Santa Clara Valley
Urban Runoff
Pollution Prevention Program

Watershed Monitoring and Assessment Program

Investigative Monitoring Project

Water and Sediment Quality and Toxicity in Stevens Creek, Santa Clara County, California

September 15, 2008

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1.0 INTRODUCTION

Changes in hydrology, in-stream physical habitat characteristics, riparian vegetation and water quality due to urbanization have been shown to cause adverse impacts on aquatic life in creeks and rivers throughout the United States (Booth et al. 2004; Busse et al. 2006; Miltner et al. 2004; Karr and Chu 1997) and in other areas around the world (Chin 2006; Finkenbine et al. 2000; Miller and Boulton 2005). Consequently, local agencies and municipalities in the U.S. have been tasked with monitoring the status of aquatic life in water bodies receiving urban runoff, identifying the sources of impacts, and implementing pollution prevention and reduction strategies through municipal stormwater National Pollutant Discharge Elimination System (NPDES) permits.

In response to the monitoring requirements in the municipal stormwater NDPES permit issued to participants of the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)[1] in 2001, the SCVURPPP developed a Multi-Year Receiving Waters Monitoring Plan (Multi-Year Plan). The Multi-Year Plan presents a monitoring and assessment approach that includes the collection of environmental indicators that can be categorized into two tiers; screening-level monitoring and assessments (i.e. Tier I) and investigative monitoring (i.e., Tier II) (SCVURPPP 2004a).

Screening level monitoring and assessments include more general measurements made at various sampling locations, providing an initial characterization of the physical, chemical, and biological integrity of a particular water body. Screening level monitoring is conducted in each watershed identified in the Multi-Year Plan for one to two fiscal years (FY) on a rotating watershed basis. To-date, the SCVURPPP had conducted screening level monitoring in all 13 of the watersheds within the Program's boundaries, with the exception of San Francisquito Creek and the Guadalupe River[2]. SCVURPPP (2007a) provides a summary of data collected during the first five years (FY 02-03 to FY 06-07) of the Multi-Year Plan.

Investigative monitoring or studies conducted by SCVURPPP include more detailed measurements typically taken in a more defined area (e.g., stream reach). Investigative monitoring is intended to address specific questions of impairment, such as: What are the extent, magnitude and cause of an observed impact?

This report summarizes the results of two investigative studies conducted in Stevens Creek in FY 07-08. The studies were designed to assist SCVURPPP in answering the following high priority monitoring questions:

1) *What are the extent, magnitude and causes of toxicity in Stevens Creek?*
2) *What is the intra-annual range and variability of chemical concentrations in bedded sediments in Stevens Creek?*

1.1 Background

1.1.1 Stevens Creek Water and Sediment Toxicity

Beginning in Fiscal Year (FY) 2002-03, a variety of monitoring programs, including the San Francisco Bay Regional Water Quality Control Board's (Water Board) Surface Water Ambient Monitoring Program (SWAMP) and the SCVURPPP collected water and/or sediment quality data at sites in Stevens Creek and its tributaries (Figure 1, Table 1). As illustrated in Figure 2, results

[1]The Santa Clara Valley Urban Runoff Pollution Prevention SCVURPPP is comprised of Santa Clara County, thirteen municipalities and the Santa Clara Valley Water District (i.e., Co-permittees).
[2]SCVURPPP did not conduct monitoring in Guadalupe River or San Francisquito Creek watersheds due to extensive monitoring efforts being conducted in these watersheds by other agencies and stakeholder groups.

from SWAMP sampling in FY 02-03 indicated that significant aquatic and chronic water toxicity were present at site STE060 (Stevens Creek at La Barranca Rd.). As a result, Stevens Creek was included on the State of California's 2006 List of Water Quality Limited Segments (i.e., 303(d) list of impaired water bodies) by the Water Board (Water Board 2006).

