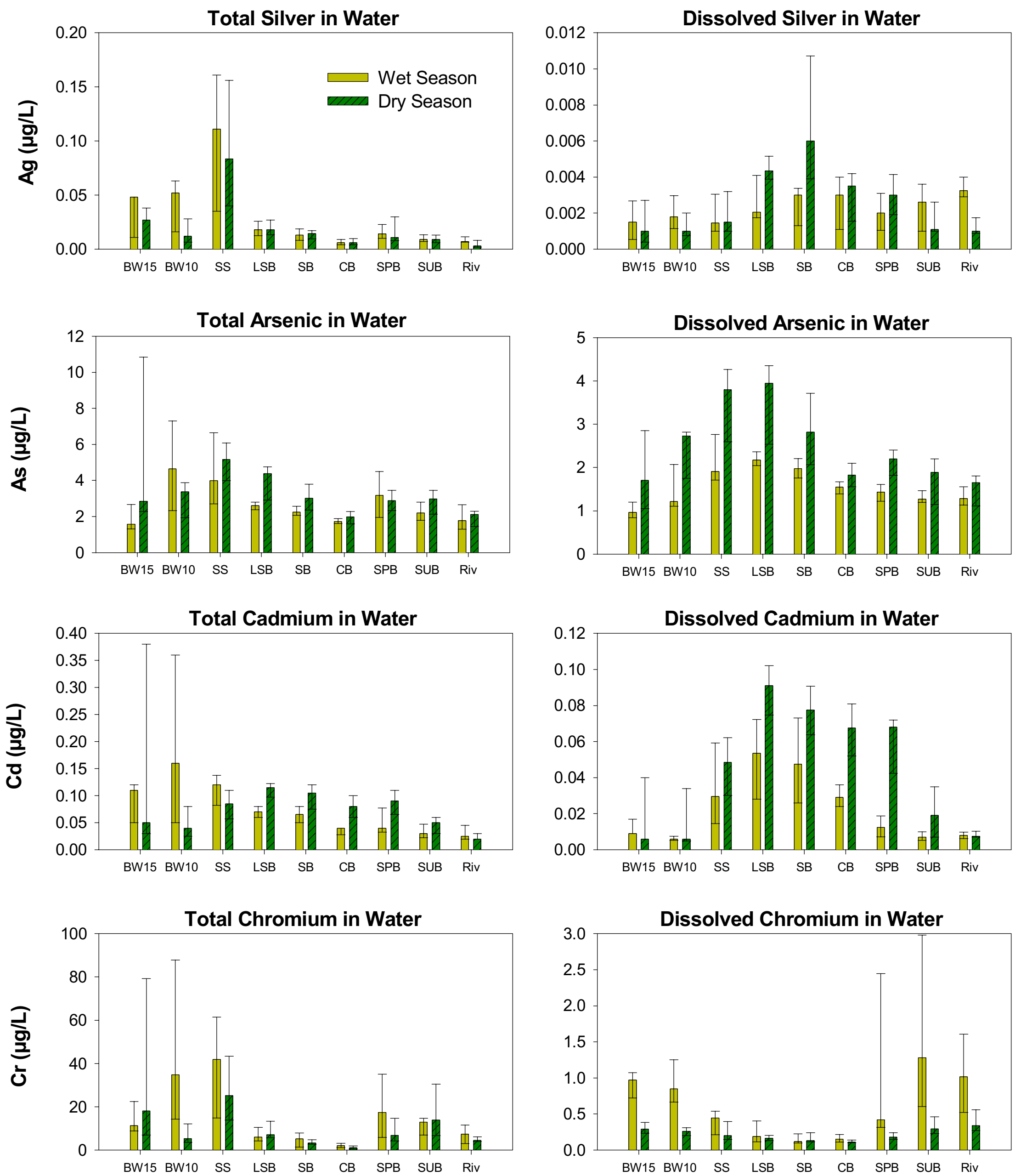

Figure 4. Trace element concentrations in water, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), Southern Sloughs (SS), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles**.**

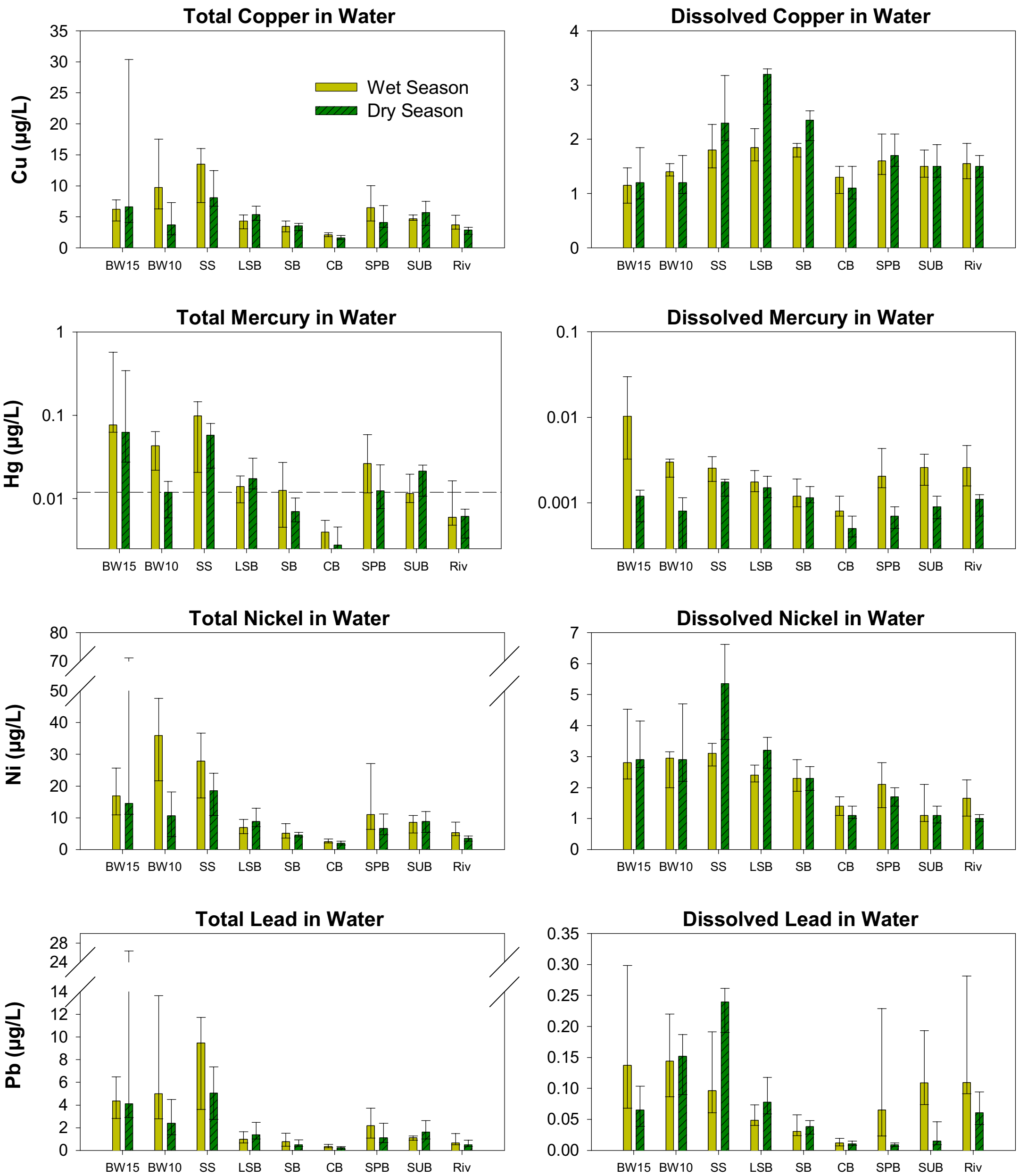

Figure 4 (cont.). Trace element concentrations in water, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), Southern Sloughs (SS), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles. Dashed line represents freshwater quality guideline listed in Table B.1. Note logarithmic scale for total and dissolved mercury.

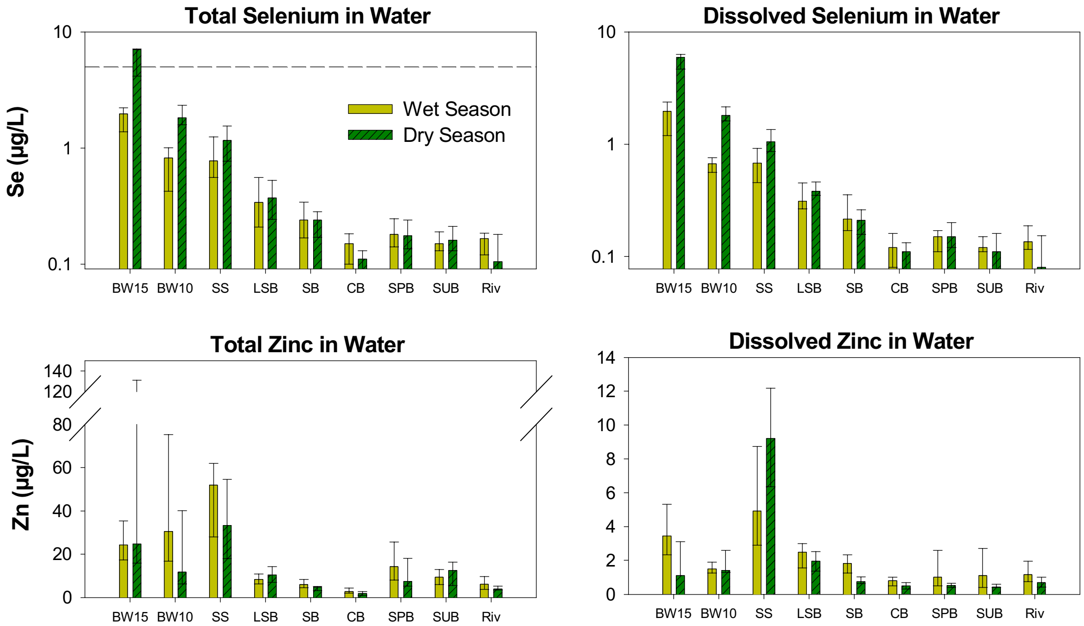

Figure 4 (cont.). Trace element concentrations in water, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), Southern Sloughs (SS), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles. Dashed line represents freshwater quality guideline listed in Table B.1. Note logarithmic scale for total and dissolved selenium.

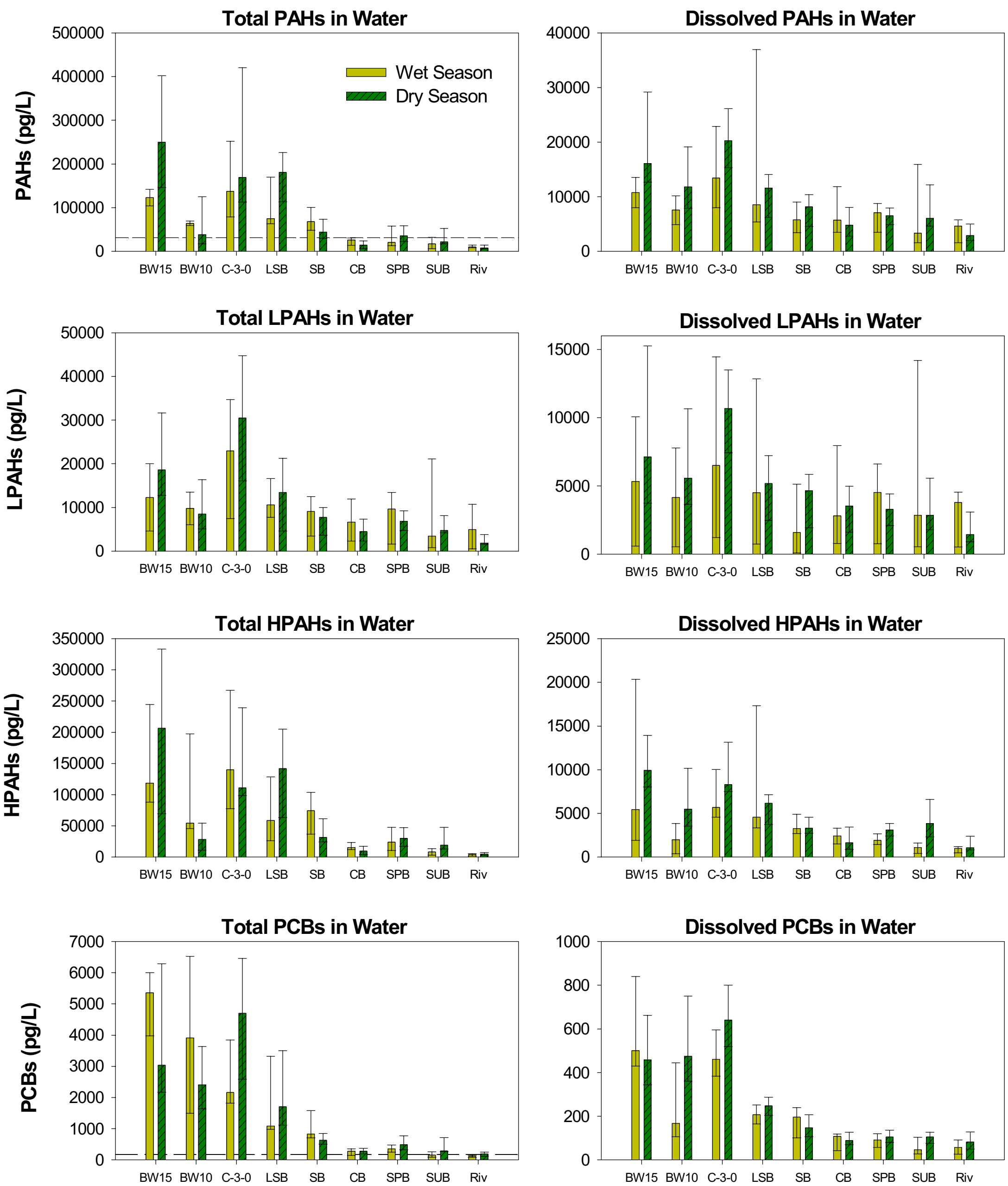

Figure 5. Organic contaminant concentrations in water, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), San Jose (C-3-0), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles. Dashed lines represent freshwater quality guidelines listed in Table B.1.

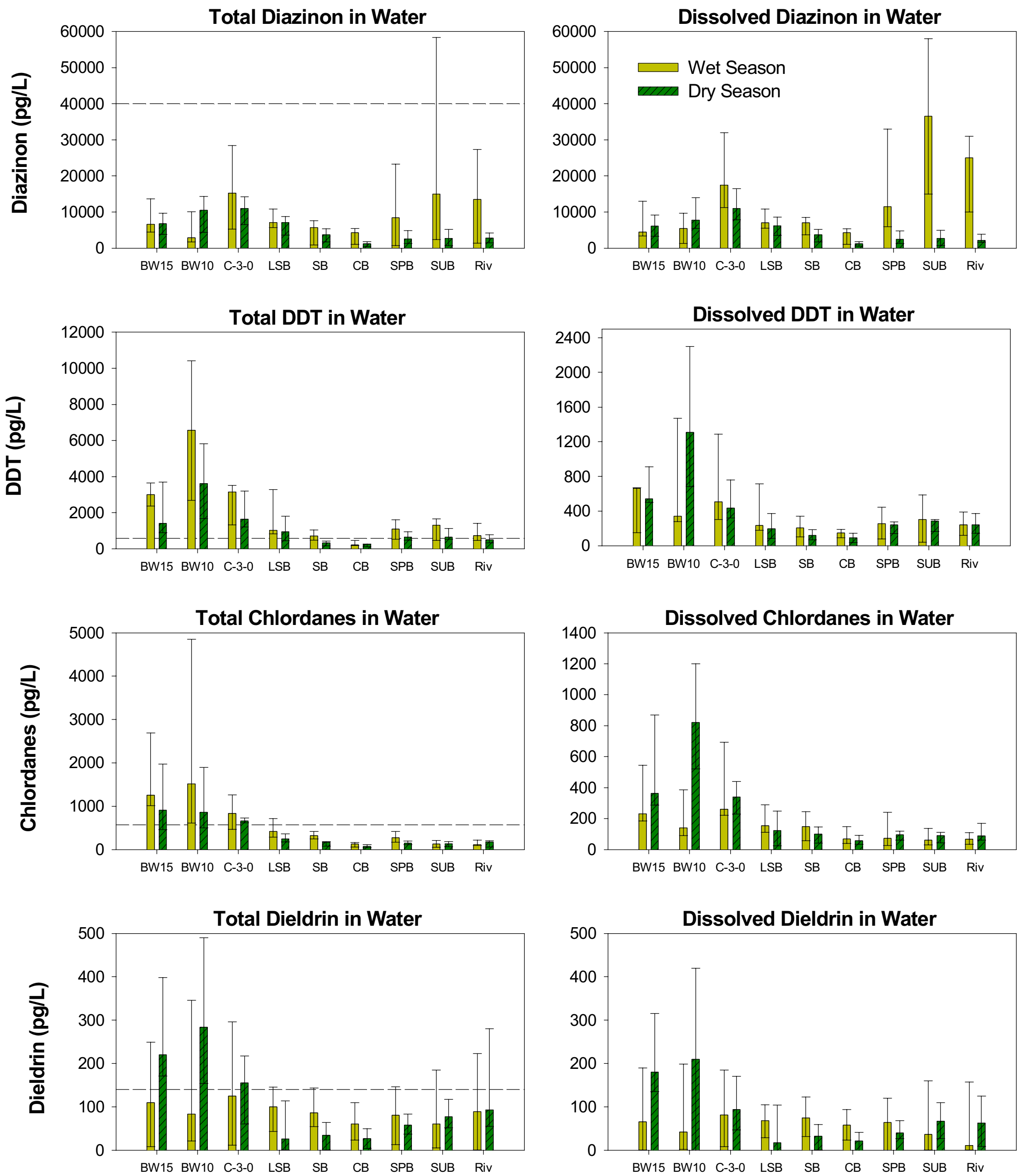

Figure 5 (cont.). Organic contaminant concentrations in water, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), San Jose (C-3-0), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25^{th} and 75^{th} percentiles. Dashed lines represent freshwater quality guidelines listed in Table B.1.

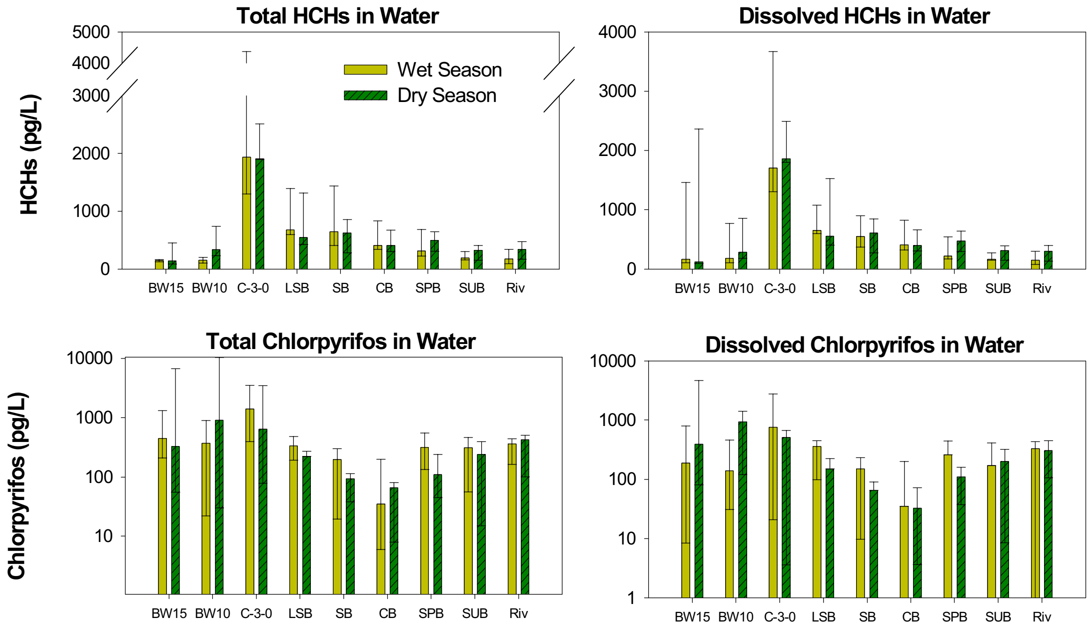

Figure 5 (cont.). Organic contaminant concentrations in water, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), San Jose (C-3-0), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25^{th} and 75^{th} percentiles. Note logarithmic scale for total and dissolved chlorpyrifos.

Table 3. Trace element concentrations in EIP water samples compared to water quality guidelines. The percentage of water samples with metal concentrations that exceeded water quality guidelines are listed. No dissolved trace element concentrations exceeded water quality guidelines in this study. Concentrations were compared to freshwater guidelines listed in Table B.1. Criteria for total trace element concentrations were calculated using procedures specified in the California Toxics Rule (CTR) (USEPA 2000). Mercury concentrations were compared to the freshwater guideline (0.012 µg/L) for total-recoverable mercury listed in the 1995 Basin Plan. h.d. = hardness dependent.

Parameter	Guideline (µg/L)	Guadalupe River (BW15) (%)	Standish Dam (BW10) (%)
Mercury	0.012	100	58
Chromium	h.d.	60	44
Selenium	5	44	0
Lead	h.d.	25	25
Copper	h.d.	11	15
Nickel	h.d.	0	23

Table 4. Organic contaminant concentrations in EIP water samples compared to water quality guidelines. The percentage of water samples with organic contaminant concentrations that exceeded water quality guidelines are listed. Concentrations were compared to freshwater guidelines listed in Table B.1

Parameter	Guideline (µg/L)	Guadalupe River (BW15) (%)	Standish Dam (BW10) (%)
Total PCBs	0.00017	100	100
p,p-DDE	0.00059	100	100
Total DDTs	0.00059	100	86
Benzo(b)fluoranthene	0.0044	100	73
Benz(a)anthracene	0.0044	100	44
Chrysene	0.0044	89	55
Indeno(1,2,3-cd)pyrene	0.0044	89	45
Chlordane	0.00057	82	78
Benzo(k)fluoranthene	0.0044	78	27
p,p-DDD	0.00083	63	17
Benzo(a)pyrene	0.0044	56	18
Dieldrin	0.00014	55	67
Heptachlor Epoxide	0.0001	40	44
p,p-DDT	0.00059	30	50
Dibenz(a,h)anthracene	0.0044	11	0

4.2. Sediment Monitoring Results

Similar to water monitoring results, contaminant concentrations in EIP sediments were compared to other segments of the Bay for trace elements (Figure 6) and organic contaminants (Figure 7). Although the figures display wet- and dry-season concentrations in sediment, statistical analyses were performed only on pooled concentrations from combined seasons. Contaminant concentrations in sediment were also compared to ERL and ERM guidelines and ASC values (> 40% fines) for trace elements (Table 5) and organic contaminants (Table 6). Prioritized contaminants in sediments are summarized below for the EIP stations. Descriptive statistics for sediment monitoring results and results from Kruskal-Wallis and Tukey-Kramer tests are listed in Appendix C (Tables C.5 and C.6).

Trace Elements in Sediment

Mercury – Of all stations monitored by the RMP, the highest mercury concentrations in sediment were measured at Guadalupe River (BW15) in both the wet (maximum = 1.08 mg/kg) and dry seasons (maximum = 0.82 mg/kg). In contrast, median concentrations of mercury in Standish Dam (BW10) sediment from wet- and dry-season sampling (0.14 mg/kg and 0.34 mg/kg, respectively) were generally consistent with concentrations measured in other segments of the Bay. One-third of the sediment samples from

Guadalupe River exceeded the ERM guideline for mercury (0.71 mg/kg) while two-thirds exceeded the ASC value (0.43 mg/kg). Mercury concentrations in sediment from Guadalupe River (BW15) were significantly higher than concentrations measured from the Central Bay and the northern reaches ($p < 0.0001$).

Selenium – Along with mercury, the Guadalupe River (BW15) sediments consistently had higher wet-season concentrations of selenium than other Bay segments (median = 0.47 mg/kg). However, dry-season concentrations of selenium were highest at Standish Dam (BW10) (median = 0.52 mg/kg). Out of all sediments sampled, only one sample from Standish Dam exceeded the ASC value of 0.64 mg/kg for selenium.

Organic Contaminants in Sediment

PCBs – As with the water monitoring results, the highest PCB concentrations in sediment were measured at the Guadalupe River (median = 42 µg/kg), Standish Dam (median = 26 µg/kg) and San Jose (C-3-0) (median = 49 µg/kg). All samples at the EIP stations exceeded the ASC value of 21.6 µg/kg, and greater than 80% exceeded the ERL guideline (22.7 µg/kg). PCB concentrations in EIP sediments were significantly higher than concentrations in segments north of the South Bay ($p < 0.0001$).

DDTs – Wet- and dry- season median concentrations of DDTs in Standish Dam (BW10) sediments were 24 µg/kg and 22 µg/kg, respectively, with a maximum concentration of 76 µg/kg. All samples from the EIP stations exceeded the ERL for DDT (1.6 µg/kg), while 25 % of the samples from Standish Dam exceeded the ERM and ASC values (both 46 µg/kg). DDT concentrations were significantly higher in Standish Dam (BW10) sediments compared to the Lower South Bay and all segments north ($p < 0.0001$). DDT concentrations measured in Guadalupe River (BW15) sediments were significantly higher than concentrations in segments north of the Lower South Bay ($p < 0.0001$).

Chlordanes – Median concentrations of total chlordane in the wet season were highest at the Guadalupe River (BW15) (8.4 µg/kg) and Standish Dam (BW10) (7.7 µg/kg). All concentrations measured at Standish Dam exceeded every guideline to which sediment results were compared for chlordanes. Guadalupe River (BW15) chlordane concentrations in all samples exceeded the ERL and ASC values (0.5 µg/kg and 1.1 µg/kg, respectively), while half of the samples exceeded the ERM guideline (6 µg/kg). Chlordane concentrations in Standish Dam (BW10) samples were significantly higher than concentrations in the Lower South Bay and all segments north, while concentrations in Guadalupe River (BW15) sediments were significantly higher than concentrations measured in segments north of the Lower South Bay ($p < 0.0001$).