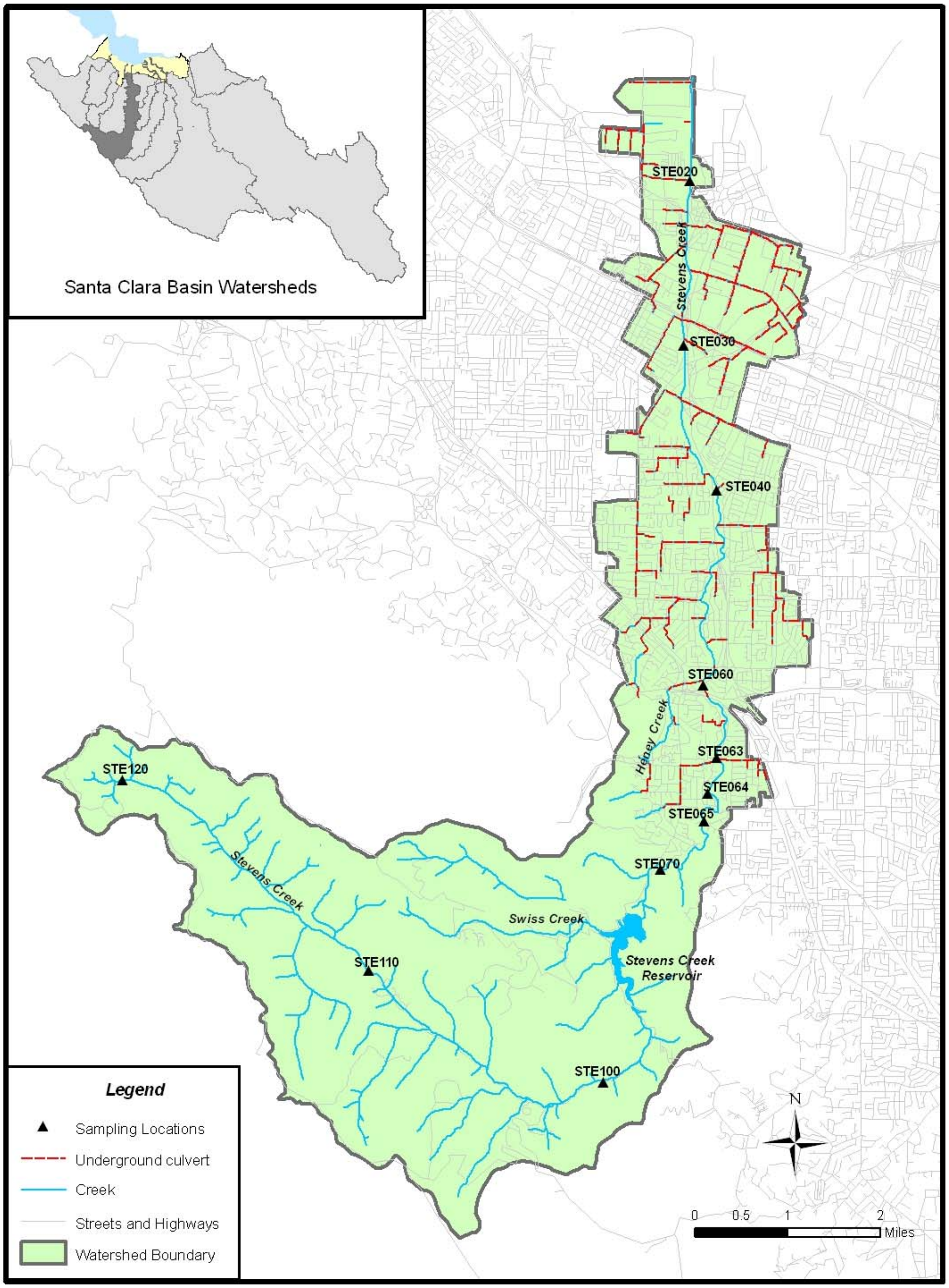

Figure 1. SCVURPPP and/or the Water Board's SWAMP sites where water, sediment or biological data were collected FY 02-03 and 07-08.

Table 1. Sampling sites and parameters sampled in Stevens Creek from Fiscal Year 2002-03 to 2007-08.					
Sampling Site	Site Description	FY02-03 (SWAMP)	FY05-06 (SCVURPPP)	FY06-07 (SCVURPPP)	FY 07-08 (SCVURPPP)
STE020	Stevens Cr at La Avenida	BMI, WC, WT, SC, ST	WQ, BMI	BMI	SC, ST
STE030	Stevens Cr at Landels School	BMI			
STE040	Stevens Cr below Diversion Channel	BMI	BMI	BMI	
STE060	Stevens Cr at Barranca, above confluence with Heney Cr	BMI, WC	WQ, BMI	WQ, BMI	WC, WT, SC, ST
STE063	Stevens Cr below Stevens Creek Rd.				WC, WT
STE064	Stevens Cr at Blackberry Farm		BMI	BMI	
STE065	Stevens Cr at McClellan Ranch		WQ	BMI	WC, WT, SC, ST
STE070	Stevens Cr at Chestnut Picnic Area	BMI	BMI	BMI	
STE100	Stevens Cr at Moss Rock	BMI	BMI	BMI	
STE110	Stevens Cr at MPOSD/Upper Park 1	BMI	BMI	BMI	
STE120	Steven Cr at Upper Park 2	BMI			

WC = Water Contaminants; WT = Water Toxicity; SQ = Sediment Contaminants; ST = Sediment Toxicity; BMI = Benthic Macroinvertebrate Bioassessment (includes physical habitat assessment).

In FYs 05-06 and 06-07, the SCVURPPP collected and analyzed water quality samples from sites on Stevens Creek (Table 1), including STE060, to further assess the condition of beneficial uses (i.e., aquatic life and recreational) in Stevens Creek and possible exceedances in water quality standards. Results from two years of SCVURPPP monitoring (SCVURPPP 2007a) and previous studies (SCVURPPP 2004b) indicate that a coldwater steelhead (*Oncorhynchus mykiss*) fishery is common to abundant in the six mile reach below the dam, which includes site STE060. Additionally, preliminary Benthic Index of Biotic Integrity (B-IBI) scores suggest that the condition of aquatic life is greatly reduced directly below the dam, compared to sites above the dam, even though physical habitat quality is optimal. Hypotheses of the causes of reduce biological integrity below the dam include: 1) altered hydrologic and temperature regimes due to the impoundment of water; 2) reduced transport of coarse substrate and food resources due to the impoundment of water; and, 3) the presence of chemicals at a concentrations causing acute and/or chronic toxicity in water or bedded sediments. Although SWAMP observed acute and chronic toxicity in FY 02-03, only chronic toxicity was observed in FYs 05-06 and 06-07 (SCVURPPP 2007a).

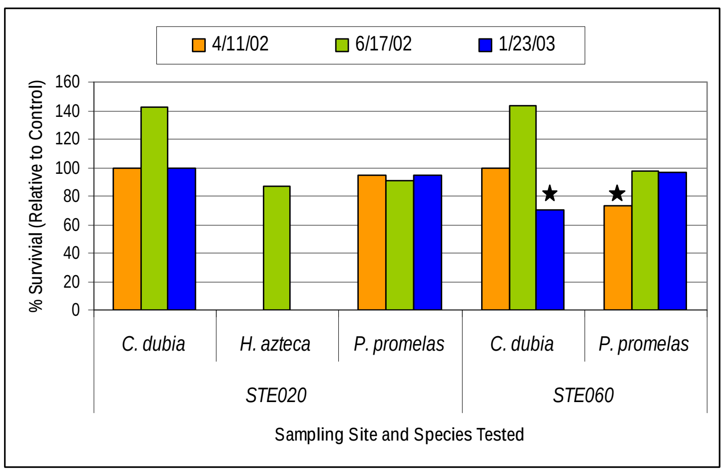

Figure 2. Sediment (*H. azteca*) and water (*P. promelas* and*C. dubia*) bioassay results from SWAMP monitoring in Stevens Creek in FY 02-03 (Water Board 2007). Stars indicate significant toxicity compared to laboratory control.

Due to the aquatic toxicity observed at STE060 by SWAMP in FY 02-03, the resulting listing of Stevens Creek on the 303(d) list of impaired water bodies, and the steelhead population present, the Program developed a study designed to evaluate the extent, magnitude, and cause(s) of aquatic toxicity observed by SWAMP in Stevens Creek.

1.1.2 Variability in Chemical Concentrations in Bedded Sediment

Historical approaches used to assess the status of aquatic life have typically included the collection and analysis of "grab" water samples from receiving waters during the dry season and runoff events to determine the concentration of various chemicals (e.g., metals and organics) and relative toxicity to laboratory organisms via bioassays. Recent experience has shown that the concentrations of metals and pesticides in water during dry season flows are relatively stable and meet numeric water quality objectives (SCVURPPP 2007a). In contrast, the concentrations of most chemicals in water are highly variable both during and between stormwater runoff events, and particularly in water bodies receiving primarily urban runoff (Pitt and Maestre 2004; Lee et al 2004; Power and Chapman 1992). Therefore, for municipalities to better understand the range, variability and "average" chemical integrity of a water body, numerous water samples must be collected and analyzed over a number of years. This magnitude of sample collection and analysis can require the expenditure of extensive public resources, which are currently limited.

Based on these observations, the SCVURPPP conducted a pilot study in FY 06-07 to expand its ability to understand status of aquatic life in creeks, identify sources of impacts, and detect changes in the physical, chemical, and biological integrity over time. The study examined the utility of a "weight of evidence" (WOE) approach to assess the status of aquatic life in Santa Clara Valley creeks. A typically WOE approach uses multiple lines of evidence to determine the status or condition of an environmental system, or the impact of a stressor category on aquatic life (Burton, Chapman, and Smith 2002; Burton et al 2002). The weight of evidence approach used by the SCVURPPP during the pilot study was the Sediment Quality Triad (SQT).

The sediment quality triad (SQT) pilot study provided insight into the status of aquatic life in neighboring watershed (Coyote Creek) and potential stressors that may be impacting benthic communities. To further examine the utility of the SQT, additional data were collected by SCVURPPP in FY 07-08 in Coyote and Lower Penitencia Creek watershed and are summarized in SCVURPPPP (2008). However, an important information gap remains that may effect the usefulness of the SQT approach. Currently, little is known about the intra-annual variations in bedded sediment chemical concentrations, and how representative a single sample may be of the concentrations found throughout a fiscal year (July – June). To answer these questions, a second investigative study was conducted by SCVURPPP in parallel to the sediment toxicity study to evaluate the variability of chemicals in bedded creek sediments, assess the representativeness of a single bedded sediment sample, which will inform the sampling design of monitoring programs in future fiscal years.

2.0 SAMPLING DESIGN AND METHODS

2.1 Sampling Sites and Watershed Characteristics

Stevens Creek and its tributaries drain a watershed of approximately 30 mi^2. Stevens Creek originates at an elevation of 2,500 feet in the Santa Cruz Mountains, flowing southeast for just over five miles along the San Andreas Fault, then bending northeast and flowing an additional three miles before reaching Stevens Creek Reservoir. The drainage area upstream of the Stevens Creek Reservoir is mostly undeveloped forest and rangeland (Table 2) and comprises over 50% of the entire Stevens Creek watershed. An extremely large portion of this area is protected by agencies, easements, and land trusts, although there is currently a small amount of development occurring in the drainage area, which includes low density houses, vineyards, horse stables and a rock quarry. This area is predominately within Unincorporated Santa Clara County.

From the reservoir outlet, Stevens Creek flows northward for approximately 2.0 miles through a 1.5 **mi^2**drainage area until it reaches site STE065. Roughly one-third of the creek flows through a golf course (Deep Cliffs) that makes up about 10% of this drainage area. The remaining drainage area is predominately forest and rangeland (Table 2).

Stevens Creek is roughly 1.0 miles in length and the drainage area is 1.2 **mi^2** between sites STE065 and STE060. Predominate land uses in this area include high density residential and urban recreation, which includes another golf course (Blackberry Farms) that is adjacent to the creek.

The most urban portion of the watershed is located in the drainage area downstream of site STE060 (north of Interstate 280) and is mostly within the boundaries of the cities of Sunnyvale and Mountain View. Land uses include heavy industrial, commercial and high-density residential in this drainage area.

Table 2. Estimated land uses within drainage areas between Stevens Creek sampling sites (ABAG 1996).

Land Use Category	Drainage Area (mi^2)				
	Above Stevens Creek Reservoir Outlet	Reservoir Outlet to STE065	STE065 to STE060	STE060 to STE020	Total
Agriculture	0.15	-	-	-	0.15
Commercial	0.03	-	0.04	0.51	0.57
Forest	13.69	0.41	0.05	0.21	14.36
Freshwater (Reservoir and Creeks)	0.33	-	-	-	0.33
Heavy Industrial	-	-	0.01	1.50	1.51
High-Density Residential	-	0.11	0.95	6.73	7.79
Mines, Quarries, Gravel Pits	0.06	0.04	-	-	0.10
Moderate-Density Residential	-	0.03	0.02	0.08	0.13
Public, Quasi-Public	-	-	0.01	0.45	0.47
Rangeland	2.77	0.74	0.05	0.04	3.60
Transportation, Communication	-	0.00	-	0.28	0.28
Urban Recreation	-	0.15	0.11	0.77	1.03
Utilities	0.17	0.02	-	-	0.19
Vacant, Undeveloped	0.06	0.01	-	-	0.06
Total	17.26	1.49	1.24	10.57	30.57

2.2 Sampling Events

To examine the magnitude and potential causes of aquatic toxicity observed at site STE060 in 2003 by SWAMP, water samples were collected from sampling sites during four sampling events in FY 07-08 (Figure 3). The first sampling event was conducted on October 9, 2007 prior to the occurrence of a significant rainfall event (>0.5 inches) during the wet weather season (October 15 to April 15). The two sampling events that occurred during the wet weather season occurred on December 12, 2008 following a small storm event, and on January 15, 2008 following the largest storm event of the season. The fourth sampling event was conducted on March 31 and April 1, 2008, after the wet weather season had concluded.