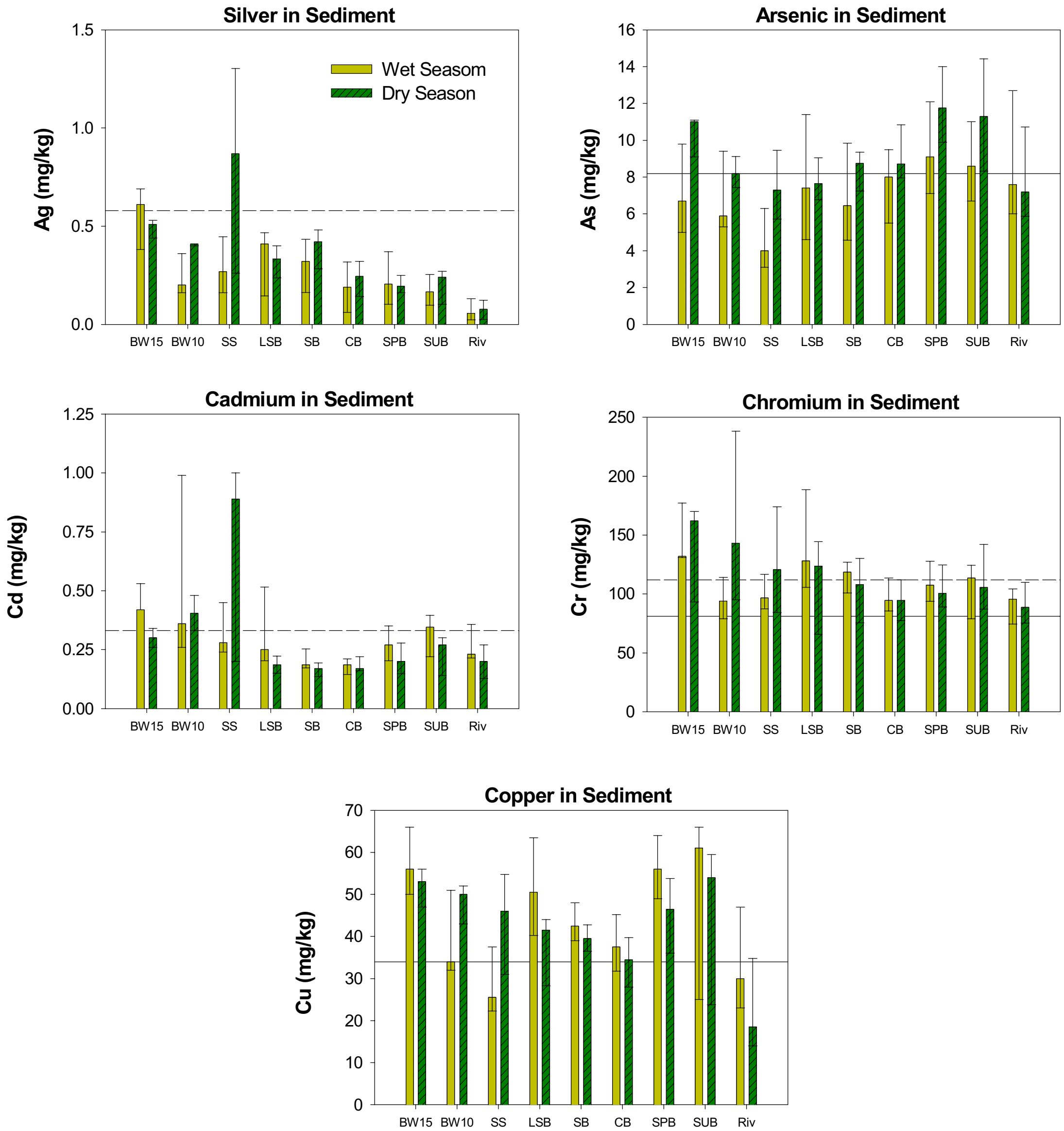

Figure 6. Trace element concentrations in sediment, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), Southern Sloughs (SS), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles. Dashed lines represent ASC values (> 40% fines) and solid lines represent ERL guidelines listed in Table B.2.

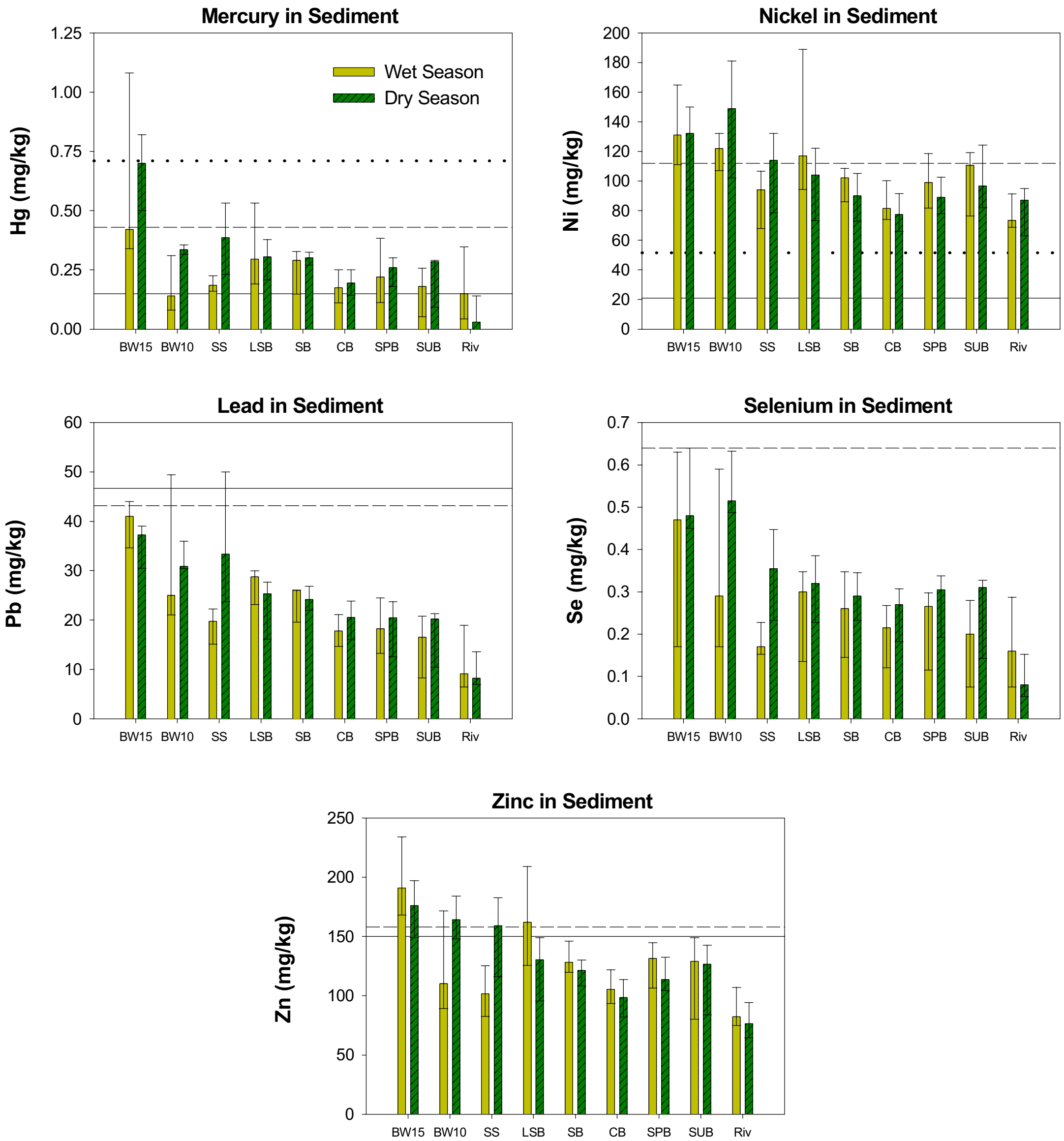

Figure 6 (cont.). Trace element concentrations in sediment, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), Southern Sloughs (SS), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles. Dashed lines represent ASC values (> 40% fines). Solid lines represent ERL guidelines. Dotted lines represent ERM guidelines. All guidelines and concentrations are listed in Table B.2.

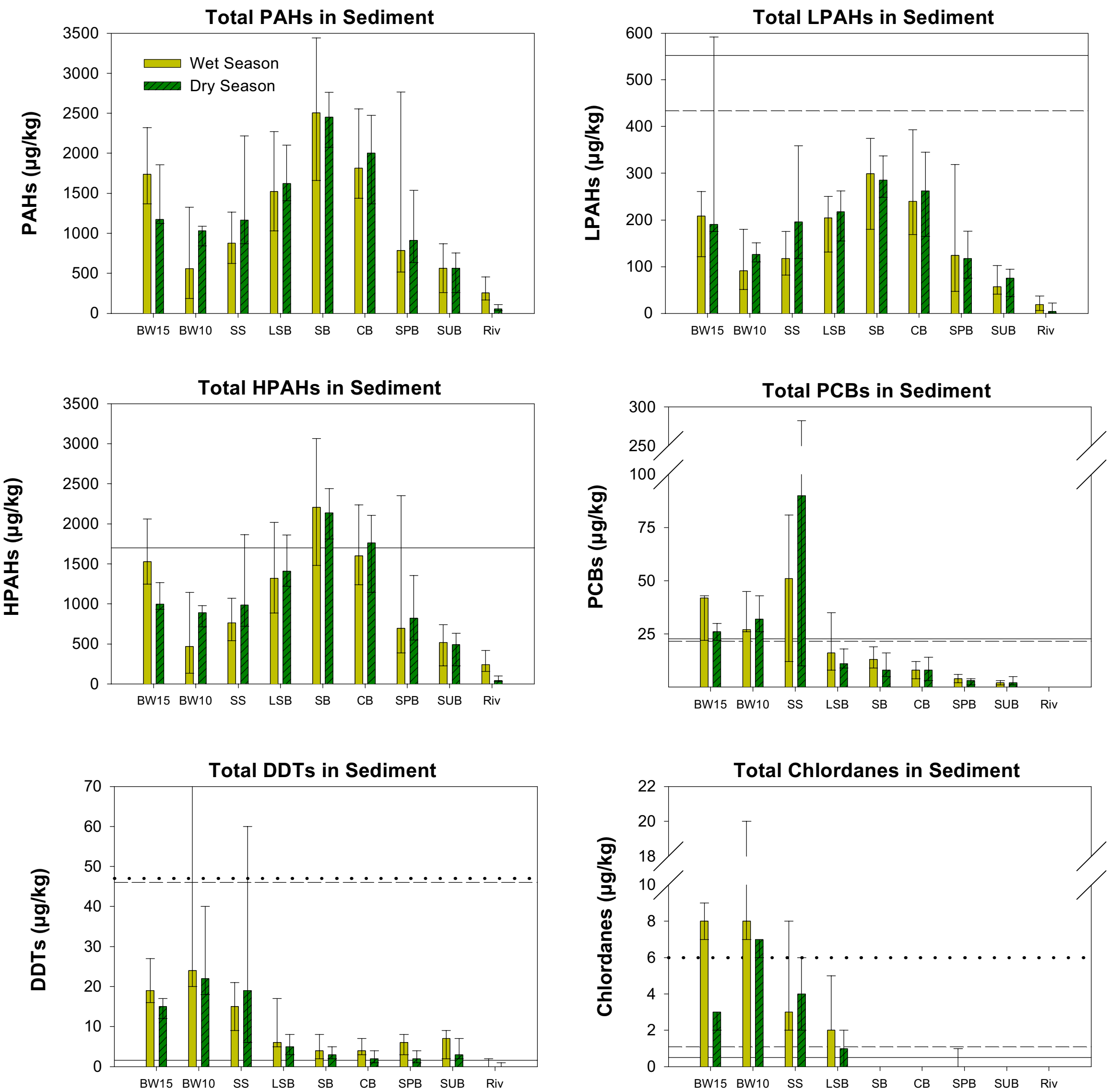

Figure 7. Organic contaminant concentrations in sediment, 1996-1999. Bars represent median concentrations at Guadalupe River (BW15), Standish Dam (BW10), Southern Sloughs (SS), Lower South Bay (LSB), South Bay (SB), Central Bay (CB), San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). Error bars represent 25th and 75th percentiles. Dashed lines represent ASC values (> 40% fines). Solid lines represent ERL guidelines. Dotted lines represent ERM guidelines. The ASC value and ERM guideline for Total DDTs are both 46.1 µg/kg. All guidelines and concentrations are listed in Table B.2.

Table 5. Trace element concentrations in EIP sediment samples compared to sediment quality guidelines. The percentage of sediment samples with trace element concentrations that exceeded sediment quality guidelines are listed. Concentrations were compared to ERL and ERM guidelines and ASC concentrations for stations with sediment > 40% fine-grained material listed in Table B.2. NA = sediment quality guideline not applicable for parameter.

Parameter	Guadalupe River (BW15)			Standish Dam (BW10)		
	ERL (%)	ERM (%)	ASC>40 (%)	ERL (%)	ERM (%)	ASC>40 (%)
Nickel	100	100	67	100	100	63
Mercury	100	33	67	63	0	0
Chromium	100	0	83	75	0	50
Copper	100	0	0	75	0	0
Zinc	83	0	83	50	0	50
Arsenic	67	0	0	50	0	0
Silver	0	0	33	0	0	0
Cadmium	0	0	80	0	0	43
Selenium	NA	NA	0	NA	NA	13
Lead	0	0	17	13	0	13

Table 6. Organic contaminant concentrations in EIP sediment samples compared to sediment quality guidelines. The percentage of sediment samples with organic contaminant concentrations that exceeded sediment quality guidelines are listed. Concentrations were compared to ERL and ERM guidelines and ASC concentrations for stations with sediment > 40% fine-grained material listed in Table B.2. NA = sediment quality guideline not applicable for parameter.

Parameter	Guadalupe River (BW15)			Standish Dam (BW10)		
	ERL (%)	ERM (%)	ASC>40 (%)	ERL (%)	ERM (%)	ASC>40 (%)
Total Chlordanes	100	50	100	100	100	100
p,p-DDE	100	0	100	100	13	100
Total PCBs	83	0	100	100	0	100
Total DDTs	100	0	0	100	25	25
Dieldrin	50	0	50	63	0	63
2-Methylnaphthalene	17	0	50	0	0	13
Total LPAHs	17	0	17	0	0	0
Total HPAHs	17	0	0	0	0	0
Fluorene	17	0	0	0	0	0
2,6-Dimethylnaphthalene	NA	NA	33	NA	NA	25
2,3,5-Trimethylnaphthalene	NA	NA	67	NA	NA	13
1-Methylphenanthrene	NA	NA	17	NA	NA	0
1-Methylnaphthalene	NA	NA	17	NA	NA	0

4.3. Sediment normalization

Contaminant concentrations in Bay sediment are variable due to differences in grain size, chemical composition of the sample, and natural contributions of metals from parent rock material. Contaminants that adsorb onto particle surfaces or partition into organic coatings on surfaces are especially affected by the particle-size distribution and the amount of organic matter present. Normalization of sediment data is often used to reduce the variability in concentrations introduced by natural factors.

Common normalization methods involve adjusting contaminant concentrations by a conservative independent variable, such as natural soil constituents that are generally not affected by human activities (*e.g*., aluminum and iron) and/or by physical parameters (*e.g*. grain size, % fines, % clay) (summarized by Schiff and Weisberg 1999). In sediment contamination studies, trace metal concentrations are *dependent* variables, parameters that are affected by contamination, while the *independent* variables are relatively independent of the influences of contamination. Several studies have consistently found linear relationships between decreasing grain size and increasing metal concentrations using different size fractions (summarized by Loring 1990). However, relationships between independent and dependent variables may be difficult to determine in regions with highly contaminated sediments because the effects of natural processes on changes in concentration may be negligible compared to the effects of spatial and temporal variation in contamination (Grant and Middleton 1998).

Methods used in this study to normalize metal concentrations in sediment are described in detail in Appendix D and based on methods outlined in previous studies of coastal sediments (Weisberg *et al.* 2000, Schiff and Weisberg 1999, Daskalaskis and O'Connor 1995). Briefly, sediment normalization methods involved evaluating the relationship between contaminant concentrations and independent variables in Bay sediments. The independent variable was chosen based on which had the best-fit linear relationship with metal concentrations. Linear regressions were then derived to represent 'baseline' or current ambient metal concentrations in the Bay. The relative degree of contamination in RMP and EIP sediment was estimated by comparing sediment data to the baseline regression. It should be noted that normalization methods used in this study addressed variation associated with only one independent variable and did not attempt to account for multiple variables simultaneously.

Results of Sediment Normalization

For RMP sediment data from 1993-1999, % fines accounted for a large proportion of the variation in five of the trace elements: mercury, silver, copper, selenium, and lead (Figure 8). Nickel, zinc, and cadmium were not as strongly correlated with % fines as they were with % iron (Figure 9). Metal concentrations were generally elevated above 'baseline' concentrations at the EIP stations and the southern segments of the Bay. In particular, all but one sample above the regression for mercury were from Guadalupe River (BW15), Southern Sloughs, and South Bay (Figure 8). Baseline linear regressions also indicate that Standish Dam (BW10) sediment had relatively high nickel concentrations compared to other segments of the Bay. Furthermore, almost all of the elevated concentrations of lead, silver, zinc, and cadmium were measured in samples from the southern segments of the Bay, with the exception of high concentrations of lead measured in sediments from Horseshoe Bay (BC21), which is in close proximity to the Golden Gate Bridge.

Total PAHs and PCBs were not strongly correlated to any of the common independent variables, possibly due to heterogeneous contamination of Bay sediments by both of these contaminants. However, a similar positive correlation was observed for both contaminants and % fines with relatively high concentrations measured in samples comprised of greater than 20% fine-grained material (Figure 10). PCB concentrations were highest in sediment samples collected from the southern segments of the Estuary. All eight samples with PCB concentrations greater than 50 µg/kg were collected from San Jose (C-3-0). When San Jose (C-3-0) sediment samples were removed from the regression, a more apparent positive correlation was observed, with highest concentrations represented by sediment samples from Guadalupe River (BW15), Standish Dam (BW10), Lower South Bay, and South Bay (Figure 11). In contrast, relatively high PAH concentrations (> 4,000 µg/kg) were collected from stations located along the deeper channels of the Lower South Bay, South Bay, Central Bay, and Northern Estuary (Figure 10). This suggests that contamination of Bay sediments by PAHs may occur from more diffuse sources throughout the Estuary.

Contamination Represented by Enrichment Factors

The extent to which concentrations were enriched above baseline conditions was numerically represented by enrichment factors, ratios of the actual concentrations to the concentrations predicted from the linear regressions. For example, an enrichment factor of two (EF = 2) means that the mean concentration was twice as high at a particular site as the baseline concentration. Enrichment factors were used to depict more accurate spatial differences in sediment metal contamination between the EIP stations and other stations in the southern segments of the Bay (Figure 11). At Guadalupe River (BW15), mean enrichment factors were distinctly elevated for mercury (1.9), lead (1.6), and silver (1.6). Standish Dam (BW10) was enriched in nickel compared to the other sites (mean = 1.4). San Jose (C-3-0) had higher mean enrichment factors than any other site for silver (4.1), copper (1.3), lead (2.0), and cadmium (3.7), and an enrichment factor as high as Guadalupe River (BW15) for mercury (1.9). Concentrations of these metals are assumed to be elevated throughout the Estuary due to the impact of anthropogenic activity (Flegal *et al.* 1994).

Effective normalization can be illustrated with greater precision in contaminant data and a reduction in the coefficient of variation (CV) (Hebert and Keenleyside 1995). For selected RMP stations in proximity to the Lower South Bay, CV values were compared between mercury concentrations in sediment and enrichment factors derived from the baseline mercury regression in Figure 8 (Table 7). RMP stations with the greatest decrease in CV values coincided with sediment samples that had the broadest range of % fines: San Jose (C-3-0), Sunnyvale (C-1-3), and Coyote Creek (BA10). The two stations for which CV values did not decrease were Guadalupe River (BW15) and South Bay (BA21), where samples were consistently comprised of sediment greater than

80% fines. The relationship between range of % fines and CV values indicates that normalization was effective in reducing variation in samples with a wide range of particle-size distribution.

Table 7. Coefficients of variation for mercury concentrations and enrichment factors in sediment from the EIP stations and RMP stations in the Lower South Bay and Southern Sloughs. Coefficients of variation (CV) are listed for mean mercury concentrations (mg/kg) and mean enrichment factors for normalized mercury based on the baseline regression from Figure 8. Range of % fines comprises the minimum and maximum measurement of % fines at each site.

		Range of % Fines	Mercury (mg/kg)		Enrichment Factor	
		(%)	Mean	CV	Mean	CV
BW15	**Guadalupe River**	90-100	0.64	0.43	1.93	0.47
BW10	**Standish Dam**	51-95	0.25	0.44	0.88	0.31
C-3-0	**San Jose**	12-96	0.34	0.60	1.90	0.36
C-1-3	**Sunnyvale**	7-96	0.21	0.41	1.36	0.29
BA10	**Coyote Creek**	36-99	0.36	0.56	1.39	0.35
BA21	**South Bay**	81-99	0.34	0.27	1.02	0.28

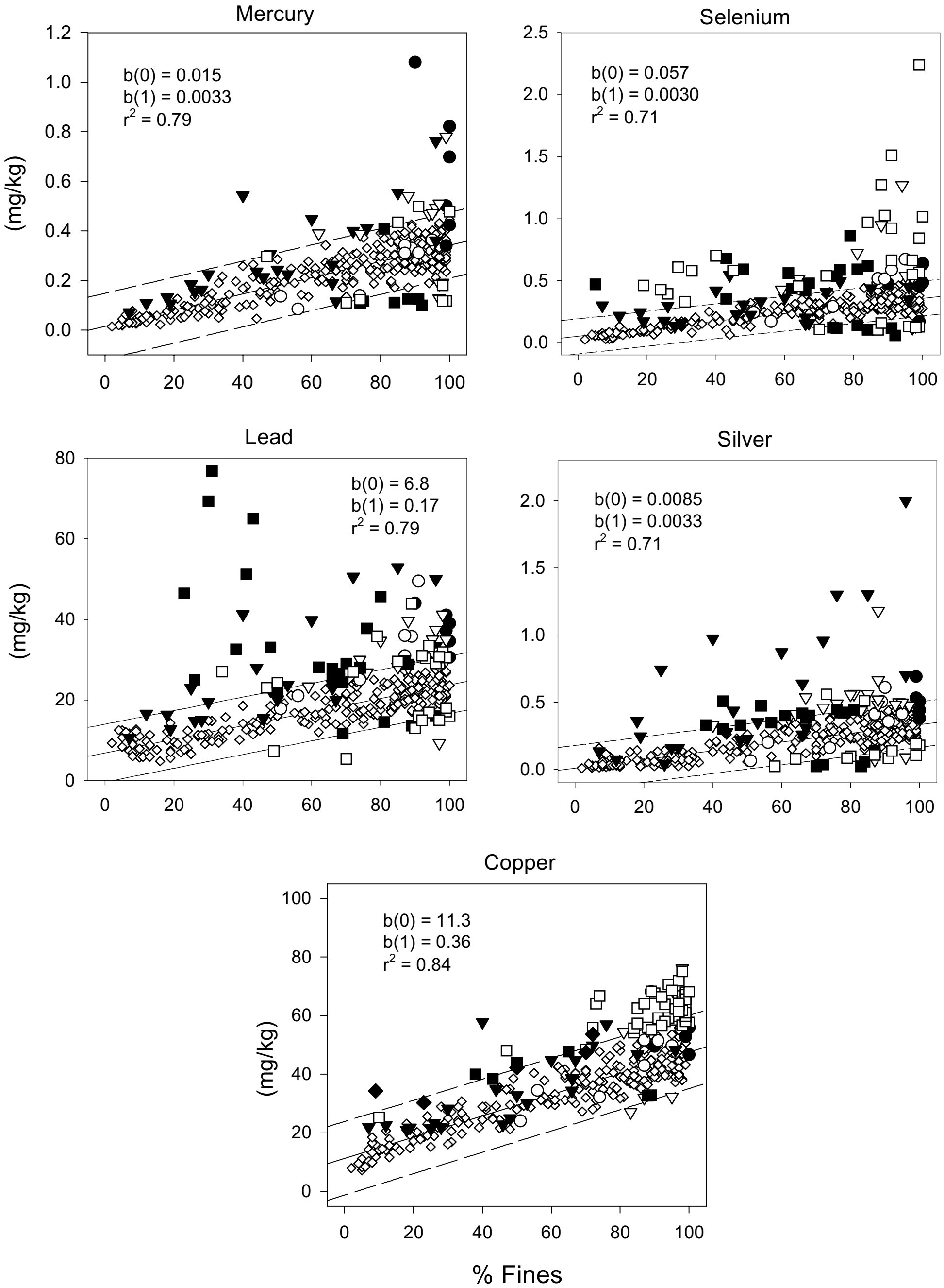

Figure 8. Baseline linear regressions of trace element concentrations and % fines. Symbols represent (◇) Baseline, (●) Guadalupe River (BW15), (○) Standish Dam (BW10), (▼) Southern Sloughs (SS), (▽) South Bay (SB), (■) Central Bay (CB), and (□) Northern Estuary (NE). Northern Estuary (NE) includes stations in San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). The South Bay (SB) includes stations in Lower South Bay (LSB). Dashed lines represent 99% prediction intervals of the regression. The coefficient of determination (r^2), y-intercept [b(0)], and slope [b(1)] are given for each linear regression for baseline concentrations.

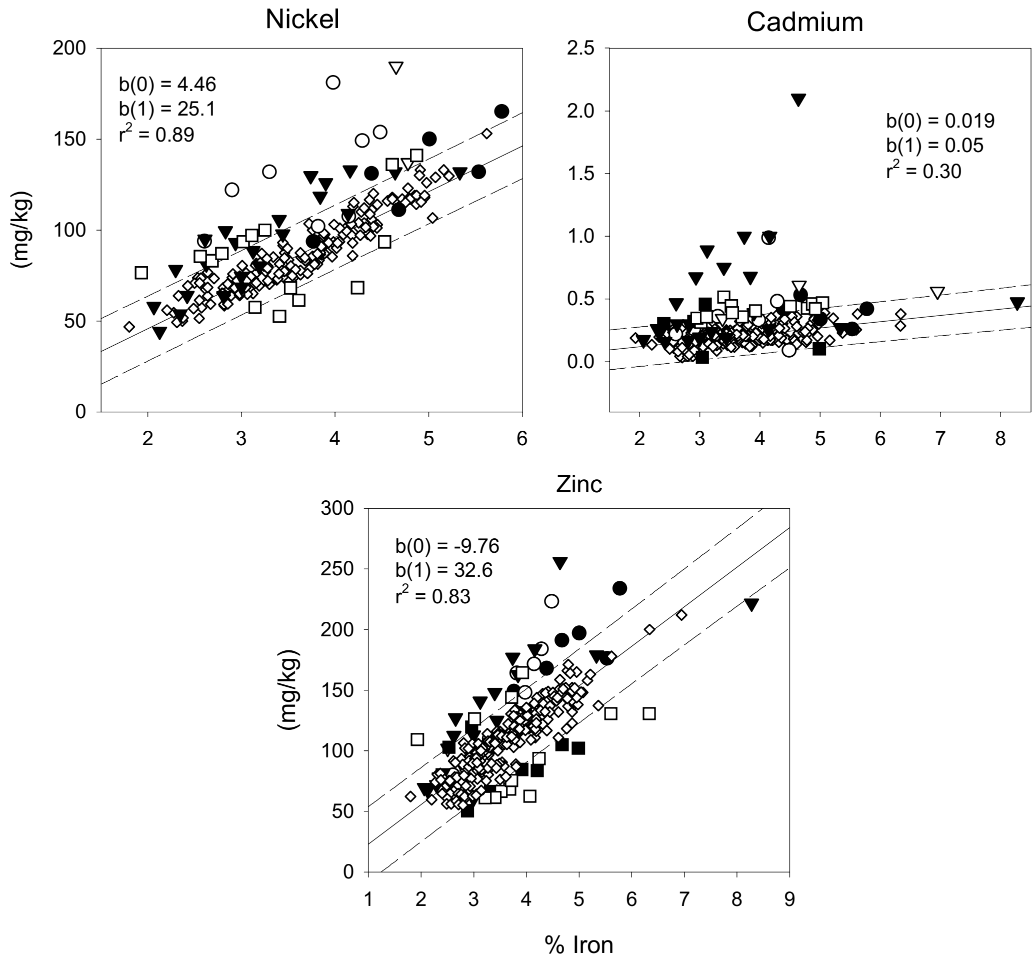

Figure 9. Baseline linear regressions of trace element concentrations and % iron. Symbols represent (◇) Baseline, (●) Guadalupe River (BW15), (○) Standish Dam (BW10), (▼) Southern Sloughs (SS), (▽) South Bay (SB), (■) Central Bay (CB), and (□) Northern Estuary (NE). Northern Estuary (NE) includes stations in San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). The South Bay (SB) includes stations in Lower South Bay (LSB). Dashed lines represent 99% prediction intervals of the regression. The coefficient of determination (r^2), y-intercept [b(0)], and slope [b(1)] are given for each linear regression for baseline concentrations.

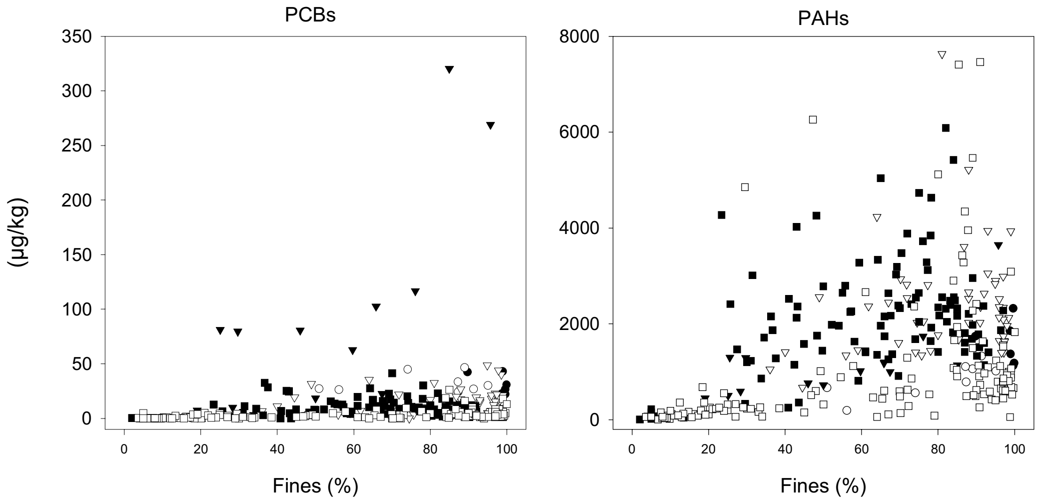

Figure 10. PAH and PCB concentrations and % fines. Symbols represent (●) Guadalupe River (BW15), (○) Standish Dam (BW10), (▼) Southern Sloughs (SS), (▽) South Bay (SB), (■) Central Bay (CB), and (□) Northern Estuary (NE). Northern Estuary (NE) includes stations in San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). The South Bay (SB) includes stations in Lower South Bay (LSB).

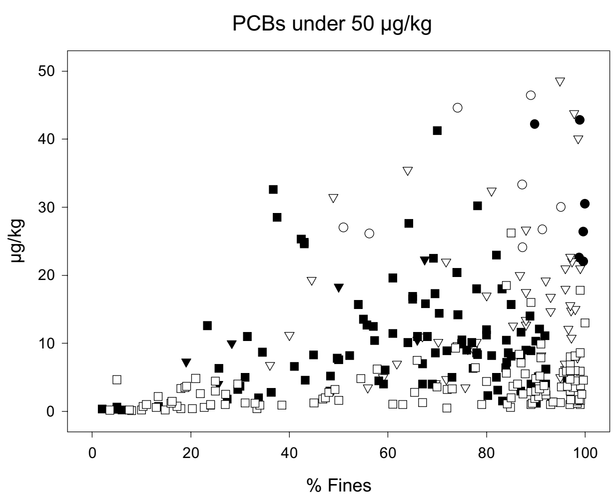

Figure 11. PCB concentrations less than 50 µg/kg and % fines. Symbols represent (●) Guadalupe River (BW15), (○) Standish Dam (BW10), (▼) Southern Sloughs (SS), (▽) South Bay (SB), (■) Central Bay (CB), and (□) Northern Estuary (NE). Northern Estuary (NE) includes stations in San Pablo Bay (SPB), Suisun Bay (SUB), and the Rivers (Riv). The South Bay (SB) includes stations in Lower South Bay (LSB).

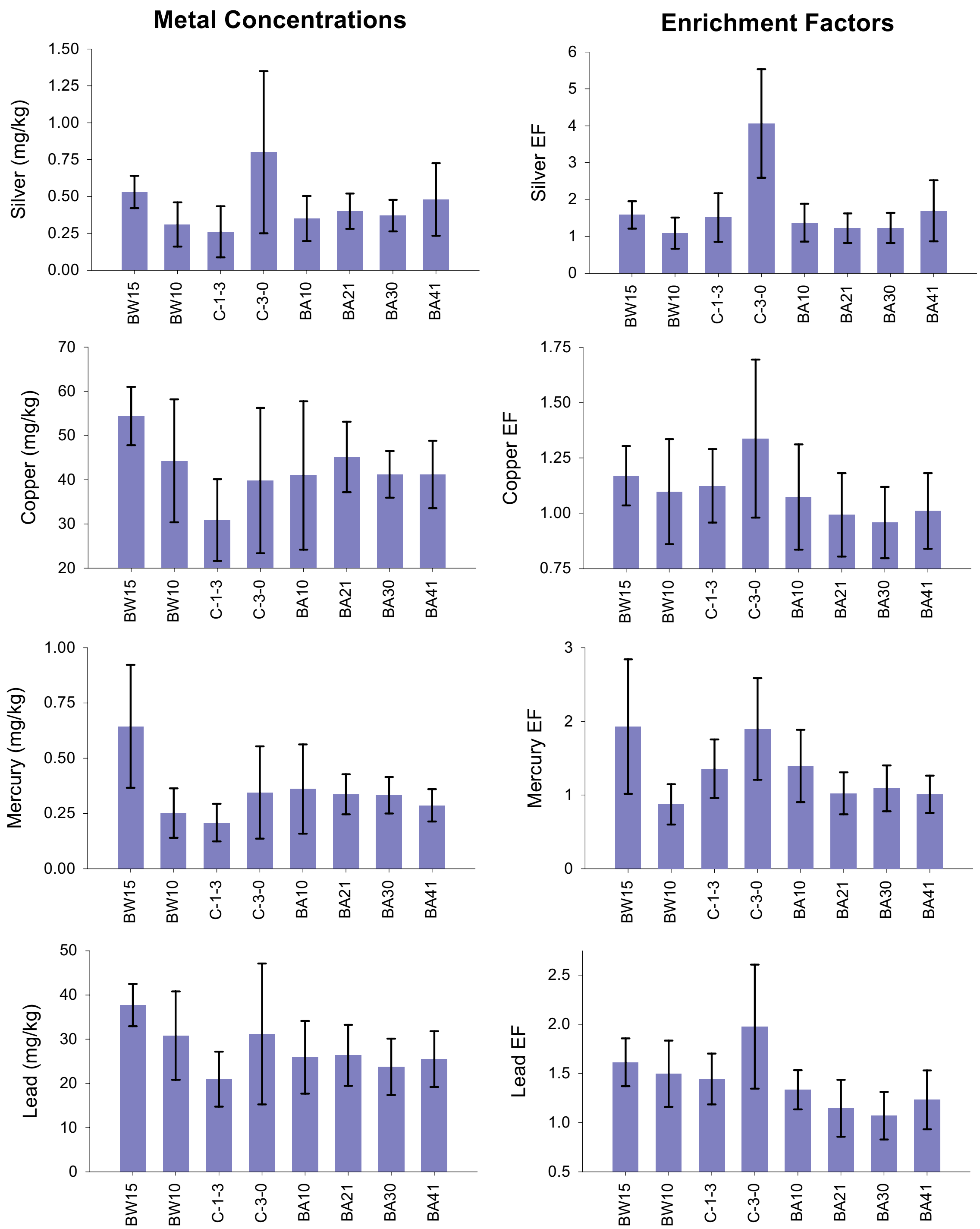

Figure 12. Concentrations and enrichment factors for trace elements in sediment. Bars represent mean values (± standard deviation) of concentrations and enrichment factors for EIP stations and RMP stations in Southern Sloughs, Lower South Bay, and South Bay.

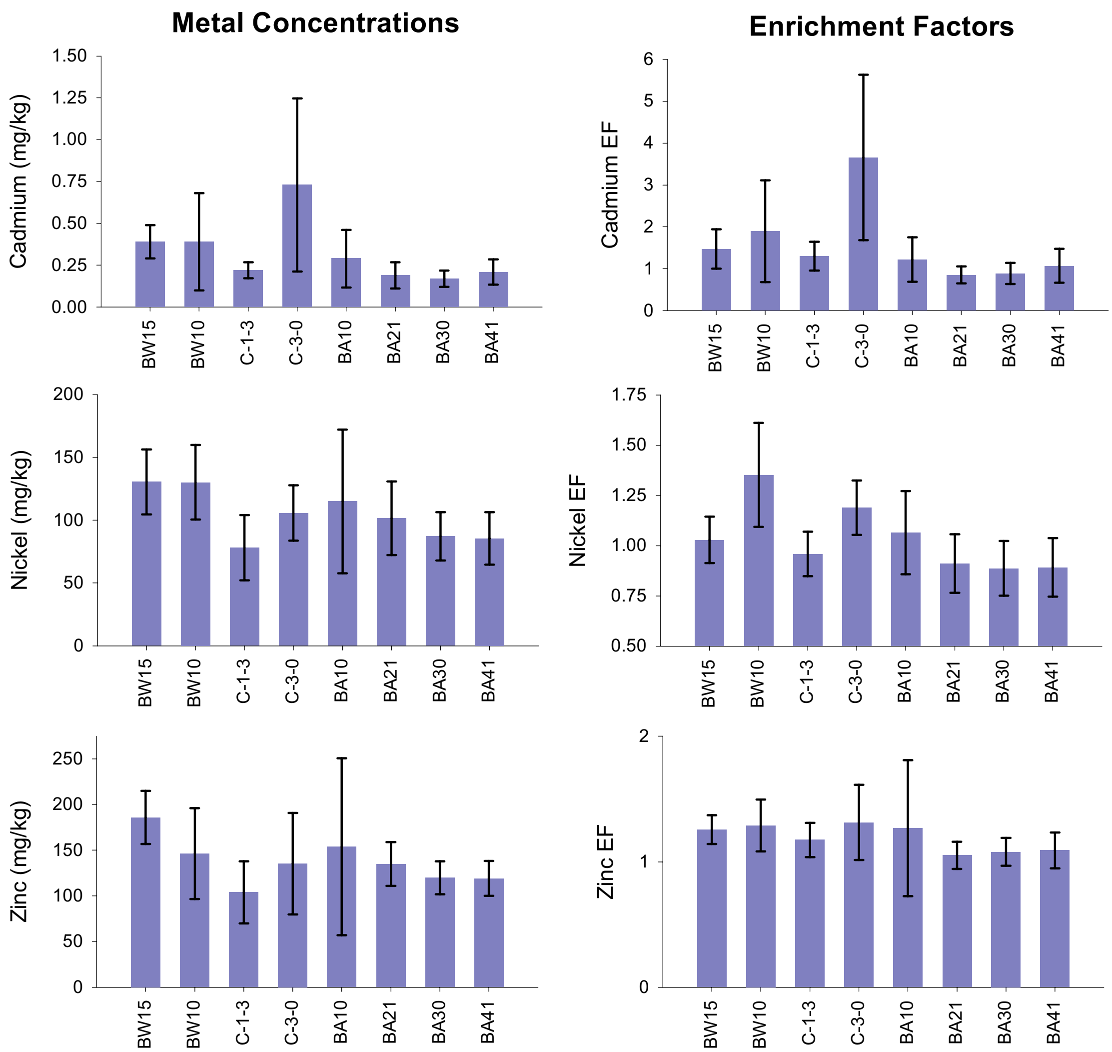

Figure 12 (cont.) Concentrations and enrichment factors for trace elements in sediment. Bars represent mean values (± standard deviation) of concentrations and enrichment factors for EIP stations and RMP stations in Southern Sloughs, Lower South Bay, and South Bay**.**

5. Discussion

5.1. Contaminants of concern

Results from this study indicate that one or both of the EIP stations have high concentrations of several contaminants of concern for San Francisco Bay: PCBs, PAHs, mercury, selenium, DDT, and chlordane. Less distinct signals of contamination were observed for copper and nickel. However, the current state of knowledge suggests that that the urbanized portion of the watersheds may contain sources of these metals that need to be controlled (WCC 1997, Tetra Tech *et al.* 2000a, Tetra Tech *et al.* 2000b). High concentrations of diazinon and chlorpyrifos in wet-season monitoring also suggest that episodic pulses of registered pesticides enter the Bay during periods of high freshwater flow. The results of the EIP study were consistent with previous studies that found high concentrations of several contaminants of concern in the margins of the San Francisco Estuary (Hunt *et al.* 1998a, Daum *et al.* 2000).

PCBs and methylmercury are of primary concern in the San Francisco Estuary due to their potential for bioaccumulation in fish and wildlife, and the subsequent risk to ecosystem integrity and human health. To minimize human exposure to these bioaccumulative contaminants, the Office of Environmental Health Hazard Assessment issued an advisory with detailed recommendations on limiting human consumption of fish caught in the Estuary (OEHHA 1994)

In response to needs of the Regional Board for development and refinement of TMDLs for PCBs and mercury in the San Francisco Bay, the county stormwater agencies recently conducted a characterization of bed sediments in storm drain conveyance systems (KLI 2001, Gunther *et al.* 2001). Because only one synoptic sampling event was conducted, the results are considered preliminary. However, the data provided useful information about potential sources and distribution throughout the watersheds, as well as an initial assessment of ranges of PCB and mercury concentrations in drainage sediments from different land-use categories. Results from the first year of storm drain sediment monitoring are discussed below in context of EIP results to relate potential watershed sources with current water quality conditions in the Bay.

Polychlorinated Biphenyls (PCBs)

Sediment and water monitoring results indicate that a clear PCB concentration gradient exists from the stations in the Lower South Bay to the northern reaches of the Estuary (Figures 5 and 7). In particular, San Jose (C-3-0) sediments consistently had higher median concentrations than any other RMP station, including Standish Dam (BW10) located nearby on Coyote Creek (Figures 7 and 8).

Johnson *et al.* (2000) analyzed PCB congener “fingerprints” (i.e. congener ratios) in RMP water samples from 1995-1996 and found strong similarities to original Aroclor mixtures 1248, 1254, and 1260. The study determined that greater than 70% of the PCB concentrations at Standish Dam (BW10) resembled patterns similar to Aroclor 1260, a higher-molecular weight mixture of PCBs, while San Jose (C-3-0) samples were mainly mixtures of 1254 and 1260. The freshest patterns of 1260 were observed in samples from winter and spring, suggesting that the samples were representative of seasonal flushes of relatively unweathered mixtures of PCBs from Coyote Creek to the Lower South Bay. High PCB concentrations measured in wet-season water samples at the EIP stations, which consistently had distinctly similar patterns of PCB congeners to Aroclor 1260, suggest that the contaminant signal may have been derived from the two watersheds. San Jose (C-3-0) water samples had estuarine water quality characteristics and patterns indicative of mixtures of both Aroclor 1254 and 1260, indicating that this site is influenced by both "new" inputs of PCBs and resuspension of weathered "legacy" deposits of sediments in the Lower South Bay.

McMurtry (2001) conducted a study to evaluate PCB concentrations in transplanted clams (*Corbicula fluminea*) at different locations along Guadalupe River and other streams within the Santa Clara Basin. Although actual concentrations were not determined in the study due to QA/QC limitations, relative differences in concentration indicated that transplanted clams in an urbanized reach of the Guadalupe River had approximately six times greater concentration of lipid-normalized PCBs than clams in a less developed reach of the tributary. PCB concentrations in clams were also three times higher in the urban Guadalupe River samples than in samples deployed in urbanized sections of the Coyote Creek or Sunnyvale East Channel. McMurtry (2001) also conducted a preliminary inventory of potential historic and current users of PCBs in the Guadalupe River and Coyote Creek and found that potential PCB sites on the Guadalupe River existed primarily along a seven-mile stretch between Alma Avenue and Trimble Road. Fewer sites existed on Coyote Creek compared to the Guadalupe River. However, most potential PCB sites were concentrated in a 6-mile stretch of an urbanized portion of San Jose. Because of the widespread use of PCBs in industrial applications and potential for leaks and/or spills, tributaries that drain urban areas, such as Guadalupe River and Coyote Creek, are likely to continue to contribute to PCB contamination of the Bay unless further source identification and remediation occurs in the watersheds.

In a recent sediment survey of PCBs and mercury in storm drain sediments, local stormwater management agencies determined that median PCB concentrations were nearly 40 times higher in samples from urban drainages than non-urban sites (KLI 2001, Gunther *et al.* 2001). Furthermore, results from the first year of monitoring indicated that the extent of PCB contamination was not evenly distributed between watersheds (Gunther *et al.* 2001). The median concentration of PCBs in sediment from industrial conveyances was approximately 81 ug/kg, with three of the samples from Santa Clara Valley and Alameda County above 500 µg/kg (25,000 µg/kg, 608 µg/kg, and 3,200 µg/kg). This suggests that localized sources of PCBs still exist in the urbanized portions of the watersheds.

Although median PCB concentrations in EIP sediments were high relative to concentrations measured in several RMP segments (Figure 7), concentrations were lower than those measured in many sediment samples collected from urban storm drains and sloughs that discharge to the Bay (Figure 13). Several samples had PCB concentrations orders of magnitude greater than maximum concentrations (~ 30 µg/kg) measured in sediment cores from Richardson Bay and San Pablo Bay that coincided with peak usage of PCBs between 1969 and 1975 (Venkatesan *et al.* 1999). Sediment cores near storm drain outfalls may provide similar insight into the recent history of contamination from urban conveyances, as well as prioritization of affected watersheds for management actions.

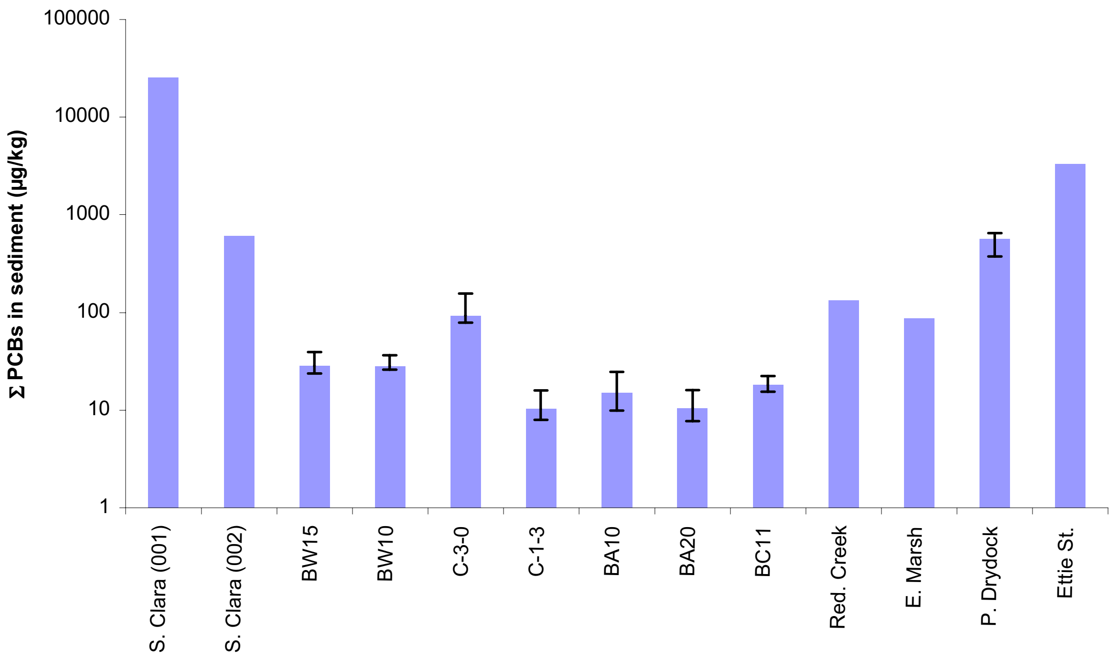

Figure 13. PCB concentrations in sediment from local watersheds, Bay margins, and RMP stations. Santa Clara (001 and 002) and Alameda (Ettie St.) storm drain data are from Gunther *et al.* (2001) and KLI (2001). Redwood Creek, Emeryville Marsh, and Pacific Drydock data are from the Bay Protection Toxic Cleanup Program (Hunt *et al.* 1998b). Bars represent median (or single sample) concentrations of PCBs in sediment. Error bars represent 25th and 75th percentiles. Note logarithmic scale.

Mercury

Monitoring at Guadalupe River (BW15) showed the influence of the mercury-mining legacy of New Almaden. During high flow events of the wet season, mercury-laden sediment most likely transported from upstream mining sources increased downstream concentrations in the receiving waters of the Lower South Bay. Concentrations of mercury in Guadalupe River (BW15) sediment (median = 0.60 mg/kg compared to the Bay-wide average 0.35 mg/kg) contributed to elevated concentrations in the water column (median = 0.064 µg/L) that consistently exceeded the water quality objective in the Basin Plan (0.025 µg/L) and the State Inland Surface Waters Plan (0.051 µg/L). The linkage between downstream concentrations and enriched sediment in the upper watershed, along with considerations of methylation and bioaccumulation, led Regional Board staff to propose a management strategy based on reducing mercury concentrations in Guadalupe River sediments (CRWQCBSFB 2000).

Several major processes contributed to the observed mercury concentrations in Bay sediments, including atmospheric deposition, drainage from the Central Valley, inputs from the local tributaries (*e.g.*, Guadalupe River) and remobilization of bed sediments (CRWQCBSFB 2000). Guadalupe River watershed inputs increased mercury concentrations in sediment at the Estuary Interface by approximately two-fold over ambient conditions. This suggests that specific actions are needed to address watershed sources of mercury: (1) identify measures needed to reduce the downstream transport of mercury-polluted sediments from the Guadalupe River watershed and (2) improve monitoring to better quantify sediment loads, mercury concentrations in sediments, and the response of those parameters to flow.

The recent survey of mercury concentrations in storm drain sediments provided additional insight into the sediment-based strategy (Gunther *et al.* 2001, KLI 2001). The median concentration of mercury in sediment collected from non-urban drainage areas (0.06 mg/kg) was consistent with pre-industrial concentrations (Hornberger *et al.* 1999). In contrast, median concentrations of mercury in sediment collected from industrial and residential areas were 0.31 mg/kg and 0.28 mg/kg, respectively, with concentrations as high as 1-4 mg/kg at locations within the Guadalupe River watershed. The Regional Board has recently adopted provisions in NPDES urban runoff permits requiring actions to reduce loads from urban conveyances. These actions include pollution prevention, recovery and recycling of mercury-containing consumer products, and strict control of sediment discharged from construction and new development. Therefore, future monitoring should be conducted with the primary goal of linking management actions to downstream water quality improvements.

Polycyclic Aromatic Hydrocarbons (PAHs)

Wet-season median concentrations of total PAHs in water were generally higher at the Guadalupe River station (BW15) (130 ng/L) and San Jose (C-3-0) (140 ng/L) than concentrations in the Lower South Bay or South Bay segments, with samples comprised predominantly of high-molecular weight PAHs (HPAHs) (Figure 5). Dry-season PAH concentrations at both stations increased substantially as the diluting effects of freshwater flows subsided. In addition, sediment in the South Bay had the highest median PAH concentration (2,500 µg/kg) of all segments, with a similarly high proportion of high-molecular weight PAHs (Figure 7). HPAHs, many of which are suspected carcinogens, are of particular concern because of their toxicological, physical, and chemical properties. Compared to low-molecular weight PAHs, HPAHs generally have lower water solubility, lower volatility, and slower degradation rates in the environment.

Along with PCBs and mercury, the Alameda Countywide Clean Water Program (ACCWP) included PAH monitoring in the storm drain sediment study and found that concentrations were clearly higher in urbanized areas, as expected (Gunther *et al.* 2001). Five samples from urban sites had PAH concentrations greater than 4,000 µg/kg with a maximum concentration of 160,000 µg/kg. Meanwhile, three non-urban samples ranged from 39-410 µg/kg. In comparison, PAH concentrations in EIP sediment ranged from 1,100-2,300 µg/kg at Guadalupe River (BW15) and from 190-1,300 µg/kg at Standish Dam (BW10). Similar to PAH patterns in water, sediment at the EIP stations contained primarily high-molecular weight PAHs.

The high proportions of high-molecular weight PAHs in water and sediment are indicative of particle-associated PAHs that most likely enter the Bay through stormwater runoff. Throughout the history of RMP monitoring, water, sediment, and tissue samples generally have patterns of individual PAHs indicative of pyrogenic or combustive origin (Davis *et al.* 1999). Therefore, surface water runoff and deposition of particles associated with anthropogenic combustion in the urbanized areas of the surrounding watersheds most likely contribute to the repository of PAHs in South Bay sediments.

Organophosphate Pesticides (OPs)

Diazinon and Chlorpyrifos

Wet-season median concentrations of diazinon were higher at Standish Dam (BW10) (9.5 ng/L) and San Jose (C-3-0) (18 ng/L) than concentrations measured in the Lower South Bay or South Bay segments, but were still much lower than concentrations measured in the northern reaches of the Bay. Chlorpyrifos concentrations, however, were generally higher at the EIP stations and San Jose (C-3-0) than the other segments of the Bay, including the rivers that drain the Central Valley watersheds. The highest concentrations of chlorpyrifos at all three stations were measured during spring and summer months, with maximum concentrations of 8.8 ng/L at Guadalupe River (BW15), 13 ng/L at Standish Dam (BW10), and 11 ng/L at San Jose (C-3-0). Concentrations in samples from the EIP stations have not exceeded the guideline for diazinon (40 ng/L). However, pulses of diazinon and chlorpyrifos are known to be associated with periods of heavy stormwater runoff (Gunther and Ogle 2000). Because RMP monitoring is not designed to capture episodic events, samples collected at the EIP stations probably do not represent peak concentrations of these contaminants in the tributaries.

Although the RMP does not currently measure diazinon and chlorpyrifos in sediment, both have been detected in sediments of urban creeks (WCC 1998). In Crandall Creek sediments, the maximum concentration of diazinon measured by WCC (1998) was 180 µg/kg, while chlorpyrifos was measured as high as 240 µg/kg. Therefore, creek sediments represent a potential source of organophosphate pesticides to the overlying water column and possibly contribute to sediment toxicity.

Gunther and Ogle (2000) conducted ambient water toxicity tests on samples from the Guadalupe Slough and Alviso Slough in the Lower South Bay to evaluate the toxic effects of episodic events on aquatic organisms. Significant toxicity was observed in five of thirty samples collected immediately after rainfall events over a two-year period. During the first year, three of the samples had concentrations of chorpyrifos above the LC_{50} for *Americamysis bahia* (35 ng/L). In the second year of sampling, two samples resulted in significant toxicity, but only one had concentrations of diazinon or chorpyrifos above the LC_{50} concentration. These findings suggest that while diazinon and chlorpyrifos cause significant toxicity in ambient waters, other causes of toxicity may be present during storm events in the sloughs of the Lower South Bay.

According to the Pesticide Use Report Program database, maintained by the California Department of Pesticide Regulation, over 42,000 pounds of diazinon were applied to areas in Santa Clara County in 1999 by operators required to supply use statistics (CDPR 2000). The CDPR database does not include residential use of pesticides sold in the retail market. The amount applied was approximately 50% of the total reportable diazinon applied in 1999 by all nine counties surrounding the San Francisco Estuary. Furthermore, Santa Clara County reported using approximately 13,600 pounds of chlorpyrifos in 1999. This amount is only 12% of the total reportable chlorpyrifos used by the nine counties, but still over twice as much as San Mateo or Alameda Counties. Of the amount of pesticide use reported by Santa Clara County, 69% of the applied diazinon and approximately 50% of the applied chlorpyrifos was used for structural pest control. The large proportion of structural use, in addition to the unreported amount applied by residents for landscape pest control, suggests that urban applications of diazinon and chlorpyrifos may contribute a significant portion of registered pesticides from these watersheds.

Organochlorine (OC) Pesticides

DDT, Chlordanes, and Dieldrin

Compared to other segments of the Bay, water and sediment at Standish Dam (BW10) consistently had higher concentrations of DDT and chlordanes in the wet season and high concentrations of dieldrin in the dry season (Figures 5 and 7). Guadalupe River (BW15) and San Jose (C-3-0) also had high concentrations of OC pesticides during wet- and dry-season sampling. Land use in the Coyote Creek watershed has historically been dominated by agriculture and still contains the largest contiguous area of agricultural land in the Santa Clara Basin (SCBWMI 2000).