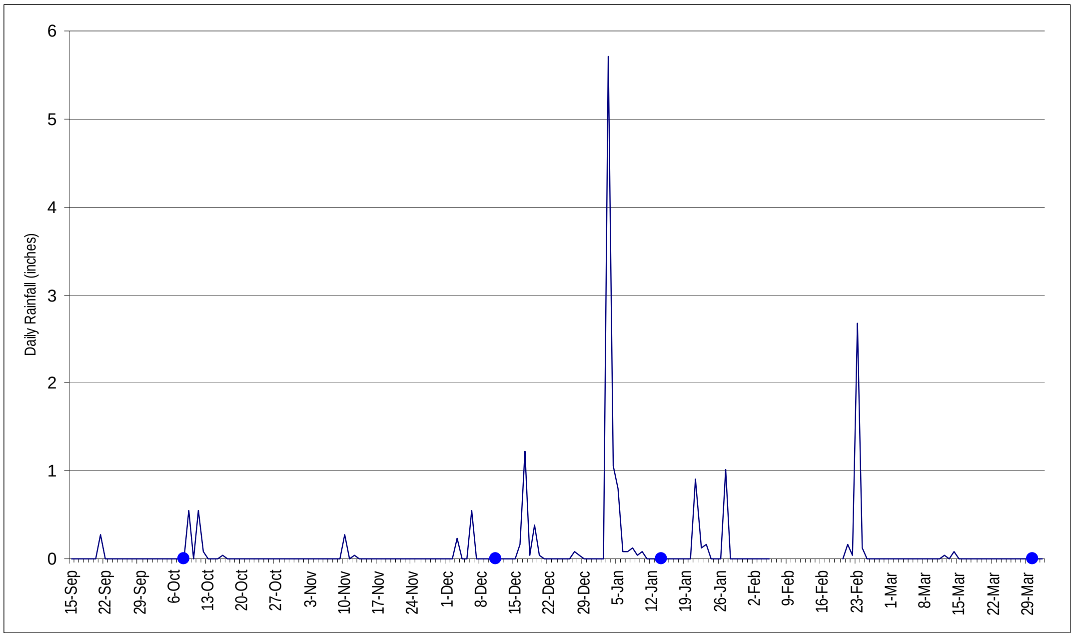

Figure 3. Daily rainfall in the Stevens Creek watershed from September 15, 2007 to April 1, 2008 (Santa Clara Valley Water District Station #1510-Stevens Creek RF100). Sampling events are illustrated as blue circles.

2.3 Water Quality and Toxicity

Dissolved oxygen, pH, temperature, conductivity and velocity were measured in-situ at all sites during all sampling events. Additionally, water samples were collected at sites STE060, STE063 and STE065, and analyzed for organophosphate pesticides. Water samples were also used to conduct *Ceriodaphnia dubia* bioassays. Additional water was also collected during each sampling event to analyze for chemical concentrations of metals in the event that significant water toxicity was observed. Analytical methods, reporting limits and maximum holding times for each analysis conducted are included in Appendix A.

2.4 Sediment Quality and Toxicity

Stevens Creek sites STE020, STE060 and STE065 were selected to assess sediment toxicity. Site STE050 (Stevens Creek at Fremont Blvd.) was originally selected for sampling, however, this site was completely dry during the first sampling event and was therefore moved to STE020. Sites were selected based on previous observations of aquatic toxicity and sediment deposition.

At each site, sediment samples were preferentially collected in areas with fine sediment deposition. Sediment samples were collected with a Tefzel-coated stainless spoon, lifted slowly through overlying water and placed into a Tefzel-coated steel pan. Samples were pooled at each site, homogenized, placed in sample containers. Toxicity of bedded sediments was evaluated by exposing the amphipod *Hyalella azteca* to the collected sediments in a standard ten-day survival test. This test uses eight replicates per site, with ten amphipods per replicate.

Bedded sediment collected at sediment sampling sites was also analyzed for total recoverable metals and a suite of pyrethroid pesticides. Additionally, total organic carbon (TOC) and grain size were also measured in each sample. Analytical methods, reporting limits and holding times for each analyte are provided in Appendix A.

To assess sediment quality, total recoverable metal concentrations in bedded sediment were compared to ecotoxicological effects-based thresholds for freshwater ecosystems developed by MacDonald et al. (2000). Thresholds includes Probable Effect Concentrations (PECs), which represent concentrations above which one would expect to observe some degree of toxic response; and, Threshold Effect Concentrations (TECs), which represent concentrations below which one would not expect to observe toxic responses (Table 3). For pyrethroid pesticides, PEC and TEC guidelines have not been developed. However, LC50s[3] have been published for seven pyrethroids (Maund et al 2002, Amweg et al 2006) and were used in the absence of PEC/TEC guidelines to assess sediment contamination (Table 3).

Table 3. Probable and threshold effects concentrations for total recoverable metals in freshwater sediments (MacDonald et al 2000) and LC50s for pyrethroids (Maund et al 2002, Amweg et al 2006).

Chemical	Probable Effects Concentration (PEC)	Threshold Effects Concentration (TEC)	LC50s (Normalized to TOC)
Total Metals (mg/kg)			
Arsenic	33	9.79	-
Cadmium	4.98	0.99	-
Chromium	111	43.4	-
Copper	149	31.6	-
Lead	128	35.8	-
Mercury	1.06	0.18	-
Nickel	48.6	22.7	-
Zinc	459	121	-
Pyrethroid Pesticides (ug/kg)			
Bifenthrin	-	-	520
Cyflurin	-	-	1,080
Cypermethrin	-	-	380
Deltamethrin	-	-	790
Esfenvalerate	-	-	1,540
L-Cyhalothrin	-	-	450
Permethrin	-	-	10,830

To assess the intra-annual variability of each metal analyzed in bedded sediments at each site, the concentration in each sample was compared to the mean concentration from all sampling events. Specifically, for each site the relative percent difference (RPD) between the metal concentration in a sample and the mean of all sampling events at that site was calculated using the following formula:

$$RPD = \left(\frac{[c] - \bar{x}_{[c]}}{\bar{x}_{[c]}} \right) \bullet 100$$

where:

$[c]$ = *concentration of a metal measured in a bedded sediment sample at a sampling site*

$\bar{x}_{[c]}$ = *the mean concentration of a metal measured at a sampling site during multiple sampling events*

To calculate the average intra-annual variability of all metals analyzed, the mean RPD was then calculated for each site. The mean RPD was used to assess the average difference in concentrations of metals in bedded sediments at a site, between two sampling regimes (i.e., once-per-year and multiple times-per year).

7 Concentrations lethal to 50% of organisms exposed.

2.5 Data Quality Assessment

Quality Assurance/Quality Control (QA/QC) activities associated with the field data collection and laboratory analyses are described in more detail in the SCVURPPP Draft Quality Assurance Project Plan (QAPP). The major goal for these QA/QC procedures is to have representative, comparable, accurate and precise data, to the extent possible under the given limitations. QA/QC activities associated with water quality field sampling and laboratory analysis included the following:

- Employing analytical chemists trained in the procedures to be followed;
- Adherence to documented procedures, USEPA methods and written SOPs;
- Calibration of analytical instruments;
- Use of quality control samples, internal standards, surrogates, and SRMs
- Complete documentation of sample tracking and analysis.

Data validation was performed in accordance with the National Functional Guidelines for Organic Data Review (EPA540/R-99/008) and Inorganic Data Review (EPA540/R-01/008).

For bioassays to meet basic quality control requirements, the lab control had to achieve a mean survival of 80%. Tests for reduced survival compared to a lab control were done using Dunnett's one-way Analysis of Variance (ANOVA) test (p = 0.05).