Although peak usage of OC pesticides preceded the implementation of pesticide-use reporting to the California Department of Pesticide Regulation, it is assumed that historic deposits of residual OC pesticides in the agricultural watersheds of California continue to get washed into tributaries (Mischke *et al*. 1985, Gilliom and Clifton 1990). OC pesticides were also widely used as insecticides for urban applications, such as termite control (Gilliom and Clifton 1990). Accordingly, Hunt *et al*. (1998a) measured the highest concentrations of total chlordanes in sediment at sites that receive urban runoff from Bay Area creeks and storm drains.

To understand the distribution and general sources of OC pesticides in San Francisco Bay watersheds, the local stormwater management agencies added these OC pesticides to the list of contaminants for further characterization of storm drain sediments. Results from the 2001 monitoring study will provide additional insight into the extent to which local tributaries represent pathways of OC pesticide contamination to the Estuary.

Other trace elements

Selenium

A distinct gradient exists for selenium concentrations in water and sediment, with higher concentrations at the EIP stations compared to other segments of the Bay (Figures 4 and 6, respectively). Standish Dam (BW10) sediment (median = 0.50 mg/kg) generally had higher concentrations than sediment at other RMP stations, while the highest concentrations of selenium in water were consistently measured at Guadalupe River (BW15) (median = 2.3 µg/L; maximum = 7.2 µg/L). Although concentrations were high at the EIP stations compared to other RMP stations, selenium concentrations greater than 0.50 mg/kg have been widely measured in sediment collected from the Bay margins (Daum *et al*. 2000, Hunt *et al*. 1998a).

Relatively limited data is available to provide definitive information on potential sources and pathways of contamination of selenium to the Estuary; however, known sources of selenium include inputs from selenium-rich marine shale deposits in the watersheds and discharge from refineries that process shale oils (Anderson 1998, Davis *et al*. 1999). Davis et al. (1999) summarized information needs for managing selenium in the Estuary and concluded that inputs from local tributaries and storm drains may be minor in comparison to other pathways of selenium contamination. Accurate estimates of selenium loadings from local tributaries would provide further indication of the extent to which these loadings influence the selenium budget in the Estuary.

Copper and Nickel

Although concentrations of copper and nickel were not significantly higher at the EIP stations compared to other Bay segments, extensive studies and monitoring have implicated copper and nickel as contaminants of concern in the Lower South Bay (summarized by Tetra Tech 1999). As part of the development of a TMDL for copper and nickel in Lower South Bay, a conceptual model and source characterization report summarized the current understanding of copper and nickel cycling within the Lower South Bay (Tetra Tech 1999). The study indicated that beneficial use impairment due to copper and nickel was unlikely. Action Plans were developed to prevent the degradation of existing water quality, protect beneficial uses, and ensure that new, site-specific water quality objectives are not exceeded for copper or nickel (Tetra Tech *et al.* 2000a, 2000b).

5.2. Estimated Contaminant Loads

Contaminant concentrations are useful indicators of environmental conditions when compared to the numeric criteria or objectives designed to protect beneficial uses in the Estuary. However, load estimates combine data on contaminant concentrations and hydrology to provide an indication of the most significant pathways through which contaminants might enter the Bay. Furthermore, load estimates are a vital element in developing mass budgets, evaluating and implementing the most effective source reduction measures, and tracking the effectiveness of those measures.

Contaminant Load Estimates at the EIP Stations

There are significant limitations to estimating contaminant loads with reliable accuracy using the current RMP monitoring design. Although continuous records of discharge were available for Coyote Creek and Guadalupe River, the EIP Study only provided contaminant data from three sampling dates per year in each of the tributaries. Furthermore, the RMP has conducted monitoring based on fixed station/fixed time sampling, and results may not include conditions that exist during the first heavy storms of the wet season. Therefore, the response of contaminants to event hydrology at the EIP stations has not been adequately defined. For contaminants with concentrations positively correlated to discharge and suspended sediment concentration, estimated loads likely underestimated the actual load considerably, especially if concentrations were not representative of peak flow conditions. For example, Whyte and Kirchner (2000) measured a range of total mercury concentrations from 0.485 µg/L to 1,040 µg/L downstream from the Gambonini mercury mine in the Tomales Bay watershed in January and February 1998. Mercury concentrations were well correlated to TSS concentrations and stream discharge indicating that mercury loads were heavily dependent on suspended sediment transport during peak flows. During the two-month study, Whyte and Kirchner (2000) estimated that 75% of the mercury load occurred in approximately 10% of the time (~ 5 days).

Despite the limitations of current RMP methods in characterizing loads from local watersheds, the RMP Sources, Pathways, and Loadings Workgroup emphasized the need to generate rough estimates of contaminant loads to determine relative contributions from different pathways of contamination. Using the concentration data from the EIP stations and the available hydrologic data from USGS and SCVWD stream gauges on Guadalupe River and Coyote Creek, contaminant loads were estimated based on flow-weighted mean concentrations using the following equation.

$$\text{LOAD} = K * Q * \frac{\sum_{i=1}^{n} (C_i * Q_i)}{\sum_{i=1}^{n} Q_i} \qquad \text{(Equation 1)}$$

Where:	LOAD	= kg per year
	K	= Unit conversion factor
		= 0.894 for trace elements
		= 8.94×10^{-7} for organic contaminants
	Q	= Mean annual discharge (cfs)
	C_i	= Concentration of contaminant during sampling event *i* (µg/L) for trace elements (pg/L) for organic contaminants
	Q_i	= Mean daily discharge during sampling event *i* (cfs)

An example calculation is presented below for mercury at Guadalupe River (BW15).

Sampling Date	Mercury (µg/L)	Q_i (cfs)	C x Q_i (µg/L*cfs)
2/7/97	0.083	253	21
4/7/97	0.62	23	14
8/1/97	0.063	12	0.75
2/5/98	0.73	478	349
4/13/98	0.060	456	28
7/30/98	0.064	26	1.7
2/11/99	0.070	93	6.5
4/22/99	0.018	41	0.74
7/22/99	0.039	18	0.70

The flow-weighted mean concentration (FWMC) can be represented by the ratio of the sum of the products of mean-daily discharge and concentration from individual sampling events divided by the sum of mean-daily discharges using the following equation.

$$\mathrm{FWMC} = \frac{\sum_{i=1}^{n} (C_i * Q_i)}{\sum_{i=1}^{n} Q_i} \qquad \text{(Equation 2)}$$

A mean annual load is then derived using Equation 1. The mean annual discharge (Q) for each tributary was derived from the annual averages of mean-daily discharge values for individual water years. Guadalupe River mean annual discharge (Q) measured at USGS station 11169000 from 10/1/96 through 9/30/99 was approximately 108 cfs. The product of the annual discharge (Q) and the FWMC of total mercury at Guadalupe River (BW15) (0.30 µg/L) resulted in an estimated annual load of 29 kg per year.

ΣQ_i	$\Sigma(C * Q_i)$ (µg/L*cfs)	FWMC (µg/L)	Load (kg per year)
1400	422	0.30	29

Using the described method, mean annual loads were estimated for trace elements, organic contaminants, and TSS for the EIP stations (Table 8). Diazinon and chlorpyrifos loads were not estimated because of the temporal and spatial variability in application patterns and episodic nature of pulses to the Estuary. Because the EIP stations were located near the bottom of the watersheds, tributary load estimates presumably encompass contaminant contributions from natural and anthropogenic sources within the watershed that may reach the Lower South Bay.

Estimated annual loads of particle-associated metals and organic contaminants were generally higher at Standish Dam (BW10), which coincided with a larger estimated load of TSS (28 million kg per year) (Table 8). However, annual loads of mercury and PAHs were greater at Guadalupe River (BW15) (29 and 14 kg per year, respectively). Furthermore, Guadalupe River (BW15) had a larger load of selenium (190 kg per year). While the difference in suspended solids load might explain higher load estimates at Standish Dam (BW10) for most contaminants, greater loads of mercury and PAHs at Guadalupe River (BW15) suggest that the Guadalupe River may be a more significant pathway of these contaminants.

Comparison of EIP Load Estimates to Stormwater Load Estimates

EIP load estimates were compared to previous estimates of stormwater loads in the Santa Clara Valley (Table 9). As part of their Metals Control Measures Plan, the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) compiled available monitoring data to identify potential sources of metals and estimate annual loads from the various sources within the Santa Clara Valley (WCC 1997). The loads were estimated using a dual-method approach that involved land-use based modeling combined with monitoring at designated land-use and stream stations within the watershed. Both methods used modeled runoff for input flow data. The load estimates from the two studies represent estimates based on two different methods of load calculation: a largely empirical measurement approach and a combination of modeling and measurement approaches. An important point for consideration is that the EIP stations were located within tidally influenced reaches of the streams, while SCVURPPP stormwater stations were exclusively fresh water.

Load estimates for the Guadalupe River were generally consistent between the two studies (Table 9). In Coyote Creek, relatively large differences in estimated loads of copper, chromium, nickel, and zinc, may be accounted for to some extent by the difference in TSS load. This suggests that Standish Dam (BW10) load estimates may be influenced by increased loads of suspended solids, and emphasizes the importance of characterizing suspended sediment loads in order to accurately estimate contaminant loads from the watersheds.

Summary of Load Estimates for Contaminants of Concern

Load estimates for total mercury and selenium at Guadalupe River (BW15) suggest that this tributary is a potentially significant pathway for these contaminants to the Lower South Bay. The estimated load of 29 kg per year of mercury is about half the best-estimate load of 49 kg per year in the draft TMDL for mercury, which estimated that Guadalupe River contributed approximately 75% of the total load from external sources to the Lower South Bay (CRWQCBSFB 2000). As mentioned previously, the EIP mercury concentrations may not represent conditions of peak discharge or sediment transport. Therefore, the Guadalupe River (BW15) load estimate probably underestimates the actual mercury load, which suggests that the annual mercury load from the Guadalupe River is significant compared to other pathways of mercury contamination to the Lower South Bay.

Luoma and Presser (2000) estimated that the most significant loads of selenium are currently discharged to the Estuary by the San Joaquin River (2830-3630 kg per year), the Sacramento River (250-1580 kg per year), and by oil refineries (640-1000 kg per year). In comparison, EIP load estimates result in a combined selenium load from Guadalupe River (BW15) and Standish Dam (BW10) of approximately 290 kg per year. This suggests that sources in these watersheds may constitute a significant portion of selenium loads to the Lower South Bay and to the Estuary as a whole.

In a preliminary PCB mass budget for San Francisco Bay, Davis (2001) concluded that continued external loading of 10 kg per year would sustain approximately 100 kg of PCBs in the sediments of the Bay, which in turn, would significantly delay declines in sediment concentrations. In this study, the lower-bound estimate of PCB loads from Coyote Creek and Guadalupe River to the Lower South Bay was approximately 1 kg per year (Table 8). The initial storm drain sediment monitoring by the stormwater agencies indicated that PCB contamination was not evenly distributed throughout the urban landscape of the surrounding watersheds of the Bay (Gunther *et al.* 2001). Therefore, accurate measurements of PCB loading from the surrounding watersheds, placed in the context of refined PCB mass budgets, may reveal whether local watersheds currently contribute sufficient loads of PCBs to prevent or delay restoration of beneficial uses in the Bay.

Loads of total PAHs were estimated to be approximately 14 kg per year from Guadalupe River (BW15) and 8.4 kg per year at Standish Dam (BW10). A mass budget for PAHs, similar to the PCB budget by Davis (2001), is currently being developed by the RMP, and may provide a means for comparing the relative magnitudes of loads from tributaries and other significant pathways of PAH contamination to the Bay.

The Copper and Nickel Action Plans summarized load estimates for these contaminants in the Lower South Bay (Tetra Tech *et al.* 2000a, 2000b). The Nickel Action Plan reported estimated loads of total and dissolved nickel for 1998 and 1999. Based on those two years, the range of annual loads was 428 to 1,071 kg per year of total nickel and 102 to 258 kg per year of dissolved nickel from the Guadalupe River. The EIP estimates for loads of total and dissolved nickel (1,800 and 250 kg per year, respectively) from Guadalupe River (BW15) were generally consistent with the Nickel Action Plan estimates (Table 8). Similarly, EIP annual load estimates for total and dissolved copper (650 and 100 kg per year, respectively) fall within the two-year range reported in the Copper Action Plan for total copper (310 to 996 kg per year) and dissolved copper (99-228 kg per year) (Tetra Tech *et al.* 2000a).

Future Estimates of Contaminant Loads from the Watersheds

The general agreement between EIP load estimates and estimates reported in previous studies suggests that the method of load estimation in this study may be sufficient for making order-of-magnitude comparisons between pathways of contamination. However, the uncertainties associated with loads based on data that may not represent periods of peak sediment transport limit the accuracy essential for quantifying actual loads and determining trends in loading over time. Therefore, future tributary monitoring should be designed to capture the temporal variability of contaminant concentrations in response to varying flow conditions and sediment transport to: (1) accurately quantify sediment and contaminant loads from local tributaries, (2) determine trends in contaminant loading over time, and (3) compare tributary loading to other pathways of contamination in the context of refined mass budget models.

Table 8. Estimated annual loads of contaminants from the EIP stations. Estimates were reported as mean annual loads in kg per year for trace elements and organic contaminants.

	Guadalupe River (BW15) (kg per year)	Standish Dam (BW10) (kg per year)
TSS (x 10^6)	11	28
Total Trace Elements		
Silver	3	3
Arsenic	230	490
Cadmium	9	14
Chromium	1,400	3,500
Copper	700	1,100
Mercury	29	5
Nickel	2,000	3,300
Lead	500	730
Selenium	200	90
Zinc	3,100	3,800
Dissolved Trace Elements		
Silver	0.11	0.15
Arsenic	100	170
Cadmium	1.1	0.71
Chromium	63	50
Copper	110	170
Mercury	0.94	0.27
Nickel	260	360
Lead	16	14
Selenium	190	77
Zinc	340	170

	Guadalupe River (BW15) (kg per year)	Standish Dam (BW10) (kg per year)
Total Organic Contaminants		
PCBs	0.49	0.53
PAHs	17	11
Dieldrin	0.009	0.014
DDTs	0.10	0.52
Chlordanes	0.14	0.24
Dissolved Organic Contaminants		
PCBs	0.059	0.034
PAHs	1.3	1.6
Dieldrin	0.006	0.008
DDTs	0.040	0.11
Chlordane	0.030	0.051

Table 9. Comparison of EIP load estimates to previous estimates of loads in stormwater from the watersheds of Guadalupe River and Coyote Creek. Estimated loads are in kg per year.

	This Study		WCC (1997)	
	Guadalupe River (BW15)	Standish Dam (BW10)	Guadalupe River	Coyote Creek
TSS (x 10^6)	11	28	9.8	4.7
Silver	3	3	10	6
Cadmium	9	14	33	14
Chromium	1,400	3,500	1,100	480
Copper	700	1,100	1,100	420
Mercury	29	5	15	4
Nickel	2,000	3,300	2,000	860
Lead	500	730	1,300	500
Selenium	200	90	28	12
Zinc	3,100	3,800	4,200	1,900

5.3. Contamination on Suspended Solids

Loads of particle-bound contaminants in tributaries are highly dependent on the magnitude and source of the suspended sediment load associated with seasonal and episodic runoff (Domagalski and Kuivila 1993, Kratzer 1998). To relate concentrations of particle-associated contaminants on suspended sediment to contaminant concentrations in Bay sediment, seasonal differences in particulate concentrations of contaminants in EIP water samples were evaluated and compared to water-particulate and sediment concentrations in the Lower South Bay and South Bay (Figures 14 and 15). The following comparisons were conducted based on two general assumptions:

(1) wet-season particulate concentrations were associated with runoff from watershed sources and re-suspension of in-channel sediments, and
(2) dry-season concentrations were influenced by a combination of dry-season runoff, re-suspension of in-channel sediments, and re-suspension and mixing of Bay sediments by wind and tidal action.

Particle-associated concentrations of organic contaminants in the water column were measured from direct analyses of the particulate fraction of the filtered sample. Particle-associated concentrations of trace elements in the water column were calculated by subtracting the dissolved concentration from the total concentration. Particulate concentrations of all contaminants on suspended solids were calculated by dividing the particle-associated concentrations by the TSS concentration. Trace element concentrations were calculated using equation 3:

$$[C_{PART}] = 1000 * \frac{([C_{TOT}]-[C_{DISS}])}{[TSS]} \qquad \text{(Equation 3)}$$

Where:
C_{PART}= particulate concentration of trace element (mg/kg)
C_{TOT} = total concentration of trace element (µg/L)
C_{DISS}= dissolved concentration of trace element (µg/L)
TSS = total suspended solids concentration (mg/L)

Particulate concentrations of PCBs, DDTs, mercury, chlordanes, and lead at Guadalupe River (BW15) were generally higher in the wet season compared to concentrations in water and sediment collected from RMP stations in the South Bay and Lower South Bay. The median particulate concentration of mercury in Guadalupe River (BW15) water (1.2 mg/kg) was over twice as high as median concentrations measured in water and sediment at any other station. This concentration is consistent with the maximum concentration of mercury measured in Guadalupe River (BW15) sediment (1.1 mg/kg), which provides further evidence that legacy-mining sources within the Guadalupe River watershed contribute to mercury contamination of water and sediment in the Estuary.

In Guadalupe River (BW15) samples, median particulate concentrations of all contaminants, except silver, were higher in the wet season than dry-season particulate and sediment concentrations at that site (Figures 14 and 15). This suggests that suspended loads transported by wet-season runoff from the Guadalupe River watershed were contaminated relative to bed and suspended sediments in the tributary during the dry season. Also, dry-season particulate concentrations and sediment concentrations were relatively consistent for most contaminants, which supports the hypothesis that resuspension of stream and Bay sediments may be a dominant influence on the overlying water column during the dry season. Elevated concentrations on suspended particles transported into the Lower South Bay from the Guadalupe River watershed indicate that unless appropriate management steps are taken to reduce the loading of contaminated sediment to the Bay from urbanized watersheds, sediment concentrations in the Estuary may continue to increase.

In Standish Dam (BW10) samples, seasonal differences between particulate concentrations were not as pronounced. Suspended solids in the wet season generally had lower median concentrations of contaminants compared to dry season samples. This pattern was observed for all contaminants except for nickel, which typically occurs in serpentinite soils of the Coast Range. One hypothesis is that the wet-season suspended load of Coyote Creek at Standish Dam (BW10) may have contained a large amount of debris from erosion of the upper watershed that diluted more contaminated suspended solids from downstream. Similar patterns have been observed for PAHs in water samples collected near the Sacramento-San Joaquin Delta (Domagalski and Kuivila 1993). An increase in concentrations in the dry season may result from a decrease in suspended solids load from the upper watershed, coupled with the possibility that water sampled during the dry season may be comprised of a large percentage of Bay waters transported by tidal action.

Assuming that reservoirs in the two watersheds retained much of the sediment load from the upper watershed, the different patterns of contamination on suspended sediment between Standish Dam (BW10) and Guadalupe River (BW15) water samples might be explained by characteristics of the effective drainage area below the reservoirs. The lower portion of the Coyote Creek receives streamflow from the Upper Penitencia Creek, which includes drainage from the Diablo Range via Arroyo Aguague Creek and Lower Silver Creek. Conversely, the existence of major reservoirs on all of the main tributaries of the Guadalupe River leaves an effective drainage area of only 50 square miles for the lower reach of the tributary (USACE and SCVWD 2001). The sediment load retained by the system of reservoirs, as well as the heavy urbanization of the Guadalupe River basin reduces the downstream supply of sediment (USACE and SCVWD 2001). Therefore, Standish Dam (BW10) samples may be more influenced by erosion from portions of the upper watershed.

Monitoring the Suspended Load of Sediment and Contaminants

The extent to which EIP sediment samples represented recently transported material from the upper watershed or sediment deposited by tidal action from the Bay was not determined within the scope of the EIP study. Heavy storms and associated stream flows transported suspended sediment at Guadalupe River (BW15) that was contaminated relative to dry-season concentrations. However, Guadalupe River (BW15) bed sediment did not necessarily reflect a pattern of high mercury concentrations from the downstream transport of contaminated sediment during high streamflow events.

Streamflow and sediment concentrations at Guadalupe River (BW15) during winter sampling were as follows:

Date	Flow (cfs)	Mercury (mg/kg)
2/7/97	253	1.1
2/4/98	816*	0.34
2/18/99	94	0.42

* included overflow from Calero Reservoir

A few hypotheses for the observed mercury concentrations in Guadalupe River (BW15) sediments are stated below.

(1) Calero Reservoir overflow from February 4^{th}, 1998 joined Guadalupe River below Alamitos Creek, which is a suspected scour source of mercury. Therefore, water and sediment from Arroyo Calero may dilute the mercury signal from Alamitos Creek.
(2) The time of sampling in relation to the position on the hydrograph (Figure 3) may have influenced sediment dynamics and associated contaminant concentrations in sediment at Guadalupe River (BW15).
(3) Sediment at Guadalupe River (BW15) consists of older sediment influenced by tidal action as evidenced by dry-season concentrations of 0.5-0.7 mg/kg.

Although the source of variability in the observed mercury concentrations cannot be determined from the existing dataset, the analysis provides clear evidence for the need for specific management actions to test such hypotheses for mercury and other particle-associated contaminants. The contaminant response to changing hydrology can be accurately characterized by tributary monitoring efforts that identify locations above tidally influenced reaches, where continuous monitoring of flow and suspended sediment can be related to discrete measurements of contaminant concentrations in bed and suspended sediments. This method of sampling proposed by Whyte and Kirchner (2000) and McKee *et al.* (2001) would provide the necessary information for establishing linkages between downstream water quality with upstream sources and management efforts in the watersheds.

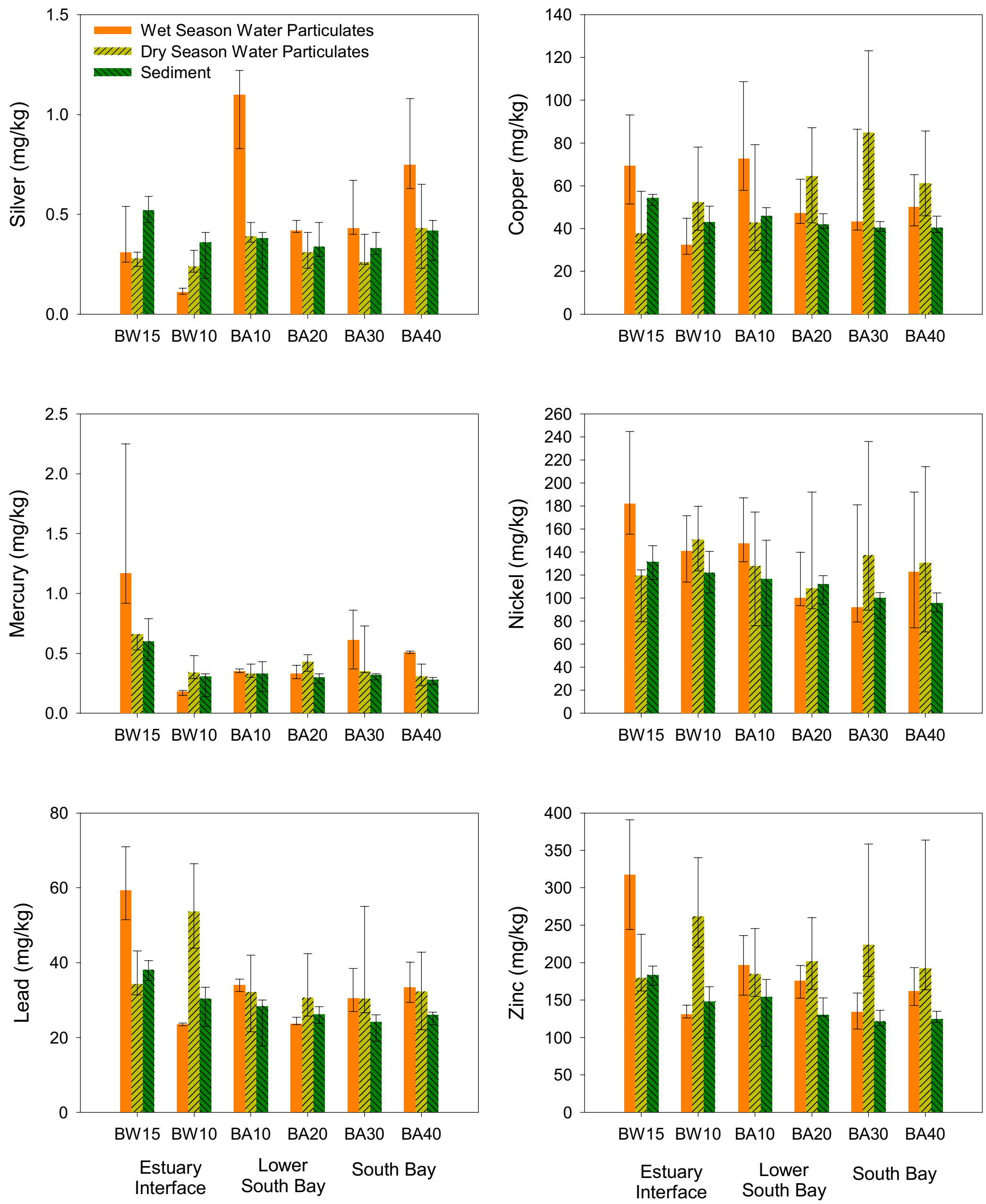

Figure 14. Trace element concentrations on suspended solids and bed sediment. Particulate concentrations of trace elements (mg/kg) were normalized to total suspended solids (TSS) (mg/L). Bars represent median particulate concentrations in the wet and dry seasons, and median concentrations in sediment. Error bars represent 25th and 75th percentiles.

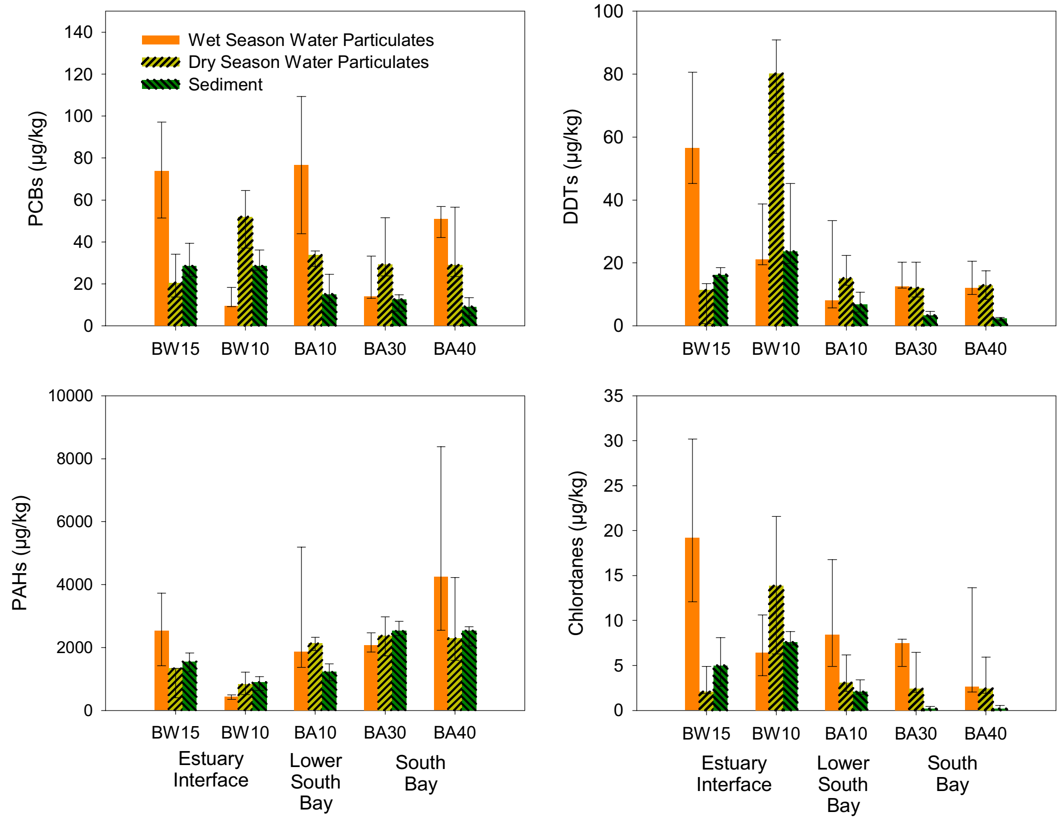

Figure 15. Organic contaminant concentrations on suspended solids and bed sediment. Bars represent median particulate concentrations in the wet and dry seasons and median concentrations in sediment. Error bars represent 25th and 75th percentiles

5.4. Metals in Sediment: Potential Indicators of Sources and Loads

To link potential sources of metals in upstream regions of the watersheds to contaminant concentrations in bed sediment of the tributaries and Bay, the degree to which sediment samples are contaminated above baseline conditions must be determined. Methods of assessing sediment contamination have typically involved comparing sediment samples to known ranges of background metal concentrations or to samples from reference sites that represent relatively clean or uncontaminated sediment. However, the limited data that exist on upland sediment concentrations in the Lower South Bay watersheds cover a relatively large range of concentrations for most metals (Andersen 1998, Stevenson and Dorsey 2000, Cooke and Drury 1998, Bradford *et al.* 1996). This is expected because, as discussed earlier, baseline metal concentrations in natural or uncontaminated sediments may vary significantly due to grain size effects. Therefore, sediment studies that focus on identifying general sources of contamination in the watershed should account for variation in natural factors that may contribute to differences in sediment metal concentrations.

Gradient Study of Metals in Coyote Creek

As part of their Stormwater Environmental Indicator Demonstration Project (SEIDP), SCVURPPP conducted a sediment characterization study along Coyote Creek to evaluate the relationship between metals concentrations in streambed sediments and urban development. The study found that cadmium, lead, and mercury concentrations were positively correlated to trends of increasing urbanization along Coyote Creek (Stevenson and Dorsey 2000).

Concentrations of mercury and copper in upstream SCVURPPP sediment samples were compared to downstream RMP sediments from Standish Dam (BW10) in Coyote Creek and San Jose (C-3-0) near the mouth of Coyote Creek (Figure 16). To address potential grain-size effects on metal concentrations, the correlation between concentrations and percent fine-grained material was evaluated. Assuming that non-urban, upstream sediments represented baseline concentrations of metals in the watershed, significant relationships were established between concentrations of both metals and % fines from non-urban sites monitored in the SCVURPPP study ($p < 0.05$). Two non-urban data points for copper concentrations were apparent outliers and not included in the baseline regression.

Copper concentrations measured in both samples from William (U4), the most downstream urban site, and one sample from Derbe (U5), were most noticeably above the predicted baseline regression (Figure 16), suggesting a correlation between sediment contamination and urbanization. Because these sites were located at least 12 miles upstream from the mouth of the Creek, continued sampling of the urban sites (U4 and U5) and sites located further downstream may reveal a more definitive relationship between copper concentrations in sediment and increased urban development along Coyote Creek. Another important note is that both non-urban "outliers" were collected at Cochran (R5), a site located directly downstream from Anderson Dam. High concentrations at this site may be caused by a local source within the upper watershed or from Anderson Dam, or from more diffuse sources, such as atmospheric deposition into the reservoir.

The comparison of SCVURPPP and RMP data showed that copper concentrations at Standish Dam (BW10) might be slightly lower than baseline levels measured in the freshwater upstream reaches. This finding is consistent with results of a sediment study on Calabazas Creek, in which sediment at a downstream site within the inter-tidal zone had lower copper concentrations than upstream reference sites (Cooke and Drury 1998). The physical and chemical processes involved with mixing of saline and freshwaters may be responsible for dilution of copper concentrations in sediment at Standish Dam (BW10) and similar tidally influenced reaches.

Figure 16 provides a clear indication of mercury contamination of sediments at urban sites along Coyote Creek. However, the most downstream sites were not necessarily the sites with the highest concentrations, suggesting that the urbanized reach of Coyote Creek may be impacted by more localized inputs of mercury. Compared to RMP stations, all mercury concentrations at San Jose (C-3-0) were elevated above baseline concentrations, while sediment at Standish Dam (BW10) was generally consistent with the established baseline relationship.

Spatial Distribution of Metals: Mercury in the Watersheds

As discussed previously, the recent sediment characterization study conducted by the local stormwater agencies found that mercury and methylmercury concentrations were significantly higher in urban drainage sediments than in sediment from open-space areas (KLI 2001, Gunther *et al.* 2001).

Mercury concentrations in sediment from Santa Clara County and Alameda County were compared to RMP and EIP stations (Figures 17 and 18, respectively). As in the previous discussion, the relationship between grain-size and mercury concentrations was evaluated using % fines. Due to the limited data set for non-urban drainage areas (n = 3) and the relatively small range of % fines (< 30 % fines), the baseline mercury regression line from the SCVURPPP gradient study (Figure 16) was transposed onto the storm drain sediment data. Assuming that baseline mercury concentrations were consistent on a regional scale, the figures provide a visual approximation of the potential degree of contamination at sampling sites in the watersheds and the Bay relative to baseline conditions in the watersheds.

All concentrations exceeding 0.4 mg/kg were collected from urban areas in the watersheds, Southern Sloughs, Lower South Bay, and Guadalupe River (BW15) (Figures 17 and 18). In fact, three of the four mercury concentrations exceeding 1 mg/kg were collected in urban areas of the Guadalupe River watershed and at the EIP station, Guadalupe River (BW15) (Figure 17). Although a significant amount of mercury enters the Bay as mercury-laden sediments from erosion in the inoperative mining region in the upper Guadalupe River watershed, it appears that sources within the urbanized regions of the watersheds may also contribute to impairment of the Bay.

Metal Concentrations in Sediment as Indicators of Sources and Loads

Gradient studies and spatial distribution studies have successfully linked metal concentrations in sediment to general sources of contamination within the watersheds (Stevenson and Dorsey 2000, Gunther *et al*. 2001, KLI 2001). Because sediment naturally integrates changing conditions in the Bay and its watersheds, concentrations of trace elements and organic contaminants are useful indicators of potential sources, as well as temporal trends in contamination (Hornberger *et al*. 1999, Venkatesan *et al*. 1999). To determine long-term trends in contaminant loading within the watersheds, tributary monitoring efforts should explore the sensitivity of sediment as an indicator of loads and possible ‘trigger’ for management actions. Increased sensitivity could be achieved by reducing variability associated with grain size by (1) deriving enrichment factors in bulk sediment samples collected from both upstream ‘baseline’ locations and potentially contaminated areas or (2) the less expensive method of sieving sediment samples prior to chemical analyses.

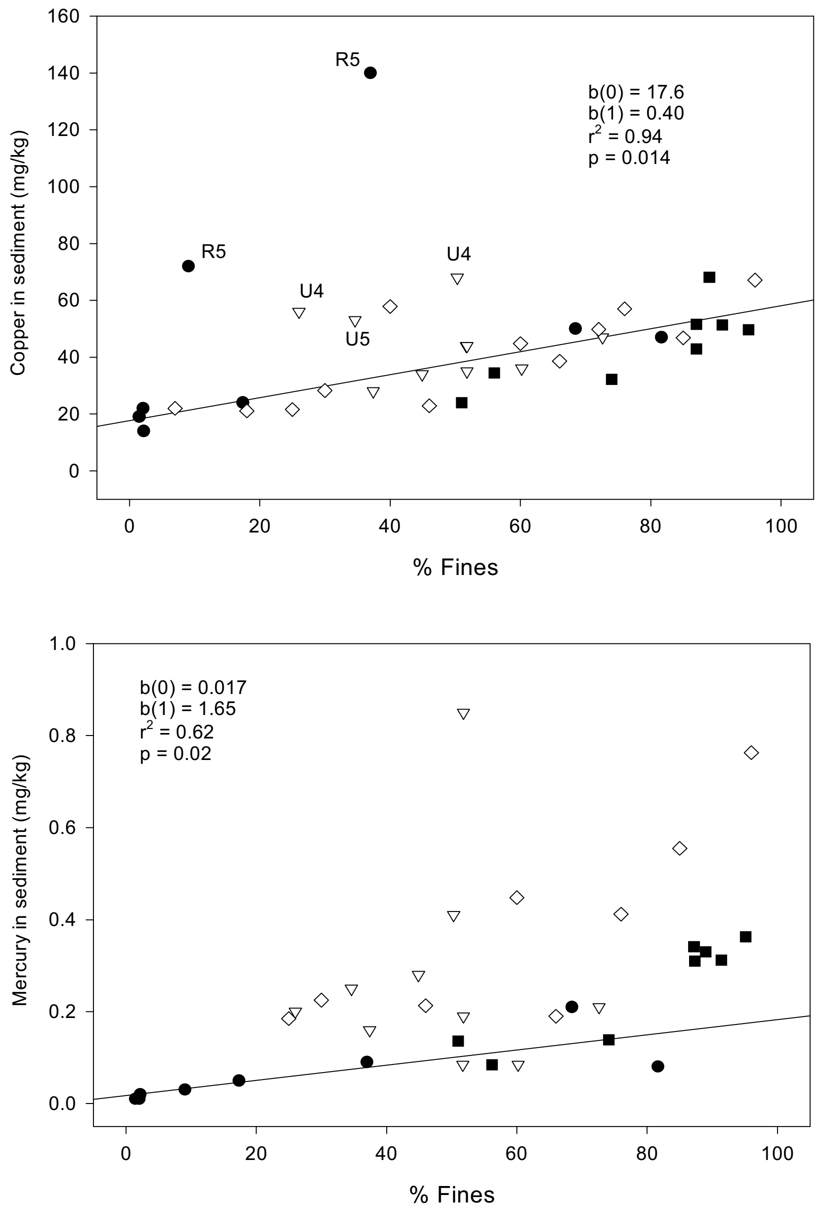

Figure 16. Copper and mercury concentrations in sediment along Coyote Creek. Symbols represent (●) Non-urban sites, (▽)Urban sites, (■) Standish Dam (BW10), and (◇) San Jose (C-3-0). Non-urban and urban data adapted from Stevenson and Dorsey (2000). The baseline linear regression was determined from non-urban data from upstream sampling locations. Copper concentrations from site R5 were not included in the regression. The coefficient of determination (r^2), y-intercept [b(0)], and slope [b(1)] are given for the linear regression for baseline concentrations.

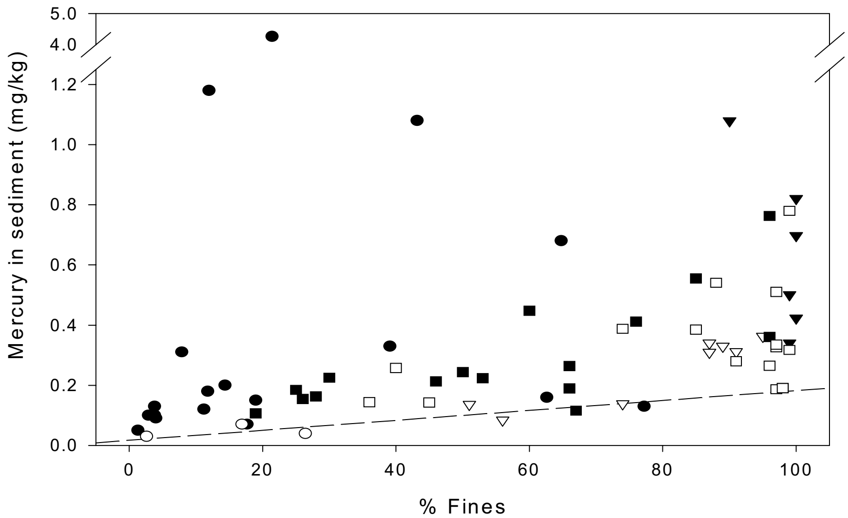

Figure 17. Mercury concentrations in sediment from Santa Clara County and RMP stations. Symbols represent (●) Urban sites, (○) Non-urban sites, (▼) Guadalupe River (BW15), (▽) Standish Dam (BW10), (■) Southern Sloughs (SS), and (□) Lower South Bay. Urban and non-urban data from KLI (2001). The dashed line represents the baseline linear regression from Figure 16 using non-urban data from upstream sampling locations on Coyote Creek (adapted from Stevenson and Dorsey 2000).

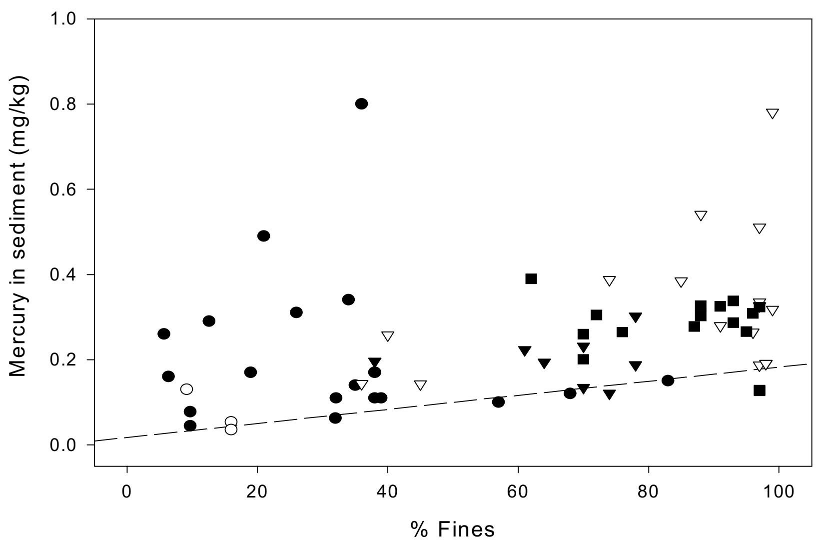

Figure 18. Mercury concentrations in sediment from Alameda County and RMP stations. Symbols represent (●) Urban sites, (○) Non-urban sites, (▼) Yerba Buena Island (BC11), (▽) Lower South Bay (LSB), and (■)South Bay (SB). Urban and non-urban data from Gunther *et al.* (2001). The dashed line represents the baseline linear regression from Figure 16 using non-urban data from upstream sampling locations on Coyote Creek (adapted from Stevenson and Dorsey 2000).

6. Conclusions

6.1 Summary of Findings

- The Estuary Interface Pilot Study in 1996-1999 fulfilled its objectives by providing a general assessment of contamination at the Estuary Interface stations, establishing potential linkages between downstream water quality conditions and surface runoff from the watersheds, and identifying several factors, such as TSS in the water column and grain size effects in sediment, that heavily influence the distribution and concentrations of contaminants. Evaluation of Study findings and activities of the RMP Sources, Pathways, and Loadings Workgroup also led to recommendations for next steps for identifying general sources of contamination, developing appropriate methods of quantifying loading of sediment and contaminants, and determining changes in concentrations and loading on temporal scales.

- Wet-season water samples were consistently characterized as freshwater based on salinity and conductivity data, which suggests that samples were primarily influenced by surface runoff from the watersheds. Wet-season water samples had significantly high total concentrations of:

  PCBs, chlordanes, and selenium in water collected from both EIP stations and DDT, PAHs, and HPAHs in Guadalupe River (BW15) water compared to concentrations measured in the Central Bay and northern segments of the Estuary.

  Mercury and lead in Guadalupe River (BW15) water samples and copper, nickel, and lead in Standish Dam (BW10) water compared to concentrations measured in the Lower South Bay, South Bay, and Central Bay.

- Sediment samples collected during this study had significantly high concentrations of:

  PCBs in sediment from both EIP stations and mercury, lead, zinc, and silver in Guadalupe River (BW15) sediment compared to concentrations measured in the Central Bay and northern segments of the Estuary.

  DDT and chlordanes in EIP sediment compared to concentrations in the South Bay, Central Bay, and northern segments. Additionally, concentrations of DDT and chlordanes in Standish Dam (BW10) sediment samples were significantly higher than concentrations measured in Lower South Bay sediment.

- EIP monitoring at Guadalupe River (BW15) helped put the influence of the inoperative mercury mining district of New Almaden into context with other sources of mercury to the Estuary. The transport of mercury-laden sediment from the upper watershed resulted in consistently high concentrations of mercury in the downstream water column. This link between enriched sediment in the upper watershed with downstream water quality led Regional Board staff to propose a management strategy based on reducing mercury concentrations in sediment.

- Although several legacy contaminants, including PCBs, DDTs and chlordanes, were relatively high in sediment and water at the EIP stations, previous studies of sediment contamination have determined that high concentrations persist throughout the margins of the Estuary. A recent survey of sediment in storm drains found that concentrations of PCBs, PAHs, mercury, and methyl mercury were significantly higher in sediment collected in conveyances that drain urbanized regions of the watersheds compared to sediment from non-urban drainage areas and generally higher than concentrations at RMP stations.

- Estimated annual contaminant loads at the EIP stations were associated with high levels of uncertainty and at best, represent a lower-bound estimate of loading from the Guadalupe River and Coyote Creek watersheds. While these estimates are not intended to represent actual contaminant loading from the watersheds, they are of some value for order-of-magnitude comparisons between different pathways of contaminant loading. In the context of a preliminary PCB mass budget, a combined lower-bound estimate of 1 kg per year of PCBs from the two tributaries indicates that local tributaries are potentially significant pathways of PCB contamination that might lead to delays in restoration of beneficial uses in the Estuary. Similarly, the lower-bound estimate of 29 kg per year from the Guadalupe River watershed suggests that the tributary is most likely a significant pathway of external loading of mercury to the Lower South Bay. The extent to which local tributaries influence water quality conditions throughout the Estuary can be determined more accurately through event-based monitoring in the tributaries placed in the context of refined mass budget models for contaminants of concern.

- Contaminant concentrations on suspended solids indicate that wet-season loads of suspended sediment at Guadalupe River (BW15) may be enriched by several metals (copper, nickel, mercury, lead, and zinc) and organic contaminants (PCBs, DDTs, chlordanes, and PAHs) compared to Bay sediments.

- Concentrations of several contaminants were generally higher in water and sediment at San Jose (C-3-0) compared to Standish Dam (BW10), which lies nearby on Coyote Creek. Consistently high PCB concentrations in San Jose (C-3-0) sediment may be a result of historic PCB deposits. Land use between the two stations is highly urbanized, which may contribute additional loading of contaminants to San Jose (C-3-0). Furthermore, San Jose (C-3-0) lies downstream from the confluence of Coyote Creek and Artesian Slough, which receives drainage from the San Jose/Santa Clara Water Pollution Control Plant (SJSC WPCP). This suggests that differences in contaminant concentrations may arise from sources located between the two stations, or as a result of intertidal processes that affect concentrations in sediment and water along different reaches of the tributaries.

6.2. Next Steps

A five-year review of the RMP in 1997 led to a set of revised RMP objectives to address more specific management questions in the Estuary (Bernstein and O'Connor 1997). One of the objectives was to "determine general sources and loadings to the Estuary." To meet this objective, the RMP Sources, Pathways, and Loadings Workgroup (SPLWG) was formed to better understand the influence of various sources and pathways on water quality in the Bay. Evaluation of Pilot Study findings and activities of the SPLWG led to recommendations for next steps in monitoring local tributaries that build upon recommendations outlined in previous SPLWG reports by Davis *et al*. (1999) and Davis *et al*. (2000).

- Develop a methodology to accurately monitor contaminant loads from local tributaries by relating continuous monitoring of sediment and streamflow with discrete measurements of contaminant concentrations in the water column at frequent time intervals during the wet season. Applying proposed methods of tributary monitoring in the freshwater reaches of selected tributaries would characterize the variability in contaminant concentrations in response to changes in flow and sediment transport.

- Prioritize monitoring locations in local tributaries based on contaminant data from recent and historic sediment studies in the Bay margins and watersheds, watershed characteristics (*e.g*., land use, size, and hydrology), and ongoing or future studies focused on filling data gaps in the local tributaries that may drain watersheds with potentially significant sources of contamination.

- Explore and develop the application of alternative load indicators for determining trends in contaminant loading in the tributaries. For example, test sediment normalization methodology for reducing variability in contaminant concentrations in sediment samples of different size fractions to determine the applicability of sediment as in indicator of potential sources and trends in contaminant loading.

- Develop a network of tributary monitoring locations in selected watersheds for long-term characterization of sources and loadings from selected watersheds with the general objectives of estimating contaminant loading from local tributaries and comparing tributary loading to other pathways of contamination to the Bay.

- Coordinate future tributary monitoring with developing and continuing watershed management efforts (*e.g.,* BASMAA) to relate changes in contaminant concentration and loading at the lower end of the watersheds to the combined effects of potential sources in the watersheds, watershed characteristics and hydrology, and management actions.

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APPENDIX A. RMP monitoring information

Table A.1. RMP and EIP station locations and sampling information

Table A.2. RMP parameters analyzed in water and sediment during the EIP Study

Table A.1. RMP and EIP station locations and sampling information.

Station Name	Station Code	Sample Type	Measurements Made	Latitude * deg	Latitude * min	Longitude * deg	Longitude * min
Coyote Creek	BA10	water, sed	Q,M,O,T	37	28.20	122	3.80
South Bay	BA20	water	Q,M,O,T	37	29.69	122	5.34
	BA21	sediment	Q,M,O,T	37	29.69	122	5.34
Dumbarton Bridge	BA30	water, sed	Q,M,O,T	37	30.90	122	8.11
Redwood Creek	BA40	water	Q,M,O	37	33.67	122	12.57
	BA41	sediment	Q,M,O,T	37	33.67	122	12.57
San Bruno Shoal	BB15	water	Q,M	37	37.00	122	17.00
	BB15	sediment	Q,M,O,T	37	37.00	122	17.00
Oyster Point	BB30	water	Q,M	37	40.20	122	19.75
	BB30	sediment	Q,M,O	37	40.20	122	19.75
Alameda	BB70	water	Q,M,O	37	44.66	122	19.30
	BB70	sediment	Q,M,O,T	37	44.66	122	19.30
Yerba Buena Island	BC10	water	Q,M,O	37	49.36	122	20.96
	BC11	sediment	Q,M,O,T	37	49.36	122	20.96
Golden Gate	BC20	water	Q,M,O	37	51.81	122	32.20
Horseshoe Bay	BC21	sediment	Q,M,O,T	37	49.98	122	28.43
Richardson Bay	BC30	water	Q,M	37	51.81	122	28.66
	BC32	sediment	Q,M,O	37	51.81	122	28.66
Point Isabel	BC41	water, sed	Q,M,O	37	53.30	122	20.55
Red Rock	BC60	water	Q,M,O	37	55.00	122	26.00
	BC60	sediment	Q,M,O,T	37	55.00	122	26.00
Petaluma River	BD15	water, sed	Q,M,O	38	6.66	122	29.00
San Pablo Bay	BD20	water	Q,M,O	38	2.92	122	25.19
	BD22	sediment	Q,M,O,T	38	2.92	122	25.19
Pinole Point	BD30	water	Q,M,O,T	38	1.48	122	21.65
	BD31	sediment	Q,M,O	38	1.48	122	21.65
Davis Point	BD40	water	Q,M,O	38	3.12	122	16.62
	BD41	sediment	Q,M,O,T	38	3.12	122	16.62
Napa River	BD50	water	Q,M,O	38	5.79	122	15.61
	BD50	sediment	Q,M,O,T	38	5.79	122	15.61
Pacheco Creek	BF10	water, sed	Q,M,O	38	3.09	122	5.80
Grizzly Bay	BF20	water	Q,M,O,T	38	6.96	122	2.31
	BF21	sediment	Q,M,O,T	38	6.96	122	2.31
Honker Bay	BF40	water, sed	Q,M,O	38	4.00	121	56.00
Sacramento River	BG20	water	Q,M,O	38	3.56	121	48.59
	BG20	sediment	Q,M,O,T	38	3.56	121	48.59
San Joaquin River	BG30	water, sed	Q,M,O,T	38	1.40	121	48.45
San Jose	C-3-0	water, sed	Q,M,O,T	37	27.85	122	1.60
Sunnyvale	C-1-3	water	Q,M,T	37	26.08	122	0.64
	C-1-3	sediment	Q,M,O	37	26.08	122	0.64
Standish Dam†	BW10	water	Q,M,O	37	27.10	121	55.29
	BW10	sediment	M,O	37	27.10	121	55.29
Guadalupe River†	BW15	water	Q,M,O	37	25.34	121	58.45
	BW15	sediment	M,O				

M = trace elements　Q = water and/or sediment quality　† = Estuary Interface Pilot Station
O = trace organics　T = toxicity (aquatic and/or sediment)
* Latitude and longitude are approximate coordinates based on 1998 RMP sampling.

Table A.2. RMP parameters analyzed in water and sediment during the EIP Study.

A. Conventional Water Quality Parameters
Conductivity
Dissolved Organic Carbon
Dissolved Oxygen (DO)
Hardness (when salinity is <5 ‰)
pH (acidity)
Phaeophytin (a chlorophyll degradation product)
Salinity
Temperature
Total Chlorophyll-*a*
Total Suspended Solids
Dissolved Phosphates
Dissolved Silicates
Dissolved Nitrate
Dissolved Nitrite
Dissolved Ammonia

B. Sediment Quality Parameters
% Clay (<4 µm)
% Silt (4 µm–62 µm)
% Sand (63 µm–2 mm)
% Gravel (>2 mm)
% Solids
pH
Total Ammonia
Total Organic Carbon
Total Sulfide

C. Trace Elements	Water	Sediment
Aluminum*		●
Arsenic	●	●
Cadmium*	●	●
Chromium	●	●
Copper*	●	●
Iron*		●
Lead*	●	●
Manganese*		●
Mercury	●	●
Nickel*	●	●
Selenium	●	●
Silver*	●	●
Zinc*	●	●

* Near-total rather than total concentrations for water. Near-total metals are extracted with a weak acid (pH < 2) for a minimum of one month, resulting in measurements that approximate bioavailability of these metals to Estuary organisms.

Table A.2 (cont.). RMP parameters analyzed in water and sediment during the EIP Study.

D. Polycyclic Aromatic Hydrocarbons (PAHs)

	Water	Sediment
2 rings		
1-Methylnaphthalene	●	●
2,3,5-Trimethylnaphthalene	●	●
2,6-Dimethylnaphthalene	●	●
2-Methylnaphthalene	●	●
Biphenyl	●	●
Naphthalene	●	●
3 rings		
1-Methylphenanthrene	●	●
Acenaphthene	●	●
Acenaphthylene	●	●
Anthracene	●	●
Dibenzothiophene	●	●
Fluorene	●	●
Phenanthrene	●	●
4 rings		
Benz(a)anthracene	●	●
Chrysene	●	●
Fluoranthene	●	●
Pyrene	●	●
5 rings		
Benzo(a)pyrene	●	●
Benzo(b)fluoranthene	●	●
Benzo(e)pyrene	●	●
Benzo(k)fluoranthene	●	●
Dibenz(a,h)anthracene	●	●
Perylene	●	●
6 rings		
Benzo(ghi)perylene	●	●
Indeno(1,2,3-cd)pyrene	●	●
Alkylated PAHs		
C1-Chrysenes	●	●
C2-Chrysenes	●	●
C3-Chrysenes	●	●
C4-Chrysenes	●	●
C1-Dibenzothiophenes	●	●
C2-Dibenzothiophenes	●	●
C3-Dibenzothiophenes	●	●
C1-Fluoranthenes/Pyrenes	●	●
C1-Fluorenes	●	●
C2-Fluorenes	●	●
C3-Fluorenes	●	●
C1-Naphthalenes	●	●
C2-Naphthalenes	●	●
C3-Naphthalenes	●	●
C4-Naphthalenes	●	●

D. PAHs (continued)

	Water	Sediment
C1-Phenanthrenes/Anthracenes	●	●
C2-Phenanthrenes/Anthracenes	●	●
C3-Phenanthrenes/Anthracenes	●	●
C4-Phenanthrenes/Anthracenes	●	●

E. Synthetic Biocides

	Water	Sediment
Cyclopentadienes		
Aldrin	●	●
Dieldrin	●	●
Endrin	●	●
Chlordanes		
alpha-Chlordane	●	●
cis-Nonachlor	●	●
gamma-Chlordane	●	●
Heptachlor	●	●
Heptachlor Epoxide	●	●
Oxychlordane	●	●
trans-Nonachlor	●	●
DDTs		
o,p'-DDD	●	●
o,p'-DDE	●	●
o,p'-DDT	●	●
p,p'-DDD	●	●
p,p'-DDE	●	●
p,p'-DDT	●	●
HCHs		
alpha-HCH	●	●
beta-HCH	●	●
delta-HCH	●	●
gamma-HCH	●	●
Other		
Diazinon	●	
Mirex	●	●
Chlorpyrifos	●	

Table A.2 (cont.). RMP parameters analyzed in water and sediment during the EIP Study.