3.0 RESULTS

3.1 Water Quality and Toxicity

Organophosphate pesticide concentrations were below reporting limits for all water samples collected during the study. Dissolved oxygen was above 9.0 mg/L at all sites and water temperature ranged between 6.6 and 16.3 ^{o}C. Conductivity and pH ranged between 300 and 850 uS/cm, and 7.2 and 8.8, respectively. All water quality data are presented in Appendix B.

Unlike the results of SWAMP (Water Board 2007a), neither acute nor chronic toxicity was observed during this study. Specifically, bioassay test organisms *Ceriodaphnia dubia* consistently survived and reproduced during exposure to water samples collected from sites STE065, STE063 and STE060 prior to, during and after the wet weather season (Appendix B).

3.2 Sediment Toxicity

In contrast to the absence of water toxicity, significant acute toxicity was observed at all sites sampled in Stevens Creek during at least one sampling event in FY 07-08 (Figure 4). Specifically, significant toxicity was present at one site prior to the wet weather season, at three sites during the wet weather season, and at one site following the wet weather season. For all sites sampled, the greatest degree of sediment toxicity was observed during the sampling event that followed the largest rainfall event of the wet weather season (January 15, 2008). Amphipods (*H. azteca*) exposed to sediments

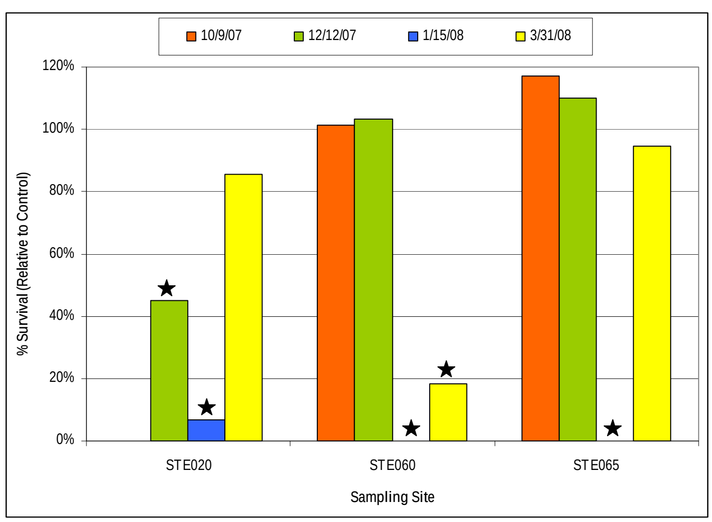

Figure 4. *Hyalella azteca* 10-day survival bioassay results. Stars indicate significantly reduced survival compared to laboratory control.

collected during this sampling event exhibited nearly complete mortality (i.e., 0-7% survival compared to control).

3.3 Sediment Quality

Total recoverable metal concentrations for each sampling event and average concentrations for each site are presented in Table 4. Metal concentrations were generally lower than the corresponding threshold effects levels (i.e., PECs and TECs), with the exception of nickel, chromium and copper (TEC only) (Table 5). Only one pyrethroid pesticide (Bifenthrin) was detected during the study (Appendix B). This pyrethroid was detected at one site during a single sampling event and was below the published LC50.

4.0 DISCUSSION

4.1 Extent, Magnitude and Causes of Toxicity

Contaminated sediments or water may affect natural populations of aquatic organisms adversely. Sediment-dwelling organisms may be exposed directly to contaminants by the ingestion of sediments and by the uptake of sediment-associated contaminants from interstitial and overlying water. Contaminated sediments may also affect water column species directly by serving as a source of contaminants to overlying waters or a sink for contaminants from overlying waters. Organisms may also be affected when contaminated sediments are suspended in the water column by natural or human activities.

Previous aquatic bioassay results suggested that aquatic toxicity was present in Stevens Creek (Water Board 2007a), which consequently resulted in a regulatory action (i.e., 303(d) listing) by the Water Board. The extent and magnitude of sediment toxicity in Stevens Creek, however, had not been fully examined. This study was designed to collect additional information on the magnitude, extent and causes of both aquatic and sediment toxicity (if present) in Stevens Creek, which would assist municipal stormwater programs and the Water Board in better defining the problem, sources and possibly developing practicable management actions to reduce toxicity.

Based on the results of toxicity testing conducted during this and previous studies (Water Board 2007a, SCVURPPP 2007a), it appears that water in Stevens Creek between 2002 and 2008 is not consistently toxic to the standard bioassay test organisms (*C. dubia or P. promelas*). Table 6 summarizes all water toxicity data collected by SWAMP (2002) and SCVURPPP (2005-2008) during this timeframe. Specifically, only 2 of 20 samples collected in Stevens Creek have exhibited acute toxicity. Furthermore, the magnitude of toxicity measured in these samples was minimal (>70% survival).

These results in Stevens Creek are similar to those reported by SCVURPPP (2007), where only 2 of 42 sampling events at 17 sites in 8 Santa Clara Basin watersheds exhibited acute aquatic toxicity. As suggested in SCVURPPP (2007), recent reductions in aquatic toxicity observed in Santa Clara creeks may be due to the phase out of the organophosphate diazinon, which is believed to be responsible for extensive aquatic toxicity in San Francisco Bay Area urban creeks during the 1990’s (Water Board 2005).

Table 4. Concentrations of total organic carbon (TOC), fine sediment (<63um), and total recoverable metals (mg/kg) in Stevens Creek bedded sediment collected in 2007 and 2008.

Site	Date	TOC (%)	Fines (%)	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
STE020	12-Dec	0.08	2.2	3	0.17	83	31	14	0.068	73	1.3	0.06	94
	15-Jan	0.04	1.6	2.9	0.2	81	28	11	0.069	69	1.2	0.11	78
	31-Mar	0.70	5.9	2.3	0.16	60	24	20	0.075	51	1	0.044	74
	Ave.	*0.27*	*3.2*	*2.7*	*0.18*	*74*	*27*	*15*	*0.07*	*64*	*1.17*	*0.07*	*82*
STE060	9-Oct	5.10	30.4	4.3	0.28	97	52	15	0.13	82	2.2	0.1	120
	12-Dec	0.16	1.6	3.1	0.14	100	31	9.5	0.057	71	1.3	0.043	69
	15-Jan	0.04	0.5	3.3	0.17	110	33	7.1	0.55	78	1.3	0.042	75
	31-Mar	0.70	2.7	2.8	0.17	83	36	15	0.052	68	1.2	0.047	79
	Ave.	*1.50*	*8.8*	*3.3*	*0.19*	*97*	*38*	*11.6*	*0.20*	*74*	*1.5*	*0.06*	*85*
STE065	9-Oct	0.23	4.1	2.3	0.14	100	37	4.4	0.09	73	0.9	0.035	53
	12-Dec	0.06	8.1	3.2	0.16	110	39	6	0.07	74	1.6	0.06	70
	15-Jan	0.09	2.8	3.3	0.16	120	42	6.1	0.045	83	1.4	0.045	76
	31-Mar	0.37	2.1	3	0.18	120	40	6.8	0.052	90	1.5	0.045	76
	Ave.	*0.19*	*4.3*	*3.0*	*0.16*	*113*	*40*	*5.8*	*0.06*	*80*	*1.3*	*0.05*	*68*

Table 5. PEC and TEC quotients(Q) for total recoverable metals in sediment collected from Stevens Creek in FY 07-08. Numbers in bold represent concentrations above the PEC or TEC value.

Site	Date	As		Cd		Cr		Cu		Pb		Hg		Ni		Zn	
		PECQ	TECQ	PECQ	TECQ	PECQ	TECQ	PECQ	TECQ	PECQ	TECQ	PECQ	TECQ	PECQ	TECQ	PECQ	TECQ
STE020	12-Dec	0.1	0.3	0.0	0.2	0.8	1.9	0.2	1.0	0.1	0.4	0.1	0.4	1.5	3.2	0.2	0.8
	15-Jan	0.1	0.3	0.0	0.2	0.7	1.9	0.2	0.9	0.1	0.3	0.1	0.4	1.4	3.0	0.2	0.6
	31-Mar	0.1	0.2	0.0	0.2	0.5	1.4	0.2	0.8	0.2	0.6	0.1	0.4	1.1	2.3	0.2	0.6
	Ave.	*0.1*	*0.3*	*0.0*	*0.2*	*0.7*	*1.7*	*0.2*	*0.9*	*0.1*	*0.4*	*0.1*	*0.4*	*1.3*	*2.8*	*0.2*	*0.7*
STE060	9-Oct	0.1	0.4	0.1	0.3	0.9	2.2	0.4	1.7	0.1	0.4	0.1	0.7	1.7	3.6	0.3	1.0
	12-Dec	0.1	0.3	0.0	0.1	0.9	2.3	0.2	1.0	0.1	0.3	0.1	0.3	1.5	3.1	0.2	0.6
	15-Jan	0.1	0.3	0.0	0.2	1.0	2.5	0.2	1.0	0.1	0.2	0.5	3.1	1.6	3.4	0.2	0.6
	31-Mar	0.1	0.3	0.0	0.2	0.8	1.9	0.2	1.1	0.1	0.4	0.1	0.3	1.4	3.0	0.2	0.7
	Ave.	*0.1*	*0.3*	*0.0*	*0.2*	*0.9*	*1.8*	*0.3*	*1.0*	*0.1*	*0.4*	*0.2*	*0.4*	*1.5*	*2.9*	*0.2*	*0.7*
STE065	9-Oct	0.1	0.2	0.0	0.1	0.9	2.3	0.3	1.2	0.0	0.1	0.1	0.5	1.5	3.2	0.1	0.4
	12-Dec	0.1	0.3	0.0	0.2	1.0	2.5	0.3	1.2	0.1	0.2	0.1	0.4	1.5	3.3	0.2	0.6
	15-Jan	0.1	0.3	0.0	0.2	1.1	2.8	0.3	1.3	0.1	0.2	0.0	0.3	1.7	3.7	0.2	0.6
	31-Mar	0.1	0.3	0.0	0.2	1.1	2.8	0.3	1.3	0.1	0.2	0.1	0.3	1.9	4.0	0.2	0.6
	Ave.	*0.1*	*0.3*	*0.0*	*0.2*	*1.0*	*1.9*	*0.3*	*1.1*	*0.1*	*0.4*	*0.1*	*0.3*	*1.7*	*2.9*	*0.2*	*0.7*

Table 6. Number of Stevens Creek water samples exhibiting significant acute toxicity to test organisms between 2002 and 2008.				
Site	*Ceriodaphnia dubia*		*Pimephales promelas*	
	Sig. Toxicity	Total # Samples	Sig. Toxicity	Total # Samples
STE020	0	5	0	5
STE060	1[a]	7	1[b]	7
STE063	0	4	0	4
STE065	0	4	0	4
Total	1	20	1	20

[a] Reported 70% survival compared to control
[b] Reported 73% survival compared to control

In contrast to water toxicity in Stevens Creek between 2002 and 2008, sediment toxicity appears to be present at a majority of the sites sampled (Table 7). The survival of test organism *Hyalella azteca* was significantly reduced in 5 of 12 samples collected between 2002 and 2008. More specifically, during this investigation bedded sediment samples collected after the largest rainfall event of the wet weather season exhibited severe toxicity (<5% survival) at all sites sampled, suggesting that large storm events are important transport pathways for chemicals causing toxicity in Stevens Creek. An association between stormwater runoff and sediment toxicity recently been observed in the San Francisco Bay Estuary has also been suggested (Anderson et al. 2007). Data collected by the Regional Monitoring Program for Water Quality in the San Francisco Bay Estuary (RMP) has indicated that the magnitude and frequency of sediment toxicity is greater in the winter wet season.

Based on water and sediment quality data collected to-date by the SCVURPPP and SWAMP, the causes of sediment toxicity in Stevens Creek are not well understood. During this investigation, nickel, chromium and copper concentrations in bedded sediment were above concentration thresholds that below which one would not expect to observe toxic responses (i.e., TECs). Additionally, pyrethroid pesticides were consistently below analytical reporting limits during all sampling events (including at sites where severe toxicity was measured) suggesting that these chemicals are not likely the cause of the toxicity observed.

Table 7. Number of Stevens Creek bedded sediment samples exhibiting significant acute toxicity to test organisms *Hyalella azteca* between 2002 and 2008.		
Site	*Hyalella azteca*	
	Sig. Toxicity	Total # Samples
STE020	2	4
STE060	2	4
STE065	1	4
Total	5	12

Additional chemicals that have been correlated with sediment toxicity in the San Francisco Bay Estuary include organochlorine pesticides (e.g., chlordane, DDT) and PAHs (Swartz et al., 1994; Thompson et al., 1999; Hunt et al., 2001). Although similar types of organic chemicals were not sampled during this study, future investigations into the causes of toxicity in Stevens Creek should include a broader suite of potential pollutants. Additionally, future studies should consider conducting toxicity identification evaluations (TIEs) when the survival of bioassay test organisms is < 50% compared to the laboratory control.