F. PCBs and Related Compounds	Water	Sediment
Hexachlorobenzene	●	●
PCB 008	●	●
PCB 018	●	●
PCB 028	●	●
PCB 031	●	●
PCB 033	●	●
PCB 044	●	●
PCB 049	●	●
PCB 052	●	●
PCB 056	●	●
PCB 060	●	●
PCB 066	●	●
PCB 070	●	●
PCB 074	●	●
PCB 087	●	●
PCB 095	●	●
PCB 097	●	●
PCB 099	●	●
PCB 101	●	●
PCB 105	●	●
PCB 110	●	●
PCB 118	●	●
PCB 128	●	●
PCB 132	●	●
PCB 138	●	●
PCB 141	●	●
PCB 149	●	●
PCB 151	●	●
PCB 153	●	●
PCB 156	●	●
PCB 158	●	●
PCB 170	●	●
PCB 174	●	●
PCB 177	●	●
PCB 180	●	●
PCB 183	●	●
PCB 187	●	●
PCB 194	●	●
PCB 195	●	●
PCB 201	●	●
PCB 203	●	●

APPENDIX B. Water and Sediment Quality Guidelines and Concentrations

Table B.1. Water quality criteria and guidelines. California Toxics Rule water quality criteria (USEPA 2000) are listed except where noted. Dissolved trace element criteria are listed (except for mercury aquatic life values). Total trace element criteria (not shown) may be calculated using the procedures specified in the proposed California Toxics Rule. Guidelines for organic compounds are listed on a total basis (dissolved + particulate). Units are µg/L. Bold and italicized values are hardness dependent criteria and are calculated for this table using a hardness value of 100 mg/L.

Parameter	Aquatic Life				Human Health (10^{-6} risk for carcinogens)	
	Fresh Water		Salt Water		Fresh Water	Salt & Fresh Water
	1-hour	4-day	1-hour	4-day	Water & Organisms	Organisms only
Ag	***3.4***	.	1.9	.	.	.
As	340	150	69	36	.	.
Cd	***4.3***	***2.2***	42	9.3	.	.
Cr VI	16	11	1100	50	.	.
Cu	***13***	***9***	4.8	3.1	1300	.
Hg [A]	2.4	0.012	2.1	0.025	0.05	0.051
Ni	***470***	***52***	74	8	610	4600
Pb	***65***	***2.5***	210	8.1	.	.
Se [B]		5	290	71	.	.
Zn	***120***	***120***	90	81	.	.
Alpha-HCH	.	.	.	.	0.0039	0.013
Acenaphthene	.	.	.	.	1200	2700
Anthracene	.	.	.	.	9600	110000
Benz(a)anthracene	.	.	.	.	0.0044	0.049
Benzo(a)pyrene	.	.	.	.	0.0044	0.049
Benzo(b)fluoranthene	.	.	.	.	0.0044	0.049
Benzo(k)fluoranthene	.	.	.	.	0.0044	0.049
Beta-HCH	.	.	.	.	0.014	0.046
Chlordane	2.4	0.0043	0.09	0.004	0.00057	0.00059
Chlorpyrifos [C]	0.083	0.041	0.011	0.0056	.	.
Chrysene	.	.	.	.	0.0044	0.049
Dibenz(a,h)anthracene	.	.	.	.	0.0044	0.049
Dieldrin	0.24	0.056	0.71	0.0019	0.00014	0.00014
Endosulfan I	0.22	0.056	0.034	0.0087	110	240
Endosulfan II	0.22	0.056	0.034	0.0087	110	240
Endosulfan Sulfate	.	.	.	.	110	240
Endrin	0.086	0.036	0.037	0.0023	0.76	0.81
Fluoranthene	.	.	.	.	300	370
Fluorene	.	.	.	.	1300	14000
Gamma-HCH	0.095	0.08	0.16	.	0.019	0.063
Heptachlor	0.52	0.0038	0.053	0.0036	0.00021	0.00021
Heptachlor Epoxide	0.52	0.0038	0.053	0.0036	0.0001	0.00011
Hexachlorobenzene	.	.	.	.	0.00075	0.00077
Indeno(1,2,3-cd)pyrene	.	.	.	.	0.0044	0.049
p,p'-DDD	.	.	.	.	0.00083	0.00084
p,p'-DDE	.	.	.	.	0.00059	0.00059
p,p'-DDT	1.1	0.001	0.13	0.001	0.00059	0.00059
Pyrene	.	.	.	.	960	11000
Mirex [C]	.	0.001	.	0.001	.	.
Total PCBs	.	0.014	.	0.03	0.00017	0.00017

[A] Mercury Aquatic Life values are from the San Francisco Basin Plan, 1995 and are for total recoverable mercury.
[B] Selenium values are region-specific criteria as outlined in the National Toxics Rule: values are for total recoverable selenium results and fresh water criteria apply to the whole estuary into the Delta.
[C] Chlorpyrifos and mirex are not listed in the proposed CTR but EPA criteria do exist for them.

Table B.2. Sediment quality guidelines and concentrations. Effects Range-Low (ERL) and Effects Range-Median (ERM) concentrations are from Long and Morgan (1990) and Long *et al.* (1995). San Francisco Bay Ambient Sediment Concentrations (ASC) are from Gandesbery (1998).

Parameter	unit	ERL	ERM	ASC-sandy <40% fines	ASC-muddy >40% fines
Arsenic	mg/Kg	8.2	70	13.5	15.3
Cadmium	mg/Kg	1.2	9.6	0.25	0.33
Chromium	mg/Kg	81	370	91.4	112
Copper	mg/Kg	34	270	31.7	68.1
Mercury	mg/Kg	0.15	0.71	0.25	0.43
Nickel	mg/Kg	20.9	51.6	92.9	112
Lead	mg/Kg	46.7	218	20.3	43.2
Selenium	mg/Kg			0.59	0.64
Silver	mg/Kg	1	3.7	0.31	0.58
Zinc	mg/Kg	150	410	97.8	158
Total HPAHs (SFEI)	µg/Kg	1700	9600	256	3060
Fluoranthene	µg/Kg	600	5100	78.7	514
Perylene	µg/Kg			24	145
Pyrene	µg/Kg	665	2600	64.6	665
Benz(a)anthracene	µg/Kg	261	1600	15.9	244
Chrysene	µg/Kg	384	2800	19.4	289
Benzo(b)fluoranthene	µg/Kg			32.1	371
Benzo(k)fluoranthene	µg/Kg			29.2	258
Benzo(a)pyrene	µg/Kg	430	1600	18.1	412
Benzo(e)pyrene	µg/Kg			17.3	294
Dibenz(a,h)anthracene	µg/Kg	63.4	260	3	32.7
Benzo(g,h,i)perylene	µg/Kg			22.9	310
Indeno(1,2,3-c,d)pyrene	µg/Kg			19	382
Total LPAHs (SFEI)	µg/Kg	552	3160	37.9	434
1-Methylnaphthalene	µg/Kg			6.8	12.1
1-Methylphenanthrene	µg/Kg			4.5	31.7
2,3,5-Trimethylnaphthalene	µg/Kg			3.3	9.8
2,6,-Dimethylnaphthalene	µg/Kg			5	12.1
2-Methylnaphthalene	µg/Kg	70	670	9.4	19.4
Naphthalene	µg/Kg	160	2100	8.8	55.8
Acenaphthylene	µg/Kg	44	640	2.2	31.7
Acenaphthene	µg/Kg	16	500	11.3	26.6
Fluorene	µg/Kg	19	540	4	25.3
Phenanthrene	µg/Kg	240	1500	17.8	237
Anthracene	µg/Kg	85.3	1100	9.3	88
Total PAHs (SFEI)	µg/Kg	4022	44792	211	3390
p,p'-DDE	µg/Kg	2.2	27		
Total DDTs (SFEI)	µg/Kg	1.58	46.1	1.58	46.1
Total Chlordanes (SFEI)	µg/Kg	0.5	6	0.42	1.1
Dieldrin	µg/Kg	0.02	8	0.18	0.44
TOTAL PCBs (NIST 18)	µg/Kg			5.9	14.8
Total PCBs (SFEI)	µg/Kg	22.7	180	8.6	21.6

APPENDIX C. Statistical data and information for EIP monitoring

Table C.1. Descriptive statistics for dissolved trace elements in water (µg/L), RMP data 1996-1999.

Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments (p < 0.05). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Dissolved Silver (Ag)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 1.32**	**p = 0.24**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 10**	**p < 0.0001**
Guadalupe River (BW15)	4	0.0016	0.0015	0.0004	0.0029			3	0.0014	0.0010	0.0004	0.0027		
Standish Dam (BW10)	4	0.0020	0.0018	0.0010	0.0033			5	0.0013	0.0010	0.0007	0.0026		
Southern Sloughs (SS)	10	0.0020	0.0015	0.0006	0.0045			10	0.0019	0.0015	0.0006	0.0039		
Lower South Bay (LSB)	10	0.0027	0.0021	0.0007	0.0049			10	0.0051	0.0044	0.0032	0.0122		
South Bay (SB)	10	0.0026	0.0030	0.0010	0.0043			10	0.0066	0.0060	0.0014	0.0118		
Central Bay (CB)	39	0.0027	0.0030	0.0005	0.0048			40	0.0036	0.0035	0.0006	0.0087		
San Pablo Bay (SPB)	25	0.0026	0.0020	0.0004	0.0115			25	0.0035	0.0030	0.0009	0.0112		
Suisun Bay (SUB)	15	0.0025	0.0026	0.0007	0.0050			15	0.0017	0.0011	0.0004	0.0032		
Rivers	10	0.0033	0.0033	0.0017	0.0050			10	0.0014	0.0010	0.0002	0.0032		
BAYWIDE	127	0.0026						128	0.0032					
Dissolved Arsenic (As)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 11.7**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 11**	**p < 0.0001**
Guadalupe River (BW15)	4	1.0	1.0	0.8	1.3			5	1.9	1.7	0.7	3.3		
Standish Dam (BW10)	4	1.5	1.2	1.1	2.4			7	2.5	2.7	1.6	3.2		
Southern Sloughs (SS)	10	2.1	1.9	1.2	3.1			14	3.4	3.8	1.5	4.8		
Lower South Bay (LSB)	10	2.2	2.2	1.9	2.5			14	3.5	3.9	1.4	4.5		
South Bay (SB)	10	2.0	2.0	1.5	2.5			14	2.9	2.8	1.5	4.1		
Central Bay (CB)	39	1.6	1.6	1.2	2.0			56	1.9	1.8	1.1	3.0		
San Pablo Bay (SPB)	25	1.6	1.4	1.1	3.3			35	2.2	2.2	1.2	3.9		
Suisun Bay (SUB)	15	1.4	1.3	1.1	2.2			21	1.8	1.9	1.0	2.6		
Rivers	10	1.3	1.3	0.9	1.7			14	1.6	1.6	1.0	2.2		**B**
BAYWIDE	127	1.6						180	2.2					
Dissolved Cadmium (Cd)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 15.1**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 25**	**p < 0.0001**
Guadalupe River (BW15)	3	0.013	0.010	0.010	0.020			3	0.020	0.010	0.010	0.040		
Standish Dam (BW10)	3	0.010	0.010	0.010	0.010			5	0.020	0.010	0.010	0.060		
Southern Sloughs (SS)	8	0.034	0.030	0.010	0.060			10	0.048	0.045	0.030	0.080		
Lower South Bay (LSB)	8	0.051	0.050	0.030	0.080			10	0.090	0.090	0.070	0.120		
South Bay (SB)	8	0.050	0.050	0.020	0.080			10	0.080	0.080	0.060	0.110		
Central Bay (CB)	31	0.033	0.030	0.010	0.070			40	0.069	0.070	0.040	0.120		
San Pablo Bay (SPB)	20	0.019	0.010	0.003	0.100			25	0.065	0.070	0.020	0.150		
Suisun Bay (SUB)	12	0.009	0.010	0.003	0.010			15	0.023	0.020	0.010	0.040		
Rivers	8	0.009	0.010	0.004	0.010			10	0.010	0.010	0.010	0.010		
BAYWIDE	101	0.027						128	0.056					
Dissolved Chromium (Cr)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 24.3**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17**	**p < 0.0001**
Guadalupe River (BW15)	4	0.92	0.97	0.64	1.11			5	0.31	0.29	0.21	0.40		
Standish Dam (BW10)	4	0.92	0.85	0.61	1.38			7	0.28	0.26	0.12	0.56		
Southern Sloughs (SS)	10	0.42	0.45	0.17	0.83			13	0.36	0.20	0.11	1.38		
Lower South Bay (LSB)	10	0.25	0.19	0.10	0.51	**A**	**B**	14	0.27	0.17	0.10	1.45		
South Bay (SB)	10	0.18	0.12	0.09	0.49	**A**	**B**	13	0.18	0.13	0.07	0.42		
Central Bay (CB)	36	0.17	0.15	0.09	0.38	**A**	**B**	55	0.16	0.11	0.07	1.28	**A**	**B**
San Pablo Bay (SPB)	25	1.72	0.42	0.11	8.79			35	0.27	0.18	0.11	1.76		
Suisun Bay (SUB)	15	1.89	1.28	0.27	6.25			21	0.42	0.29	0.11	1.55		
Rivers	10	1.37	1.02	0.26	5.03			14	0.44	0.34	0.21	1.12		
BAYWIDE	124	0.86						177	0.27					
Dissolved Copper (Cu)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 6.93**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 26**	**p < 0.0001**
Guadalupe River (BW15)	4	1.2	1.2	0.8	1.5			5	1.3	1.2	0.9	2.5		
Standish Dam (BW10)	4	1.4	1.4	1.3	1.6			7	1.4	1.2	0.9	2.7		
Southern Sloughs (SS)	10	2.0	1.8	1.3	3.5			14	2.5	2.3	1.4	4.0		
Lower South Bay (LSB)	10	2.0	1.9	1.5	2.9			14	3.0	3.2	2.0	4.1		
South Bay (SB)	10	1.9	1.9	1.4	2.8			14	2.4	2.4	1.9	3.2		
Central Bay (CB)	39	1.3	1.3	0.4	2.1			56	1.1	1.1	0.3	2.2		
San Pablo Bay (SPB)	25	2.0	1.6	1.1	4.5			35	2.0	1.7	1.1	3.8		
Suisun Bay (SUB)	15	1.6	1.5	1.1	2.8			21	1.6	1.5	1.2	2.1		
Rivers	10	1.6	1.6	1.2	2.2			14	1.5	1.5	0.9	1.8		
BAYWIDE	127	1.6						180	1.7					

Table C.1 (cont.). Descriptive statistics for dissolved trace elements in water (µg/L), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Dissolved Mercury (Hg)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 14.5**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 15**	**p < 0.0001**
Guadalupe River (BW15)	4	0.0145	0.0103	0.0026	0.0348			3	0.0011	0.0012	0.0006	0.0014		
Standish Dam (BW10)	4	0.0028	0.0030	0.0017	0.0033			6	0.0008	0.0008	0.0001	0.0016		
Southern Sloughs (SS)	10	0.0026	0.0026	0.0008	0.0041			12	0.0017	0.0018	0.0007	0.0041		
Lower South Bay (LSB)	8	0.0018	0.0018	0.0012	0.0024			13	0.0026	0.0015	0.0008	0.0106		
South Bay (SB)	9	0.0015	0.0012	0.0008	0.0037	**A**		12	0.0013	0.0012	0.0007	0.0020		
Central Bay (CB)	31	0.0009	0.0008	0.0001	0.0030	**A**	**B**	44	0.0007	0.0005	0.0001	0.0075		
San Pablo Bay (SPB)	24	0.0056	0.0021	0.0006	0.0353			27	0.0008	0.0007	0.0003	0.0021		
Suisun Bay (SUB)	15	0.0030	0.0026	0.0013	0.0077			17	0.0011	0.0009	0.0005	0.0027		
Rivers	10	0.0034	0.0026	0.0012	0.0084			13	0.0010	0.0011	0.0004	0.0015		
BAYWIDE	115	0.0032						147	0.0011					

Dissolved Nickel (Ni)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 10.2**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 54**	**p < 0.0001**
Guadalupe River (BW15)	4	3.2	2.8	2.1	5.1			5	3.3	2.9	2.5	4.3		
Standish Dam (BW10)	4	2.7	3.0	1.7	3.2			7	3.4	2.9	2.2	6.1		
Southern Sloughs (SS)	10	3.1	3.1	1.6	4.8			14	5.3	5.4	2.2	8.6		
Lower South Bay (LSB)	10	2.5	2.4	2.0	3.2			14	3.4	3.2	2.0	6.6		
South Bay (SB)	10	2.3	2.3	1.7	2.9			14	2.3	2.3	1.7	3.0		
Central Bay (CB)	39	1.4	1.4	0.6	2.2	**A**	**B**	56	1.2	1.1	0.4	2.2	**A**	**B**
San Pablo Bay (SPB)	25	4.2	2.1	1.0	37.4			35	1.9	1.7	1.2	4.1	**A**	**B**
Suisun Bay (SUB)	15	1.7	1.1	0.9	4.5	**A**	**B**	21	1.2	1.1	0.7	2.2	**A**	**B**
Rivers	10	1.7	1.7	1.0	3.1			14	1.0	1.0	0.8	1.3	**A**	**B**
BAYWIDE	127	2.4						180	2.0					

Dissolved Lead (Pb)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 19.7**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 56**	**p < 0.0001**
Guadalupe River (BW15)	4	0.17	0.14	0.07	0.33			5	0.07	0.07	0.03	0.14		
Standish Dam (BW10)	4	0.15	0.14	0.08	0.23			7	0.16	0.15	0.08	0.26		
Southern Sloughs (SS)	10	0.12	0.10	0.03	0.24			14	0.23	0.24	0.13	0.34		
Lower South Bay (LSB)	10	0.06	0.05	0.02	0.14			14	0.09	0.08	0.04	0.17		
South Bay (SB)	10	0.04	0.03	0.01	0.10			14	0.04	0.04	0.02	0.08		**B**
Central Bay (CB)	39	0.01	0.01	0.00	0.08	**A**	**B**	56	0.01	0.01	0.00	0.04	**A**	**B**
San Pablo Bay (SPB)	25	0.18	0.07	0.01	0.99			35	0.01	0.01	0.01	0.03	**A**	**B**
Suisun Bay (SUB)	15	0.15	0.11	0.01	0.49			21	0.03	0.02	0.01	0.16	**A**	**B**
Rivers	10	0.17	0.11	0.05	0.38			14	0.06	0.06	0.02	0.11		
BAYWIDE	127	0.10						180	0.05					

Dissolved Selenium (Se)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 18.6**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 38**	**p < 0.0001**
Guadalupe River (BW15)	4	1.84	1.96	0.96	2.48			5	5.56	5.94	4.29	6.42		
Standish Dam (BW10)	4	0.66	0.67	0.53	0.78			7	1.85	1.80	1.14	2.55		
Southern Sloughs (SS)	10	0.82	0.68	0.35	2.30			14	1.13	1.05	0.37	2.14		
Lower South Bay (LSB)	10	0.34	0.31	0.19	0.51			14	0.44	0.38	0.19	1.18		
South Bay (SB)	10	0.27	0.22	0.15	0.53			14	0.22	0.21	0.13	0.37	**A**	**B**
Central Bay (CB)	39	0.13	0.12	0.01	0.34	**A**	**B**	54	0.11	0.11	0.01	0.32	**A**	**B**
San Pablo Bay (SPB)	25	0.15	0.15	0.04	0.28	**A**	**B**	35	0.16	0.15	0.08	0.31	**A**	**B**
Suisun Bay (SUB)	15	0.13	0.12	0.03	0.31	**A**	**B**	21	0.12	0.11	0.05	0.23	**A**	**B**
Rivers	10	0.17	0.14	0.08	0.37	**A**	**B**	14	0.10	0.08	0.04	0.21	**A**	**B**
BAYWIDE	127	0.29						178	0.46					

Dissolved Zinc (Zn)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 8.88**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 24**	**p < 0.0001**
Guadalupe River (BW15)	4	3.7	3.5	2.3	5.6			5	1.9	1.1	1.1	4.8		
Standish Dam (BW10)	4	1.6	1.5	1.2	2.0			7	2.8	1.4	1.1	9.4		
Southern Sloughs (SS)	10	6.7	4.9	2.5	19.5			14	9.9	9.2	3.1	22.5		
Lower South Bay (LSB)	10	2.3	2.5	0.9	3.5			14	2.1	2.0	0.7	4.6		
South Bay (SB)	10	1.8	1.8	0.5	3.2			14	0.9	0.8	0.4	1.8		
Central Bay (CB)	39	0.8	0.8	0.1	2.4	**A**		56	0.5	0.5	0.1	1.8	**A**	**B**
San Pablo Bay (SPB)	25	1.9	1.0	0.2	8.4			35	0.6	0.5	0.2	1.0	**A**	**B**
Suisun Bay (SUB)	15	1.4	1.1	0.2	3.6			21	0.6	0.4	0.3	2.1	**A**	**B**
Rivers	10	1.4	1.2	0.4	3.4			14	0.7	0.7	0.4	1.4		**B**
BAYWIDE	127	1.9						180	1.6					

Table C.2. Descriptive statistics for total trace elements in water (µg/L), RMP data 1996-1999.

Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments (p < 0.05). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Total Silver (Ag)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 15.4**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 13.8**	**p < 0.0001**
Guadalupe River (BW15)	3	0.036	0.048	0.011	0.048			3	0.031	0.027	0.027	0.038		
Standish Dam (BW10)	3	0.044	0.052	0.016	0.063			5	0.016	0.012	0.002	0.037		
Southern Sloughs (SS)	8	0.103	0.111	0.015	0.195			10	0.092	0.084	0.030	0.179		
Lower South Bay (LSB)	8	0.021	0.018	0.011	0.050			10	0.021	0.018	0.009	0.043		
South Bay (SB)	8	0.014	0.013	0.006	0.029			10	0.014	0.015	0.005	0.020		
Central Bay (CB)	31	0.007	0.006	0.002	0.018	**A**	**B**	39	0.007	0.006	0.000	0.025	**A**	
San Pablo Bay (SPB)	20	0.023	0.014	0.006	0.098			25	0.020	0.011	0.003	0.059		
Suisun Bay (SUB)	12	0.010	0.009	0.007	0.017			15	0.009	0.009	0.000	0.025		
Rivers	8	0.009	0.007	0.005	0.019	**A**	**B**	10	0.005	0.003	0.000	0.010	**A**	
BAYWIDE	101	0.022						127	0.019					
Total Arsenic (As)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 14.8**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.1**	**p < 0.0001**
Guadalupe River (BW15)	4	1.9	1.6	1.3	3.0		**B**	5.0	5.8	2.8	2.2	17.7		
Standish Dam (BW10)	4	4.8	4.6	2.2	7.5			7.0	3.2	3.4	1.6	4.9		
Southern Sloughs (SS)	10	4.8	4.0	2.4	9.4			14.0	5.0	5.2	1.9	8.2		
Lower South Bay (LSB)	10	2.7	2.6	2.1	3.8			14.0	4.0	4.4	2.2	5.9		
South Bay (SB)	10	2.3	2.2	1.6	2.8			14.0	3.0	3.0	1.4	4.2		
Central Bay (CB)	39	1.7	1.7	0.9	2.4		**B**	56.0	2.0	2.0	1.1	3.5	**A**	**B**
San Pablo Bay (SPB)	25	3.4	3.2	1.6	7.7			35.0	3.1	2.9	1.7	7.7		
Suisun Bay (SUB)	15	2.4	2.2	1.6	4.3			21.0	3.0	3.0	1.2	7.4		
Rivers	10	1.9	1.8	0.0	3.7		**B**	14.0	2.0	2.1	1.2	2.6	**A**	**B**
BAYWIDE	127	2.6						180.0	2.9					
Total Cadmium (Cd)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 10.2**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 11.2**	**p < 0.0001**
Guadalupe River (BW15)	3	0.093	0.110	0.050	0.120			3	0.153	0.050	0.030	0.380		
Standish Dam (BW10)	3	0.190	0.160	0.050	0.360			5	0.050	0.040	0.020	0.090		
Southern Sloughs (SS)	8	0.113	0.120	0.070	0.150			10	0.083	0.085	0.040	0.140		
Lower South Bay (LSB)	8	0.069	0.070	0.040	0.090			10	0.112	0.115	0.080	0.140		
South Bay (SB)	8	0.064	0.065	0.020	0.100			10	0.098	0.105	0.050	0.130		
Central Bay (CB)	30	0.036	0.040	0.020	0.070	**A**	**B**	39	0.077	0.080	0.030	0.140		
San Pablo Bay (SPB)	20	0.059	0.040	0.020	0.170			25	0.087	0.090	0.030	0.190		
Suisun Bay (SUB)	12	0.034	0.030	0.020	0.060	**A**	**B**	15	0.050	0.050	0.010	0.110		
Rivers	8	0.030	0.025	0.010	0.060	**A**	**B**	10	0.022	0.020	0.010	0.030		
BAYWIDE	100	0.057						127	0.077					
Total Chromium (Cr)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 22.7**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 36.3**	**p < 0.0001**
Guadalupe River (BW15)	4	14.2	11.3	8.3	25.9			5	38.1	18.0	3.6	125.9		
Standish Dam (BW10)	4	45.7	34.8	12.2	100.9			7	7.9	5.4	1.0	16.5		
Southern Sloughs (SS)	10	39.7	41.8	6.0	65.0			14	28.1	25.2	5.7	62.0		
Lower South Bay (LSB)	9	7.4	6.0	1.9	17.2		**B**	14	9.3	7.1	3.6	20.1		
South Bay (SB)	10	5.3	5.2	1.0	14.7		**B**	14	3.7	3.3	0.7	7.1	**A**	
Central Bay (CB)	38	2.5	2.1	0.3	9.4	**A**	**B**	56	1.6	1.1	0.1	8.9	**A**	**B**
San Pablo Bay (SPB)	25	22.7	17.5	2.2	74.9			35	12.7	6.8	1.1	63.9		
Suisun Bay (SUB)	15	13.6	12.9	4.2	41.4			21	38.0	14.0	3.3	198.2		
Rivers	10	9.1	7.4	2.7	26.1			14	13.2	4.6	1.5	80.4		
BAYWIDE	125	13.7						180	13.0					
Total Copper (Cu)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 35.9**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 42.6**	**p < 0.0001**
Guadalupe River (BW15)	4	6.1	6.2	3.8	8.1			5	15.1	6.6	3.9	47.0		
Standish Dam (BW10)	4	11.2	9.8	5.3	20.0			7	4.9	3.7	2.0	9.6		
Southern Sloughs (SS)	10	12.0	13.5	4.3	17.8			14	10.4	8.1	3.5	30.8		
Lower South Bay (LSB)	10	4.3	4.3	3.0	6.0		**B**	14	5.9	5.4	3.5	10.4		
South Bay (SB)	10	3.5	3.5	2.1	5.2		**B**	14	3.6	3.6	2.7	5.7	**A**	
Central Bay (CB)	39	2.1	2.1	0.5	3.9	**A**	**B**	55	1.7	1.6	0.3	4.0	**A**	**B**
San Pablo Bay (SPB)	25	7.7	6.5	2.5	20.2			35	6.1	4.1	1.9	17.7		
Suisun Bay (SUB)	15	5.4	4.7	3.2	10.9			21	5.9	5.7	1.7	15.3		
Rivers	10	4.5	3.7	2.5	9.9		**B**	14	2.9	2.9	2.1	4.1	**A**	
BAYWIDE	127	5.2						179	4.8					