4.2 Intra-Annual Variability in Sediment Chemistry

Understanding the temporal variability of chemical concentrations in bedded sediment is important for stormwater managers for two main reasons. First, from an ecological perspective, it is important to know if concentrations of potentially toxic chemicals in bedded sediments are associated with other environmental conditions. For example, higher chemical concentrations and associated toxicity may occur more frequently during a certain season or following a certain sized storm event that generates stormwater runoff. If relationships like these can be documented, management practices designed to reduce the toxic response may be focused on specific timeframes or be applied during certain environmental conditions, thus enabling more efficient and directed implementation.

The degree of intra-annual variability in an environmental indicator like bedded sediment is also important to understand from a monitoring perspective, as it affects our ability to collect representative data and detect change overtime. For example, if the concentration of chemical-x has a high degree of seasonal variability at a specific site, then a monitoring program would likely chose to annually measure for chemical-x during multiple sampling events to establish a better understanding of the “average” annual concentration. Alternatively, if intra-annual variability is relatively low, then a single sampling event per year may suffice.

At the onset of this investigation, the intra-annual variability of metal concentrations in bedded sediments collected from urban creeks in the Santa Clara Basin had not been examined. Therefore, no local monitoring data were available to assist the SCVURPPP in developing a bedded sediment sampling program, which ideally should be both scientifically sound and comply with monitoring requirements (i.e., bedded sediment sampling 1x per year) in the Draft NPDES Permit (Tentative Order) proposed by the San Francisco Bay Water Board (Water Board 2007b).

Based on the results of this investigation, it appears that concentrations of metals in bedded sediments on average varied by less than an order-of-magnitude at all sites sampled during FY 07-08 monitoring in Stevens Creek (Figure 5). Site STE060 had the greatest variability of the three sites sampled, as the mean relative percent difference (RPD) was ±66%. Additionally, on average the concentrations of all metals detected in bedded sediments collected after significant rainfall events and following the wet weather season are the most representative of the average annual concentrations of metals at a site. All data used to develop mean RPDs are included in Appendix C.

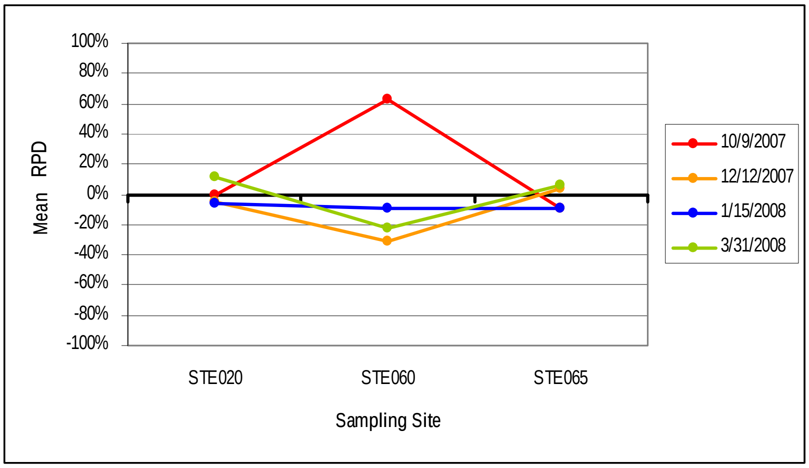

Figure 5. Mean relative percent differences (RPDs) per sampling site for all chemicals analyzed in Stevens Creek bedded sediments. Bold line illustrates the average of all mean RPDs for each site.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following preliminary conclusions and recommendations were based on the results and interpretation of data collected during the Stevens Creek investigative study conducted by SCVURPPP in FY 07-08.

1. Based on SWAMP and SCVURPPP data collected between 2002 and 2008, only 2 of 20 samples exhibited acute aquatic toxicity, suggesting that aquatic toxicity impacts are currently minimal in Stevens Creek.

   ***Recommendation*:** At this time, SCVURPPP should consider additional investigative studies in Stevens Creek aimed at evaluating the extent, magnitude and causes of aquatic toxicity a low priority, as creek water does not appear to be acutely toxic to standard bioassay test organisms.

2. Significant sediment toxicity appears to be present in Stevens Creek. In particular, a high degree of toxicity was present after storm events that generate runoff from primarily urban land uses. In general, all metals (with the exception of naturally occurring chromium and nickel) and pyrethroid pesticides appear to be below concentrations which one would expect to observe some degree of toxic response, suggesting that these chemicals are not the primary causes of the observed toxicity.

   ***Recommendation*:** SCVURPPP should consider conducting follow-up investigative studies to determine the causes and (to the extent possible) sources of sediment toxicity in Stevens Creek. Consideration should be given to conducting toxicity identification evaluations (TIEs) when bioassay test organism survival is < 50% compared to the laboratory control. In parallel, sediment samples should also be analyzed for a larger list of analytes, including those associated with toxicity observed in the San Francisco Bay Estuary (e.g., PAHs).

3. On average, the intra-annual variability of metal concentrations in bedded sediments in Stevens Creek is minimal (±20%). Based on this result, the SCVURPPP should feel confident that the concentration of a metal in a single bedded sediment sample collected after a significant rainfall event or following the wet weather season will be representative of the average annual concentration.

   ***Recommendation*:** Future screening-level bedded sediment sampling conducted by SCVURPPP should focus on measuring priority chemicals annually. The degree to which a single sample is representative of the average annual concentration may increase if sampling occurs after a significant rainfall event or following the wet weather season (i.e., in the spring season).

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APPENDIX A - SEDIMENT ANALYTICAL CHEMISTRY METHODS, REPORTING LIMITS, AND HOLDING TIMES.