Table C.2 (cont.). Descriptive statistics for total trace elements in water (µg/L), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Total Mercury (Hg)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 25.2**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 36.7**	**P < 0.0001**
Guadalupe River (BW15)	4	0.236	0.077	0.060	0.730			5	0.161	0.063	0.018	0.622		
Standish Dam (BW10)	4	0.043	0.043	0.022	0.064			7	0.019	0.012	0.005	0.066		
Southern Sloughs (SS)	10	0.092	0.098	0.018	0.212			14	0.056	0.058	0.009	0.118		
Lower South Bay (LSB)	10	0.017	0.014	0.007	0.048	**A**		14	0.023	0.018	0.008	0.056		
South Bay (SB)	10	0.016	0.013	0.001	0.036	**A**		14	0.008	0.007	0.003	0.014	**A**	
Central Bay (CB)	39	0.005	0.004	0.000	0.029	**A**	**B**	55	0.004	0.003	0.001	0.016	**A**	**B**
San Pablo Bay (SPB)	24	0.036	0.026	0.006	0.126			35	0.022	0.013	0.003	0.088		
Suisun Bay (SUB)	15	0.016	0.012	0.006	0.046	**A**		21	0.022	0.021	0.004	0.084		
Rivers	10	0.011	0.006	0.001	0.038	**A**	**B**	14	0.006	0.006	0.002	0.010	**A**	
BAYWIDE	126	0.030						179	0.020					
Total Nickel (Ni)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 29.9**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 42.6**	**p < 0.0001**
Guadalupe River (BW15)	4	17.9	16.9	10.0	27.6			5	35.8	14.5	10.3	107.3		
Standish Dam (BW10)	4	35.1	35.9	19.5	49.0			7	11.9	10.6	3.7	24.0		
Southern Sloughs (SS)	10	26.0	27.9	4.0	44.0			14	23.6	18.5	8.2	80.0		
Lower South Bay (LSB)	10	7.3	7.0	4.0	11.0		**B**	14	10.3	8.9	4.2	21.0		
South Bay (SB)	10	5.6	5.2	2.1	10.0	**A**	**B**	14	4.9	4.5	3.0	8.6	**A**	
Central Bay (CB)	39	2.9	2.4	0.8	8.5	**A**	**B**	55	2.3	2.0	0.4	6.5	**A**	**B**
San Pablo Bay (SPB)	25	16.7	11.0	3.9	41.3			35	10.4	6.6	2.5	36.0		
Suisun Bay (SUB)	15	10.1	8.5	4.0	28.5		**B**	21	9.0	8.8	2.1	24.1		
Rivers	10	7.3	5.3	3.0	21.8		**B**	14	3.5	3.5	1.8	5.2	**A**	**B**
BAYWIDE	127	10.7						179	8.5					
Total Lead (Pb)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 27.0**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 36.9**	**p < 0.0001**
Guadalupe River (BW15)	4	4.6	4.3	2.7	6.8			5	12.5	4.1	2.5	44.2		
Standish Dam (BW10)	4	7.1	5.0	2.7	15.9			7	2.7	2.4	0.9	4.9		
Southern Sloughs (SS)	9	7.8	9.5	1.3	13.3			12	5.1	5.1	1.1	11.8		
Lower South Bay (LSB)	9	1.1	1.0	0.4	2.4	**A**	**B**	14	1.7	1.4	0.4	3.4		
South Bay (SB)	10	1.0	0.8	0.2	2.6	**A**	**B**	14	0.6	0.5	0.2	1.2	**A**	**B**
Central Bay (CB)	39	0.4	0.4	0.1	1.7	**A**	**B**	55	0.3	0.2	0.0	1.6	**A**	**B**
San Pablo Bay (SPB)	25	2.6	2.2	0.5	6.6			35	1.8	1.1	0.2	6.0	**A**	
Suisun Bay (SUB)	15	1.2	1.1	0.5	2.5	**A**	**B**	21	1.7	1.6	0.3	3.8		
Rivers	10	1.0	0.7	0.4	2.4	**A**	**B**	14	0.6	0.5	0.3	1.2	**A**	**B**
BAYWIDE	125	2.0						177	1.7					
Total Selenium (Se)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 14.7**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 36.4**	**p < 0.0001**
Guadalupe River (BW15)	4	1.86	1.97	1.21	2.28			5	5.92	7.02	1.54	7.22		
Standish Dam (BW10)	4	0.75	0.82	0.34	1.02			7	2.08	1.83	1.29	3.63		
Southern Sloughs (SS)	10	0.97	0.78	0.39	2.41			14	1.20	1.17	0.45	2.20		
Lower South Bay (LSB)	10	0.37	0.34	0.10	0.65			14	0.44	0.37	0.15	1.19		
South Bay (SB)	10	0.28	0.24	0.15	0.63			14	0.24	0.24	0.07	0.43	**A**	**B**
Central Bay (CB)	38	0.15	0.15	0.03	0.30	**A**	**B**	54	0.11	0.11	0.02	0.34	**A**	**B**
San Pablo Bay (SPB)	25	0.21	0.18	0.08	0.51	**A**	**B**	34	0.18	0.18	0.03	0.39	**A**	**B**
Suisun Bay (SUB)	15	0.15	0.15	0.04	0.32	**A**	**B**	21	0.16	0.16	0.04	0.27	**A**	**B**
Rivers	10	0.17	0.17	0.01	0.43	**A**	**B**	14	0.12	0.11	0.06	0.20	**A**	**B**
BAYWIDE	126	0.33						177	0.50					
Total Zinc (Zn)	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 31.9**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 43.9**	**p < 0.0001**
Guadalupe River (BW15)	4	25.6	24.3	16.4	37.6			5	63.7	24.7	14.0	215.6		
Standish Dam (BW10)	4	40.9	30.5	15.3	87.1			7	21.8	11.7	3.8	55.4		
Southern Sloughs (SS)	10	47.3	51.9	16.9	77.6			14	39.2	33.3	11.5	98.6		
Lower South Bay (LSB)	10	9.2	8.4	5.2	18.5		**B**	14	11.8	10.4	4.2	31.5		
South Bay (SB)	10	6.5	6.1	1.6	13.1	**A**	**B**	14	4.4	4.8	2.0	8.2	**A**	**B**
Central Bay (CB)	39	3.3	2.8	0.6	9.5	**A**	**B**	55	2.3	1.8	0.3	7.8	**A**	**B**
San Pablo Bay (SPB)	25	18.1	14.3	3.3	50.2			35	13.1	7.5	2.2	91.3	**A**	
Suisun Bay (SUB)	15	10.5	9.4	3.9	23.4		**B**	21	15.4	12.4	2.4	94.1		
Rivers	10	7.7	6.1	3.1	18.2	**A**	**B**	14	4.2	3.9	2.0	6.1	**A**	**B**
BAYWIDE	127	13.5						179	12.4					

Table C.3. Descriptive statistics for dissolved organic contaminants in water (pg/L), RMP data 1996-1999.

Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Dissolved PCBs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 12.2**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**13.9**	**p < 0.0001**
Guadalupe River (BW15)	4	591	501	430	930			5	494	458	262	720		
Standish Dam (BW10)	4	239	167	95	528			7	521	474	274	896		
San Jose (C-3-0)	5	483	460	343	670			7	693	640	398	1,190		
Lower South Bay (LSB)	5	208	207	140	259			6	240	248	93	341		
South Bay (SB)	10	175	196	58	265			14	156	148	58	259		**B**
Central Bay (CB)	19	97	107	35	230	**A**		27	92	89	20	149	**A**	**B**
San Pablo Bay (SPB)	25	85	91	12	147	**A**		35	139	105	53	810	**A**	**B**
Suisun Bay (SUB)	5	62	46	26	135	**A**	**B**	7	108	105	57	170	**A**	**B**
Rivers	10	57	58	16	99	**A**	**B**	14	108	82	35	309	**A**	**B**
BAYWIDE	87	154						122	198					
Dissolved DDTs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 3.6**	**p = 0.002**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 9.0**	**p < 0.0001**
Guadalupe River (BW15)	3	493	660	152	668			5	672	540	492	1,157		
Standish Dam (BW10)	3	696	340	279	1,469			7	1,438	1,308	228	2,324		
San Jose (C-3-0)	4	699	506	271	1,512			7	555	434	260	1,245		
Lower South Bay (LSB)	4	376	235	170	863			5	221	194	55	451		
South Bay (SB)	8	218	204	75	405			12	141	120	22	397		
Central Bay (CB)	16	159	146	20	400			24	98	94	13	238	**A**	**B**
San Pablo Bay (SPB)	20	281	254	32	711			33	216	240	42	440		**B**
Suisun Bay (SUB)	4	310	304	16	615			7	256	287	133	338		
Rivers	8	244	241	73	399			13	282	240	99	780		
BAYWIDE	70	300						113	310					
Dissolved Chlorpyrifos	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 1.9**	**p = 0.072**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 16.4**	**p < 0.0001**
Guadalupe River (BW15)	4	329	188	2.9	940			5	1,970	390	ND	8,100		
Standish Dam (BW10)	4	210	140	1.5	560			7	2,481	930	ND	13,000		
San Jose (C-3-0)	5	1,260	760	6.5	4,000			7	1,838	510	ND	11,000		
Lower South Bay (LSB)	5	291	360	7.1	450			5	120	150	ND	250	**A**	**B**
South Bay (SB)	10	148	150	ND	490			13	71	65	ND	230	**A**	**B**
Central Bay (CB)	19	102	35	ND	410			26	50	33	ND	220	**A**	**B**
San Pablo Bay (SPB)	23	258	260	ND	1,200			35	114	110	ND	340	**A**	**B**
Suisun Bay (SUB)	5	198	170	ND	460			7	194	200	ND	400		
Rivers	9	270	330	ND	590			14	312	305	ND	900	**A**	**B**
BAYWIDE	84	270						119	442					
Dissolved Diazinon	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 1.1**	**p = 0.37**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 4.9**	**p < 0.0001**
Guadalupe River (BW15)	3	6,967	4,500	3,400	13,000			5	6,220	6,100	1,700	9,900		
Standish Dam (BW10)	2	5,500	5,500	1,300	9,700			7	8,629	7,800	ND	14,000		
San Jose (C-3-0)	4	20,250	17,500	10,000	36,000			6	12,467	11,000	6,500	24,000		
Lower South Bay (LSB)	4	7,800	7,050	5,100	12,000			5	6,080	6,200	3,100	9,700		
South Bay (SB)	8	6,638	7,050	1,000	14,000			11	3,377	3,700	ND	5,600		**B**
Central Bay (CB)	18	5,670	4,300	ND	32,000			24	1,276	1,250	ND	3,900	**A**	**B**
San Pablo Bay (SPB)	18	17,394	11,500	ND	44,000			35	2,900	2,500	ND	7,600		
Suisun Bay (SUB)	2	36,500	36,500	15,000	58,000			7	3,144	2,700	540	6,400		
Rivers	7	20,970	25,000	790	37,000			14	2,754	2,150	ND	6,500		
BAYWIDE	66	12,608						114	3,742					
Dissolved Chlordanes	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 3.2**	**p = 0.003**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 11.4**	**p < 0.0001**
Guadalupe River (BW15)	4	320	232	170	648			5	535	363	262	1,288		
Standish Dam (BW10)	4	206	141	74	467			7	881	820	344	1,443		
San Jose (C-3-0)	5	417	260	190	1,014			7	353	340	160	637		
Lower South Bay (LSB)	5	191	153	92	379			6	130	122	7.0	251		**B**
South Bay (SB)	10	178	148	18	581			14	94	101	8.0	237	**A**	**B**
Central Bay (CB)	19	93	68	10	302			27	62	57	5.0	145	**A**	**B**
San Pablo Bay (SPB)	25	136	72	ND	349			35	94	96	32	169	**A**	**B**
Suisun Bay (SUB)	5	79	60	13	181			7	84	91	29	115	**A**	**B**
Rivers	10	77	66	8.1	190			14	113	88	33	270	**A**	**B**
BAYWIDE	87	152						122	168					

Table C.3 (cont.). Descriptive statistics for dissolved organic contaminants in water (pg/L), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments (p < 0.05). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Dissolved HCHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 7.9**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 4.9**	**p < 0.0001**
Guadalupe River (BW15)	3	576	162	105	1,460			5	1,006	120	81	4,270		
Standish Dam (BW10)	3	352	183	104	770			7	880	280	164	4,130		
San Jose (C-3-0)	5	2,329	1,700	1,237	4,936			7	2,423	1,861	862	5,689		
Lower South Bay (LSB)	5	801	650	597	1,358			5	882	553	390	1,546		
South Bay (SB)	10	689	547	249	1,626			13	587	608	180	1,280		
Central Bay (CB)	19	515	408	230	1,118			27	486	400	80	1,086		
San Pablo Bay (SPB)	22	369	218	44	1,335			35	470	470	53	1,180		
Suisun Bay (SUB)	4	194	165	147	299			7	292	308	88	566		
Rivers	9	174	150	24	341			14	316	302	43	1,078		
BAYWIDE	80	569						120	635					
Dissolved Dieldrin	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 0.098**	**p = 1.0**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 5.5**	**p < 0.0001**
Guadalupe River (BW15)	4	85	66	ND	210			5	216	180	120	440		
Standish Dam (BW10)	4	81	42	ND	240			7	216	210	ND	460		
San Jose (C-3-0)	5	94	81	ND	190			7	108	94	ND	220		
Lower South Bay (LSB)	5	67	68	ND	120			5	45	17	ND	140	**A**	
South Bay (SB)	10	75	75	ND	150			13	35	32	ND	120	**A**	
Central Bay (CB)	19	68	58	ND	190			26	26	22	ND	83	**A**	**B**
San Pablo Bay (SPB)	25	77	64	ND	270			35	46	40	ND	120	**A**	
Suisun Bay (SUB)	5	72	36	ND	250			7	66	67	ND	110		
Rivers	9	72	11	ND	240			14	83	63	ND	320		
BAYWIDE	86	75						119	67					
Dissolved PAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 1.5**	**p = 0.17**	**n**	**Mean**	**Median**	**Min**	**Max**	**F =7.3**	**p < 0.0001**
Guadalupe River (BW15)	2	10,765	10765	8000	13530			4	19,318	16,100	12,640	32,430		
Standish Dam (BW10)	2	7,549	7549	4900	10197			6	14,344	11,774	ND	39,730		
San Jose (C-3-0)	4	14,782	13411	6700	25605			6	20,517	20,273	12,250	28,627		
Lower South Bay (LSB)	4	16,964	8529	4800	46000			4	10,619	11,585	5,200	14,106		
South Bay (SB)	8	6,316	5745	2100	12518			12	8,283	8,154	2,020	20,260		
Central Bay (CB)	15	8,398	5697	2400	20288			22	5,903	4,800	ND	16,432	**A**	
San Pablo Bay (SPB)	15	6,939	7100	2900	13319			28	6,732	6,543	630	14,404	**A**	
Suisun Bay (SUB)	3	6,948	3290	1600	15954			6	8,077	6,010	4,400	16,693		
Rivers	6	3,971	4642	1200	5904			12	3,723	2,902	1,380	8,925	**A**	**B**
BAYWIDE	59	8,286						100	8,398					
Dissolved LPAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 0.53**	**p = 0.83**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 4.2**	**p = 0.0002**
Guadalupe River (BW15)	2	5,337	5,337	600	10,074			4	8,713	7,130	3,280	17,310		
Standish Dam (BW10)	2	4,167	4,167	550	7,784			6	7,361	5,560	ND	20,940		
San Jose (C-3-0)	4	7,392	6,499	1,010	15,561			6	10,577	10,680	4,610	16,700		
Lower South Bay (LSB)	4	6,031	4,497	130	15,000			4	4,953	5,170	2,100	7,371		
South Bay (SB)	8	2,638	1,583	ND	9,145			12	4,421	4,670	1,100	8,510		
Central Bay (CB)	15	4,622	2,812	370	11,154			22	3,677	3,519	ND	11,138		
San Pablo Bay (SPB)	15	4,637	4,531	550	10,602			28	3,347	3,280	ND	6,372		
Suisun Bay (SUB)	3	5,866	2,848	550	14,200			6	3,570	2,848	1,420	7,472		
Rivers	6	2,929	3,774	160	4,725			12	2,173	1,445	580	5,712	**A**	**B**
BAYWIDE	59	4,540						100	4,374					
Dissolved HPAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 6.3**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 9.9**	**p < 0.0001**
Guadalupe River (BW15)	4	9,232	5,433	1,400	24,660			4	10,613	9,905	7,520	15,120		
Standish Dam (BW10)	4	2,058	1,967	ND	4,300			6	6,971	5,494	ND	18,790		
San Jose (C-3-0)	5	6,970	5,660	3,625	10,044			6	9,947	8,305	7,090	16,207		
Lower South Bay (LSB)	5	9,185	4,548	3,200	30,000			4	5,664	6,163	3,060	7,270		
South Bay (SB)	10	4,402	3,281	1,600	13,000			12	3,858	3,299	300	12,140		
Central Bay (CB)	19	3,178	2,410	560	12,000			22	2,228	1,635	ND	8,130	**A**	**B**
San Pablo Bay (SPB)	25	2,798	1,900	ND	17,000			28	3,376	3,090	630	8,396	**A**	
Suisun Bay (SUB)	5	1,025	1,080	350	1,754	**A**		6	4,486	3,830	1,807	9,221		
Rivers	10	2,719	1,007	ND	20,000	**A**		12	1,541	1,077	704	3,213	**A**	**B**
BAYWIDE	87	3,823						100	4,019					

Table C.4. Descriptive statistics for total organic contaminants in water (pg/L), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments (p < 0.05). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Total PCBs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 23.1**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 23.1**	**p < 0.0001**
Guadalupe River (BW15)	4	5,110	5,350	3,639	6,100			4	3,832	3,036	2,086	7,169		
Standish Dam (BW10)	4	3,978	3,907	1,098	7,000			7	2,551	2,413	1,360	4,000		
San Jose (C-3-0)	4	2,603	2,156	1,800	4,300			7	4,824	4,700	1,730	10,313		
Lower South Bay (LSB)	3	1,793	1,081	981	3,317			6	2,193	1,707	851	4,539		
South Bay (SB)	8	1,210	833	608	3,060			14	695	625	277	1,263		**B**
Central Bay (CB)	16	297	275	77	1,000	**A**	**B**	27	389	281	38	2,417	**A**	**B**
San Pablo Bay (SPB)	22	454	355	130	1,400	**A**	**B**	35	695	493	130	2,475	**A**	**B**
Suisun Bay (SUB)	4	169	157	78	282	**A**	**B**	7	460	287	259	1,100	**A**	**B**
Rivers	8	113	118	75	165	**A**	**B**	14	201	189	54	473	**A**	**B**
BAYWIDE	73	1,070						121	1,080					
Total DDTs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 8.2**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 21.6**	**p < 0.0001**
Guadalupe River (BW15)	2	3,009	3,009	2,369	3,649			5	2,123	1,413	418	5,595		
Standish Dam (BW10)	2	6,558	6,558	2,696	10,419			6	4,126	3,627	1,361	9,900		
San Jose (C-3-0)	3	2,667	3,149	1,332	3,519			7	1,961	1,645	510	3,875		
Lower South Bay (LSB)	3	1,713	1,029	824	3,285			5	1,093	948	223	2,171		
South Bay (SB)	6	752	720	446	1,079			12	319	335	98	590	**A**	**B**
Central Bay (CB)	13	322	221	145	754	**A**	**B**	24	208	250	33	439	**A**	**B**
San Pablo Bay (SPB)	15	1,217	1,087	197	2,753			33	813	656	183	3,100		**B**
Suisun Bay (SUB)	3	1,149	1,319	470	1,659			7	1,043	655	341	3,200		
Rivers	5	894	724	315	1,769			11	555	499	276	980		**B**
BAYWIDE	52	1,291						110	942					
Total Chlorpyrifos	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 2.6**	**p =0.021**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 3.6**	**p = 0.0011**
Guadalupe River (BW15)	3	656	449	210	1,310			4	2,375	329	ND	8,840		
Standish Dam (BW10)	3	427	370	22	890			4	3,768	910	ND	13,250		
San Jose (C-3-0)	4	1,776	1,400	195	4,110			6	2,254	640	ND	11,270		
Lower South Bay (LSB)	2	337	337	191	482			3	166	224	ND	273		
South Bay (SB)	9	192	197	0	490			11	97	94	ND	262		
Central Bay (CB)	9	90	35	0	271			23	61	66	ND	231		
San Pablo Bay (SPB)	16	400	316	4	1,253			34	146	110	ND	416		
Suisun Bay (SUB)	4	277	314	0	481			7	234	240	9	436		
Rivers	8	330	363	0	604			12	406	423	ND	950		
BAYWIDE	58	409						104	505					
Total Diazinon	**n**	**Mean**	**Median**	**Min**	**Max**	**F =1.1**	**p = 0.38**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 7.3**	**p < 0.0001**
Guadalupe River (BW15)	3	8,250	6,600	4,500	13,650			5	6,716	6,780	1,700	9,900		
Standish Dam (BW10)	3	4,917	2,900	1,760	10,090			6	9,340	10,525	ND	15,000		
San Jose (C-3-0)	5	16,536	15,270	550	36,150			7	11,206	11,000	340	24,570		
Lower South Bay (LSB)	4	7,895	7,105	5,370	12,000			5	6,384	7,130	3,100	9,850		
South Bay (SB)	10	5,375	5,740	73	14,000			11	3,422	3,700	ND	5,697		
Central Bay (CB)	18	5,683	4,300	0	32,000			25	1,253	1,200	ND	4,070	**A**	**B**
San Pablo Bay (SPB)	24	13,376	8,425	0	44,320			35	2,991	2,530	ND	7,770		
Suisun Bay (SUB)	3	25,250	15,000	2,400	58,350			7	3,193	2,700	540	6,400		
Rivers	10	15,155	13,500	52	37,690			12	2,916	2,760	ND	6,710		
BAYWIDE	80	10,727						113	3,814					
Total Chlordanes	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 16.0**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 14.9**	**p < 0.0001**
Guadalupe River (BW15)	4	1,652	1,255	1,000	3,100			5	1,152	910	412	2,187		
Standish Dam (BW10)	4	2,326	1,515	573	5,700			6	1,241	860	400	3,400		
San Jose (C-3-0)	5	859	836	360	1,429			7	698	656	498	1,065		
Lower South Bay (LSB)	5	483	420	252	782			6	256	241	16	489		
South Bay (SB)	8	358	320	176	722			12	144	168	16	289	**A**	**B**
Central Bay (CB)	16	133	127	36	357	**A**	**B**	23	82	73	20	165	**A**	**B**
San Pablo Bay (SPB)	22	295	273	54	702	**A**	**B**	31	155	147	34	330	**A**	**B**
Suisun Bay (SUB)	5	129	124	21	254	**A**	**B**	7	138	134	40	270	**A**	**B**
Rivers	8	141	110	87	256	**A**	**B**	10	146	176	39	302	**A**	**B**
BAYWIDE	77	466						107	285					

Table C.4 (cont). Descriptive statistics for total organic contaminants in water (pg/L), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments (p < 0.05). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON							DRY SEASON						
Total HCHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 8.0**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 5.0**	**p < 0.0001**
Guadalupe River (BW15)	2	145	145	124	165			3	226	140	87	451		
Standish Dam (BW10)	2	152	152	104	200			4	435	333	208	866		
San Jose (C-3-0)	4	2,536	1,935	1,275	4,997			7	2,506	1,905	997	5,829		
Lower South Bay (LSB)	3	890	680	598	1,391			4	760	543	420	1,535		
South Bay (SB)	7	798	645	265	1,637			13	604	624	200	1,280		
Central Bay (CB)	15	541	408	240	1,123			27	501	406	80	1,095		
San Pablo Bay (SPB)	17	453	310	190	1,344			34	492	493	60	1,192		
Suisun Bay (SUB)	3	216	191	157	299			7	307	321	101	602		
Rivers	5	206	176	30	353			12	367	342	111	1,078		
BAYWIDE	58	629						111	609					
Total Dieldrin	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 0.22**	**p =0.99**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 7.9**	**p < 0.0001**
Guadalupe River (BW15)	4	122	110	2.7	268			5	272	220	137	476		
Standish Dam (BW10)	4	150	83	14	420			6	304	284	15	580		
San Jose (C-3-0)	5	148	125	2.5	340			7	132	155	ND	226		
Lower South Bay (LSB)	5	96	100	ND	157			5	51	26	ND	140	**A**	
South Bay (SB)	10	91	86	ND	169			13	39	34	ND	130	**A**	**B**
Central Bay (CB)	19	74	61	ND	202			27	30	27	ND	83	**A**	**B**
San Pablo Bay (SPB)	24	99	81	ND	333			35	57	58	ND	120	**A**	**B**
Suisun Bay (SUB)	5	88	61	5.0	280			7	87	77	27	160		
Rivers	9	106	89	ND	275			12	144	94	3.7	380		
BAYWIDE	85	99						117	86					
Total PAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 11.5**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.4**	**p < 0.0001**
Guadalupe River (BW15)	2	123,100	123,100	104,200	142,000			4	266,200	250,050	119,000	445,700		
Standish Dam (BW10)	2	64,100	64,100	59,200	69,000			6	80,000	37,750	9,900	313,100		
San Jose (C-3-0)	4	156,100	137,400	69,600	280,000			6	275,100	169,600	54,400	847,000		
Lower South Bay (LSB)	4	102,675	74,850	62,000	199,000			4	173,725	181,250	98,000	234,400		
South Bay (SB)	8	74,400	67,550	31,000	140,000			12	49,383	44,300	9,100	100,900		
Central Bay (CB)	15	25,480	26,300	5,600	52,300	**A**		22	19,541	14,150	3,600	70,000	**A**	
San Pablo Bay (SPB)	15	32,040	20,500	7,800	96,000	**A**		28	54,282	35,000	15,000	246,700		
Suisun Bay (SUB)	3	18,367	17,000	6,500	31,600	**A**		6	35,250	22,050	14,300	96,800	**A**	
Rivers	6	11,517	10,450	4,500	22,900	**A**	**B**	12	8,967	7,550	2,500	15,100	**A**	**B**
BAYWIDE	59	50,707						100	67,518					
Total LPAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 0.97**	**p = 0.47**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 8.0**	**p < 0.0001**
Guadalupe River (BW15)	2	12,300	12,300	4,600	20,000			4	20,975	18,550	11,800	35,000		
Standish Dam (BW10)	2	9,750	9,750	6,000	13,500			6	11,283	8,450	3,000	30,300		
San Jose (C-3-0)	4	21,700	22,950	3,900	37,000			6	29,967	30,500	10,800	45,900		
Lower South Bay (LSB)	4	11,625	10,550	7,400	18,000			4	13,075	13,400	3,500	22,000		
South Bay (SB)	8	8,425	9,100	2,100	14,800			12	7,525	7,700	600	15,900		
Central Bay (CB)	15	7,067	6,600	400	17,100			22	4,941	4,450	1,100	12,100	**A**	
San Pablo Bay (SPB)	15	8,567	9,600	700	23,600			28	7,786	6,800	1,900	23,500		
Suisun Bay (SUB)	3	8,433	3,400	800	21,100			6	6,567	4,700	3,700	16,700		
Rivers	6	6,550	4,950	200	21,500			12	2,883	1,850	900	7,100	**A**	**B**
BAYWIDE	59	9,219						100	8,747					
Total HPAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.4**	**p < 0.0001**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.4**	**p < 0.0001**
Guadalupe River (BW15)	4	150,200	118,450	84,100	279,800			5	202,620	206,500	32,400	430,200		
Standish Dam (BW10)	4	99,125	54,450	45,600	242,000			7	62,914	28,200	6,900	282,800		
San Jose (C-3-0)	5	165,820	140,000	51,500	291,600			7	225,971	111,000	43,600	802,700		
Lower South Bay (LSB)	5	73,560	58,400	3,200	192,000			5	135,700	142,000	36,200	230,900		
South Bay (SB)	10	74,690	74,550	27,800	143,000			14	38,850	31,200	8,500	85,100		
Central Bay (CB)	19	17,553	15,300	2,600	41,300	**A**	**B**	26	14,488	9,400	1,400	61,000	**A**	
San Pablo Bay (SPB)	25	34,024	23,900	6,300	138,900	**A**		33	42,706	30,000	2,400	223,200		
Suisun Bay (SUB)	5	8,020	8,200	2,300	16,000	**A**	**B**	7	31,329	19,000	9,700	80,200		
Rivers	10	3,910	4,150	1,100	9,100	**A**	**B**	14	5,371	4,600	700	13,000	**A**	**B**
BAYWIDE	87	48,327						118	53,713					

Table C.5. Descriptive statistics for trace elements in sediment (mg/kg), RMP data 1996-1999.

Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON					DRY SEASON					COMBINED SEASONS	
Silver (Ag)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 10.3**	**p < 0.0001**
Guadalupe River (BW15)	3	0.56	0.61	0.38	0.69	3	0.49	0.51	0.44	0.53		
Standish Dam (BW10)	3	0.24	0.20	0.16	0.36	3	0.41	0.41	0.40	0.41		
Southern Sloughs (SS)	8	0.30	0.27	0.04	0.64	7	0.90	0.87	0.24	2.00		
Lower South Bay (LSB)	8	0.33	0.41	0.05	0.48	6	0.32	0.33	0.14	0.46		
South Bay (SB)	8	0.31	0.32	0.07	0.52	6	0.39	0.42	0.26	0.48		
Central Bay (CB)	32	0.20	0.19	0.01	0.42	24	0.23	0.25	0.02	0.47	**A**	
San Pablo Bay (SPB)	20	0.22	0.21	0.02	0.39	15	0.19	0.19	0.02	0.36	**A**	
Suisun Bay (SUB)	12	0.17	0.17	0.02	0.33	9	0.20	0.24	0.07	0.30	**A**	
Rivers	8	0.07	0.06	0.02	0.15	6	0.08	0.08	0.02	0.13	**A**	**B**
BAYWIDE	102	0.23				79	0.30					
Arsenic (As)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F =4.0**	**p = 0.0002**
Guadalupe River (BW15)	3	7.2	6.7	5.0	9.8	3	10.4	11.0	9.1	11.1		
Standish Dam (BW10)	3	6.9	5.9	5.3	9.4	4	8.3	8.2	7.3	9.3		
Southern Sloughs (SS)	7	4.5	4.0	2.5	6.8	8	7.4	7.3	2.9	11.0		
Lower South Bay (LSB)	7	8.0	7.4	4.5	12.5	8	7.8	7.7	4.3	11.0		
South Bay (SB)	8	7.1	6.5	4.0	11.0	8	8.1	8.8	4.4	9.7		
Central Bay (CB)	31	7.9	8.0	3.8	16.4	32	9.3	8.7	5.9	14.0		
San Pablo Bay (SPB)	19	9.6	9.1	3.6	16.6	20	11.9	11.8	6.2	18.0		
Suisun Bay (SUB)	11	8.7	8.6	3.6	15.0	12	11.9	11.3	7.4	19.0		
Rivers	7	9.6	7.6	5.4	15.8	8	8.2	7.2	4.3	14.2		
BAYWIDE	96	8.1				103	9.7					
Cadmium (Cd)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 7.5**	**p < 0.0001**
Guadalupe River (BW15)	3	0.46	0.42	0.42	0.53	2	0.30	0.30	0.26	0.34		
Standish Dam (BW10)	3	0.54	0.36	0.26	0.99	2	0.41	0.41	0.33	0.48		
Southern Sloughs (SS)	8	0.34	0.28	0.16	0.67	7	0.81	0.89	0.19	2.10		
Lower South Bay (LSB)	8	0.33	0.25	0.20	0.61	6	0.19	0.19	0.15	0.23		
South Bay (SB)	8	0.21	0.19	0.15	0.28	6	0.17	0.17	0.12	0.20	**A**	**B**
Central Bay (CB)	32	0.18	0.19	0.04	0.32	25	0.19	0.17	0.05	0.46	**A**	**B**
San Pablo Bay (SPB)	20	0.27	0.27	0.08	0.46	16	0.22	0.20	0.09	0.51		
Suisun Bay (SUB)	12	0.32	0.35	0.10	0.47	9	0.24	0.27	0.13	0.33		
Rivers	8	0.27	0.23	0.16	0.45	6	0.21	0.20	0.12	0.36		
BAYWIDE	102	0.27				79	0.26					
Chromium (Cr)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 3.0**	**p = 0.0034**
Guadalupe River (BW15)	3	147	132	131	177	3	142	162	93	170		
Standish Dam (BW10)	3	96	94	79	114	3	159	143	95	238		
Southern Sloughs (SS)	8	98	97	58	130	8	127	121	57	200		
Lower South Bay (LSB)	8	140	128	71	216	8	108	124	38	154		
South Bay (SB)	8	114	119	72	148	8	105	108	56	138		
Central Bay (CB)	32	98	95	48	163	32	95	95	53	148	**A**	
San Pablo Bay (SPB)	20	108	108	67	138	20	107	101	68	154		
Suisun Bay (SUB)	12	108	114	64	154	12	109	106	55	146		
Rivers	8	90	96	69	105	8	93	89	65	128	**A**	
BAYWIDE	102	106				102	106					
Copper (Cu)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 7.3**	**p < 0.0001**
Guadalupe River (BW15)	3	57	56	50	66	3	52	53	47	56		
Standish Dam (BW10)	3	39	34	32	51	3	48	50	43	52		
Southern Sloughs (SS)	8	29	26	22	45	8	44	46	22	67	**A**	
Lower South Bay (LSB)	8	50	51	23	76	8	38	42	22	48		
South Bay (SB)	8	43	43	32	53	8	40	40	34	45		
Central Bay (CB)	30	37	38	8	52	32	32	35	8	47	**A**	
San Pablo Bay (SPB)	19	52	56	14	68	20	43	47	10	66		
Suisun Bay (SUB)	11	53	61	18	75	12	46	54	22	62		
Rivers	7	34	30	17	54	8	23	19	13	40	**A**	
BAYWIDE	97	43				102	38					

Table C.5 (cont.). Descriptive statistics for trace elements in sediment (mg/kg), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON					DRY SEASON					COMBINED SEASONS	
Mercury (Hg)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 6.6**	**p < 0.0001**
Guadalupe River (BW15)	3	0.61	0.42	0.34	1.08	3	0.67	0.70	0.50	0.82		
Standish Dam (BW10)	3	0.18	0.14	0.08	0.31	4	0.34	0.34	0.31	0.36		
Southern Sloughs (SS)	8	0.19	0.19	0.12	0.24	8	0.39	0.39	0.11	0.76		
Lower South Bay (LSB)	8	0.37	0.30	0.14	0.78	8	0.29	0.31	0.14	0.39		
South Bay (SB)	8	0.25	0.29	0.13	0.34	8	0.30	0.30	0.26	0.39		
Central Bay (CB)	32	0.18	0.18	0.02	0.30	32	0.19	0.20	0.02	0.31	**A**	
San Pablo Bay (SPB)	20	0.25	0.22	0.04	0.50	20	0.23	0.26	0.04	0.38	**A**	
Suisun Bay (SUB)	12	0.17	0.18	0.04	0.34	12	0.22	0.29	0.08	0.33	**A**	
Rivers	8	0.20	0.15	0.03	0.53	7	0.10	0.03	0.02	0.39	**A**	
BAYWIDE	102	0.23				102	0.25					
Nickel (Ni)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 7.4**	**p < 0.0001**
Guadalupe River (BW15)	3	136	131	111	165	3	125	132	94	150		
Standish Dam (BW10)	3	120	122	107	132	3	144	149	102	181		
Southern Sloughs (SS)	8	90	94	54	126	8	104	114	44	133		
Lower South Bay (LSB)	8	138	117	64	228	8	98	104	47	137		
South Bay (SB)	8	99	102	64	133	8	91	90	66	115		
Central Bay (CB)	32	85	82	51	123	32	79	78	49	122	**A**	**B**
San Pablo Bay (SPB)	20	103	99	61	141	20	95	89	64	129		
Suisun Bay (SUB)	12	104	111	68	153	12	101	97	68	135		
Rivers	8	78	74	59	100	8	81	87	57	103	**A**	**B**
BAYWIDE	102	98				102	92					
Lead (Pb)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 10.5**	**p < 0.0001**
Guadalupe River (BW15)	3	40	41	35	44	3	36	37	31	39		
Standish Dam (BW10)	3	32	25	21	49	3	32	31	30	36		
Southern Sloughs (SS)	8	19	20	15	23	7	34	33	13	53		
Lower South Bay (LSB)	8	27	29	13	35	8	22	25	9.3	30		
South Bay (SB)	8	24	26	19	28	8	24	24	12	29		
Central Bay (CB)	32	22	18	8.7	69	32	22	21	12	77	**A**	
San Pablo Bay (SPB)	20	18	18	5.7	29	20	19	21	7.3	31	**A**	**B**
Suisun Bay (SUB)	12	15	17	5.9	23	12	17	20	10	22	**A**	**B**
Rivers	8	12	9.1	5.4	27	8	10	8.2	4.8	15	**A**	**B**
BAYWIDE	102	21				101	22					
Selenium (Se)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 4.9**	**p < 0.0001**
Guadalupe River (BW15)	3	0.42	0.47	0.17	0.63	3	0.52	0.48	0.45	0.64		
Standish Dam (BW10)	3	0.35	0.29	0.17	0.59	4	0.55	0.52	0.48	0.67		
Southern Sloughs (SS)	8	0.19	0.17	0.13	0.30	8	0.35	0.36	0.17	0.49		
Lower South Bay (LSB)	8	0.27	0.30	0.12	0.44	8	0.31	0.32	0.18	0.40		
South Bay (SB)	8	0.26	0.26	0.12	0.42	8	0.29	0.29	0.22	0.39		
Central Bay (CB)	32	0.19	0.22	0.06	0.32	32	0.25	0.27	0.06	0.38	**A**	**B**
San Pablo Bay (SPB)	20	0.21	0.27	0.03	0.32	20	0.26	0.31	0.03	0.42		
Suisun Bay (SUB)	12	0.19	0.20	0.06	0.38	12	0.25	0.31	0.10	0.34		
Rivers	8	0.20	0.16	0.06	0.54	8	0.11	0.08	0.03	0.32	**A**	**B**
BAYWIDE	102	0.22				103	0.28					
Zinc (Zn)	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 9.4**	**p < 0.0001**
Guadalupe River (BW15)	3	198	191	168	234	3	174	176	149	197		
Standish Dam (BW10)	3	124	110	89	172	3	165	164	148	184		
Southern Sloughs (SS)	8	102	102	78	135	8	155	159	68	256	**A**	
Lower South Bay (LSB)	8	183	162	75	396	8	123	130	62	166		
South Bay (SB)	8	130	128	95	158	8	121	121	102	144		
Central Bay (CB)	32	106	105	63	143	32	98	99	56	144	**A**	
San Pablo Bay (SPB)	20	125	132	65	171	20	115	114	67	164	**A**	
Suisun Bay (SUB)	12	121	129	61	178	12	118	127	78	152	**A**	
Rivers	8	87	82	62	111	8	78	76	56	102	**A**	**B**
BAYWIDE	102	121				102	115					

Table C.6. Descriptive statistics for organic contaminants in sediment (µg/kg), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON					DRY SEASON					COMBINED SEASONS	
PCBs	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 40.0**	**p < 0.0001**
Guadalupe River (BW15)	3	36	42	22	43	3	27	26	23	31		
Standish Dam (BW10)	3	32	27	26	45	4	33	32	24	46		
Southern Sloughs (SS)	8	50	51	4.0	103	6	131	90	7.3	320		
Lower South Bay (LSB)	8	20	16	6.8	44	8	12	11	3.4	23		
South Bay (SB)	8	13	13	5.2	22	8	14	8.1	4.1	49		
Central Bay (CB)	32	8.5	8.2	ND	20	32	9.3	8.0	ND	30	**A**	**B**
San Pablo Bay (SPB)	20	4.2	4.1	ND	9.3	20	2.8	2.9	ND	8.6	**A**	**B**
Suisun Bay (SUB)	12	2.4	2.5	0.2	4.5	12	2.3	1.6	ND	5.9	**A**	**B**
Rivers	8	0.2	ND	ND	0.6	8	0.9	0.1	ND	3.7	**A**	**B**
BAYWIDE	102	12				101	16					
PAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.8**	**p < 0.0001**
Guadalupe River (BW15)	3	1,808	1,737	1,366	2,320	3	1,384	1,173	1,123	1,856		
Standish Dam (BW10)	3	689	558	186	1,324	4	988	1,032	787	1,100		
Southern Sloughs (SS)	8	918	879	502	1,300	6	1,530	1,166	447	3,650		
Lower South Bay (LSB)	8	1,763	1,522	681	3,933	8	1,733	1,620	669	2,988		
South Bay (SB)	8	2,533	2,505	1,396	3,945	8	2,389	2,448	1,601	3,054		
Central Bay (CB)	32	2,009	1,813	40	4,269	32	1,949	2,003	51	4,632		
San Pablo Bay (SPB)	20	1,688	785	13	7,406	20	1,450	911	50	6,260		
Suisun Bay (SUB)	12	557	563	127	1,067	12	515	563	54	862	**A**	
Rivers	8	384	257	37.0	1,293	8	113	56.5	2.0	509	**A**	
BAYWIDE	102	1539				101	1472					
LPAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 19.1**	**p < 0.0001**
Guadalupe River (BW15)	3	197	208	121	261	3	319	190	175	592		
Standish Dam (BW10)	3	107	91	51	180	4	129	126	106	158		
Southern Sloughs (SS)	8	128	117	76	224	6	263	196	77	745		
Lower South Bay (LSB)	8	214	204	125	423	8	209	217	99	298		
South Bay (SB)	8	284	299	162	418	8	282	285	172	342		
Central Bay (CB)	32	296	240	ND	1,091	32	287	262	4.0	1,163		
San Pablo Bay (SPB)	20	195	124	ND	873	20	156	117	8.0	564		
Suisun Bay (SUB)	12	67	57	15	146	12	73	75	3.0	153	**A**	
Rivers	8	25	19	2.0	79	8	14	4.0	ND	63	**A**	
BAYWIDE	102	199				101	201					
HPAHs	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.4**	**p < 0.0001**
Guadalupe River (BW15)	3	1,611	1,528	1,245	2,059	3	1,065	998	932	1,265		
Standish Dam (BW10)	3	582	467	135	1,144	4	859	888	666	994		
Southern Sloughs (SS)	8	790	763	425	1,103	6	1,267	986	369	2,906		
Lower South Bay (LSB)	8	1,550	1,319	555	3,511	8	1,524	1,406	569	2,690		
South Bay (SB)	8	2,249	2,206	1,234	3,527	8	2,107	2,139	1,430	2,712		
Central Bay (CB)	32	1,713	1,600	40	3,486	32	1,662	1,762	23	3,469		
San Pablo Bay (SPB)	20	1,493	696	13	6,533	20	1,294	820	38	5,806		
Suisun Bay (SUB)	12	490	517	112	938	12	442	490	52	769	**A**	
Rivers	8	359	240	34	1,214	8	99	43	2.0	446	**A**	
BAYWIDE	102	1,340				101	1,272					

Table C.6 (cont.). Descriptive statistics for organic contaminants in sediment (µg/kg), RMP data 1996-1999.
Kruskal-Wallis one-way analyses of variance indicate significant differences in concentrations between Bay segments ($p < 0.05$). Tukey-Kramer multiple comparisons on ranks of data indicate significantly lower concentrations in Bay segments compared to (A) Guadalupe River (BW15) and/or (B) Standish Dam (BW10).

	WET SEASON					**DRY SEASON**					**COMBINED SEASONS**	
DDTs	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 17.0**	**p < 0.0001**
Guadalupe River (BW15)	3	21	19	16	27	3	15	15	12	17		
Standish Dam (BW10)	3	40	24	20	76	4	26	22	17	44		
Southern Sloughs (SS)	8	16	15	0.80	32	6	35	19	5.7	127		
Lower South Bay (LSB)	8	10	5.6	3.9	25	8	6.0	4.6	2.9	15		**B**
South Bay (SB)	8	5.1	4.4	1.6	9.2	8	3.5	3.0	1.6	5.4	**A**	**B**
Central Bay (CB)	32	4.5	3.7	0.20	10	32	3.6	2.4	ND	30	**A**	**B**
San Pablo Bay (SPB)	20	6.2	6.3	0.70	13	20	3.8	2.4	ND	14	**A**	**B**
Suisun Bay (SUB)	12	5.9	6.7	0.80	11	12	4.3	2.9	1.0	12	**A**	**B**
Rivers	8	1.5	0.45	ND	6.5	8	0.6	0.45	ND	1.7	**A**	**B**
BAYWIDE	102	7.6				101	6.8					
Chlordanes	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**	**F = 40.6**	**p < 0.0001**
Guadalupe River (BW15)	3	8.2	8.4	7.1	9.2	3	2.5	2.6	2.0	2.9		
Standish Dam (BW10)	3	11.5	7.7	7.2	20	4	7.2	7.3	6.4	7.9		
Southern Sloughs (SS)	8	4.0	2.9	0.10	10	6	4.1	4.0	2.1	6.7		
Lower South Bay (LSB)	8	3.2	2.2	1.0	7.0	8	1.1	1.0	ND	2.5		**B**
South Bay (SB)	8	0.51	0.35	ND	1.6	8	0.25	0.10	ND	0.90	**A**	**B**
Central Bay (CB)	32	0.16	ND	ND	1.3	32	0.18	ND	ND	2.0	**A**	**B**
San Pablo Bay (SPB)	20	0.45	0.20	ND	1.3	20	0.13	ND	ND	0.90	**A**	**B**
Suisun Bay (SUB)	12	0.29	0.20	ND	0.90	12	0.11	ND	ND	0.90	**A**	**B**
Rivers	8	ND	ND	ND	ND	8	ND	ND	ND	ND	**A**	**B**
BAYWIDE	102	1.4				101	0.81					
Dieldrin	**n**	**Mean**	**Median**	**25th**	**Max**	**n**	**Mean**	**Median**	**25th**	**Max**	**F = 4.5**	**p < 0.0001**
Guadalupe River (BW15)	3	0.63	0.81	ND	1.1	3	0.34	ND	ND	1.0		
Standish Dam (BW10)	3	0.65	0.76	0.13	1.1	4	0.75	0.43	ND	2.2		
Southern Sloughs (SS)	8	0.24	ND	ND	0.92	6	0.29	ND	ND	1.8		
Lower South Bay (LSB)	8	0.44	0.16	ND	1.9	8	0.06	ND	ND	0.30		
South Bay (SB)	8	0.06	ND	ND	0.25	8	0.06	ND	ND	0.28		
Central Bay (CB)	32	0.03	ND	ND	0.20	32	0.02	ND	ND	0.20		
San Pablo Bay (SPB)	20	0.08	ND	ND	0.71	20	0.07	ND	ND	0.83	**A**	
Suisun Bay (SUB)	12	0.03	ND	ND	0.28	12	0.03	ND	ND	0.16	**A**	**B**
Rivers	8	ND	ND	ND	ND	8	ND	ND	ND	ND	**A**	
BAYWIDE	103	0.13				101	0.09					
HCHs	**n**	**Mean**	**Median**	**Min**	**Max**	**n**	**Mean**	**Median**	**Min**	**Max**		
Guadalupe River (BW15)	3	1.4	1.3	ND	2.8	3	0.17	ND	ND	0.50		
Standish Dam (BW10)	3	0.07	ND	ND	0.20	4	0.33	0.30	ND	0.70		
Southern Sloughs (SS)	8	0.05	ND	ND	0.30	6	0.12	0.05	ND	0.30		
Lower South Bay (LSB)	8	0.38	ND	ND	1.6	8	0.11	ND	ND	0.40		
South Bay (SB)	8	0.19	ND	ND	1.0	8	ND	ND	ND	ND		
Central Bay (CB)	32	0.11	ND	ND	1.1	32	0.13	ND	ND	1.4		
San Pablo Bay (SPB)	20	0.03	ND	ND	0.30	20	ND	ND	ND	ND		
Suisun Bay (SUB)	12	ND	ND	ND	ND	12	ND	ND	ND	ND		
Rivers	8	ND	ND	ND	ND	8	0.03	ND	ND	0.20		
BAYWIDE	102	0.13				101	0.08					

APPENDIX D. Estimating baseline concentrations of metals in RMP sediment.

EIP study sediment normalization methods were conducted using the following steps.

(1) Evaluate the relationship between independent variable and dependent variable.

The relationship between metal concentrations in sediment and several independent variables, including % fines, total organic carbon (TOC), % iron, and % aluminum were evaluated with Pearson's product moment correlation coefficients (Table D.1). In addition, scatter plots of trace metals versus independent variables (% fines and iron) were visually inspected to verify the best-fit linear relationship for each trace element. For RMP sediment data from 1993-1999, % fines accounted for a large proportion of the variation in five of the trace elements: mercury, silver, copper, selenium, and lead (Figure 8). Nickel, zinc, and cadmium were not as strongly correlated with % fines as they were with % iron (Figure 9).

(2) *Determine a "baseline" linear model that best describes the relationship between independent and dependent variables at relatively clean or uncontaminated sites.*

Baseline and background metal concentrations in sediments

For purposes of this study, "baseline" concentrations were defined according to Rice (1999) as ambient concentrations measured at the particular time of study. Conversely, "background" concentrations refer to concentrations of trace elements associated with the natural composition of the geologic source material, with an important distinction being the difference in anthropogenic influence. Similarly, Hunt *et al.* (1998b) described "ambient" conditions at relatively uncontaminated reference sites in San Francisco Bay sediments, as opposed to background or natural conditions that existed before anthropogenic influence. These terms differ slightly from a study of historical trends of metal concentrations in sediment by Hornberger *et al.* (1999), which related 'baseline' concentrations to the 'natural' levels of San Francisco Bay sediments that existed before human activity. It should be emphasized that 'baseline' concentrations were not defined here as natural or 'background' concentrations, but as a qualitative statement differentiating low-levels of contamination in the Estuary relative to "hot spots."

Identifying sites that represent baseline concentrations is complicated by the array of sources that contribute contaminants to the San Francisco Estuary. Therefore, an iterative approach based on methods described by Weisberg *et al.* (2000) and Schiff and Weisberg (1999) were used to identify and remove "outliers" or potentially contaminated sites and select data from cleaner sites that best represent baseline concentrations. Because the stations included in the RMP Status and Trends monitoring design were originally chosen to represent ambient conditions in the Estuary, the iterative analysis was conducted with data from all RMP stations, except the Southern Slough stations (C-1-3 and C-3-0) and the EIP stations (BW10 and BW15).

After establishing a linear relationship between independent variables and metal concentrations, "outliers" were removed based on a comparison of the variance of the regression, represented by the mean square error (MSE), to the estimated variance in laboratory measurement of duplicates for field samples and standard reference materials (Weisberg *et al.* 2000). If the magnitude of the variances were not relatively equal, residuals outside the range of two standard deviations were removed and a new regression was determined with the remaining data (Schiff and Weisberg 1999). The process was repeated until all residuals fell within two standard deviations and a baseline linear regression was established for metal concentrations. Ideally, the MSE would be explained by error in laboratory measurement to the extent that the independent variable is deterministic. However, it is probable that other factors may contribute to scatter in the correlation. The variance associated with the baseline regression for silver, copper, and nickel was greater than the variance associated with measurement error. This may be due to other sources of variation, such as regional differences in geology (Schiff and Weisberg 1999).

(3) Compare sediment concentrations to 'threshold' intervals to identify relatively contaminated samples compared to baseline concentrations.

To identify sites that may be contaminated compared to the baseline regression, 99% prediction intervals were used as a 'threshold', i.e. concentrations that fall outside of the prediction intervals were assumed to be contaminated.

Table D.1. Pearson's product moment correlation coefficients for contaminants and independent variables in RMP sediment samples, 1993-1996. Statistics for independent variables used in sediment normalization analyses in this report appear in bold italics. r = correlation coefficient, n = number of samples.

	% FINES			TOC			Aluminum			Iron		
	r	n	p	r	n	p	r	n	p	r	n	p
Aluminum	0.71	206	<0.0001	0.68	191	<0.0001	.	.	.	0.87	186	<0.0001
Arsenic	0.35	200	<0.0001	0.23	187	0.0013	0.37	200	<0.0001	0.23	180	0.0018
Cadmium	0.26	183	0.0005	0.30	172	0.0001	0.32	183	<0.0001	***0.24***	***163***	***0.0018***
Chromium	0.57	206	<0.0001	0.53	191	<0.0001	0.83	206	<0.0001	0.83	186	<0.0001
Copper	***0.85***	***206***	***<0.0001***	0.75	191	<0.0001	0.82	206	<0.0001	0.84	186	<0.0001
Iron	0.69	186	<0.0001	0.61	171	<0.0001	0.87	186	<0.0001	.	.	.
Mercury	***0.63***	***205***	***<0.0001***	0.53	191	<0.0001	0.52	205	<0.0001	0.42	185	<0.0001
Manganese	0.45	206	<0.0001	0.54	191	<0.0001	0.53	206	<0.0001	0.61	186	<0.0001
Nickel	0.55	206	<0.0001	0.53	191	<0.0001	0.73	206	<0.0001	***0.84***	***186***	***<0.0001***
Lead	***0.37***	***205***	***<0.0001***	0.33	190	<0.0001	0.30	205	<0.0001	0.26	185	0.0003
Selenium	0.68	206	<0.0001	0.59	191	<0.0001	0.49	206	<0.0001	0.33	186	<0.0001
Silver	***0.46***	***206***	***<0.0001***	0.41	191	<0.0001	0.45	206	<0.0001	0.42	186	<0.0001
Zinc	0.69	206	<0.0001	0.61	191	<0.0001	0.74	206	<0.0001	***0.77***	***186***	***<0.0001***
Aldrin	0.03	204	0.6738	-0.04	189	0.6060	-0.01	204	0.9329	0.00	184	0.9890
Chlordanes	0.15	204	0.0293	0.30	189	<0.0001	0.10	204	0.1585	0.14	184	0.0600
DDTs	0.21	204	0.0030	0.24	189	0.0011	0.12	204	0.1015	0.14	184	0.0618
Dieldrin	0.20	204	0.0045	0.20	189	0.0059	0.20	204	0.0044	0.30	184	<0.0001
Endrin	0.04	204	0.5518	0.02	189	0.8204	0.01	204	0.9337	0.10	184	0.1563
HCHs	0.18	204	0.0094	0.20	189	0.0066	0.16	204	0.0209	0.23	184	0.0021
HPAHs	0.37	204	<0.0001	0.28	189	0.0001	0.26	204	0.0002	0.12	184	0.1028
LPAHs	0.27	204	0.0001	0.21	189	0.0037	0.19	204	0.0059	0.08	184	0.3054
PAHs	***0.37***	***204***	***<0.0001***	0.27	189	0.0001	0.25	204	0.0003	0.12	184	0.1157
PCBs	***0.14***	***204***	***0.0499***	0.13	189	0.0675	0.11	204	0.1127	0.09	184	0.2328