Analyte	Analytical Method	Reporting Limit	Hold Time
TOTAL RECOVERABLE METALS (mg/kg)			
Aluminum	EPA 6020	1	6 months
Arsenic	EPA 6020	0.1	6 months
Cadmium	EPA 6020	0.1	6 months
Chromium	EPA 6020	0.1	6 months
Copper	EPA 6020	0.1	6 months
Lead	EPA 6020	0.1	6 months
Mercury	EPA 7471M	0.02	6 months
Manganese	EPA 6020	0.1	6 months
Nickel	EPA 6020	0.1	6 months
Selenium	EPA 6020	0.1	6 months
Silver	EPA 6020	0.1	6 months
Zinc	EPA 6020	1	6 months
PHYSICAL CHARACTERISTICS			
Total Organic Carbon	EPA 9060	0.1%	28 days
Percent Solids	EPA 160.3	0.1%	28 days
Sediment Grain Analysis	Plumb, 1981	NA	6 months
Pyrethroid Pesticides (ng/g)	EPA 8270C(m)	2-25	40 days
Piperonyl butoxide (ng/g)	EPA 8270C(m)	5	40 days
BIOASSAY(TOXICITY TESTING)			
Hyalella azteca	EPA-600-R-99-064 2nd Edition	NA	8 weeks

APPENDIX B – STEVENS CREEK SEDIMENT AND WATER QUALITY DATA COLLECTED BY THE SAN FRANCISCO BAY WATER BOARD'S SWAMP PROGRAM (2002) AND SCVURPPP (2005-2008).

INCLUDED ON CD-ROM
OR
AVAILABLE UPON REQUEST

APPENDIX C – RELATIVE PERCENT DIFFERENCE (RPD) CALCULATION TABLES FOR METALS IN BEDDED SEDIMENT COLLECTED IN STEVENS CREEK IN FY 2007-08.

SITE STE020	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc	Average
Concentrations (mg/kg)											
12/12/2007	3.00	0.17	83	31	14	0.07	73	1.3	0.06	94	-
1/15/2008	2.90	0.20	81	28	11	0.07	69	1.2	0.11	78	-
3/31/2008	2.30	0.16	60	24	20	0.08	51	1.0	0.04	74	-
Mean	2.73	0.18	74.67	27.67	15.00	0.07	64.33	1.17	0.07	82.00	-
Difference from Mean											
12/12/2007	0.27	-0.01	8.33	3.33	-1.00	0.00	8.67	0.13	-0.01	12.00	-
1/15/2008	0.17	0.02	6.33	0.33	-4.00	0.00	4.67	0.03	0.04	-4.00	-
3/31/2008	-0.43	-0.02	-14.67	-3.67	5.00	0.00	-13.33	-0.17	-0.03	-8.00	-
Relative Percent Difference (RPD)											
12/12/2007	9.8%	-3.8%	11.2%	12.0%	-6.7%	-3.8%	13.5%	11.4%	-15.9%	14.6%	4.2%
1/15/2008	6.1%	13.2%	8.5%	1.2%	-26.7%	-2.4%	7.3%	2.9%	54.2%	-4.9%	5.9%
3/31/2008	-15.9%	-9.4%	-19.6%	-13.3%	33.3%	6.1%	-20.7%	-14.3%	-38.3%	-9.8%	-10.2%

Site STE060	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc	Average
Concentrations (mg/kg)											
10/9/2007	4.3	0.28	97	52	15	0.13	82	2.2	0.1	120	-
12/12/2007	3.1	0.14	100	31	9.5	0.057	71	1.3	0.043	69	-
1/15/2008	3.3	0.17	110	33	7.1	0.55	78	1.3	0.042	75	-
3/31/2008	2.8	0.17	83	36	15	0.052	68	1.2	0.047	79	-
Mean	3.375	0.19	97.5	38	11.65	0.19725	74.75	1.5	0.058	85.75	-
Difference from Mean											
10/9/2007	0.925	0.09	-0.5	14	3.35	-0.06725	7.25	0.7	0.042	34.25	-
12/12/2007	-0.275	-0.05	2.5	-7	-2.15	-0.14025	-3.75	-0.2	-0.015	-16.75	-
1/15/2008	-0.075	-0.02	12.5	-5	-4.55	0.35275	3.25	-0.2	-0.016	-10.75	-
3/31/2008	-0.575	-0.02	-14.5	-2	3.35	-0.14525	-6.75	-0.3	-0.011	-6.75	-
Relative Percent Difference (RPD)											
10/9/2007	27.4%	47.4%	-0.5%	36.8%	28.8%	-34.1%	9.7%	46.7%	72.4%	39.9%	27.4%
12/12/2007	-8.1%	-26.3%	2.6%	-18.4%	-18.5%	-71.1%	-5.0%	-13.3%	-25.9%	-19.5%	-20.4%
1/15/2008	-2.2%	-10.5%	12.8%	-13.2%	-39.1%	178.8%	4.3%	-13.3%	-27.6%	-12.5%	7.8%
3/31/2008	-17.0%	-10.5%	-14.9%	-5.3%	28.8%	-73.6%	-9.0%	-20.0%	-19.0%	-7.9%	-14.8%

Site STE065	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc	Average
Concentrations (mg/kg)											
10/9/2007	2.3	0.14	100	37	4.4	0.09	73	0.9	0.035	53	-
12/12/2007	3.2	0.16	110	39	6	0.07	74	1.6	0.06	70	-
1/15/2008	3.3	0.16	120	42	6.1	0.045	83	1.4	0.045	76	-
3/31/2008	3	0.18	120	40	6.8	0.052	90	1.5	0.045	76	-
Mean	3.2	0.17	117	40	6.3	0.06	82	1.5	0.05	74	
Difference from Mean											
10/9/2007	-0.87	-0.03	-16.67	-3.33	-1.90	0.03	-9.33	-0.60	-0.02	-21.00	-
12/12/2007	0.03	-0.01	-6.67	-1.33	-0.30	0.01	-8.33	0.10	0.01	-4.00	-
1/15/2008	0.13	-0.01	3.33	1.67	-0.20	-0.01	0.67	-0.10	-0.01	2.00	-
3/31/2008	-0.17	0.01	3.33	-0.33	0.50	0.00	7.67	0.00	-0.01	2.00	-
Relative Percent Difference (RPD)											
10/9/2007	-27.4%	-16.0%	-14.3%	-8.3%	-30.2%	61.7%	-11.3%	-40.0%	-30.0%	-28.4%	-14.4%
12/12/2007	1.1%	-4.0%	-5.7%	-3.3%	-4.8%	25.7%	-10.1%	6.7%	20.0%	-5.4%	2.0%
1/15/2008	4.2%	-4.0%	2.9%	4.1%	-3.2%	-19.2%	0.8%	-6.7%	-10.0%	2.7%	-2.8%
3/31/2008	-5.3%	8.0%	2.9%	-0.8%	7.9%	-6.6%	9.3%	0.0%	-10.0%	2.7%	0.8%