Pollutants of concern (POC) loads monitoring data progress report, water years (WYs) 2012 and 2013

Prepared by

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1. Introduction

The San Francisco Regional Water Quality Control Board (Water Board) has determined that San Francisco Bay is impaired by mercury and PCBs due to threats to wildlife and human consumers of fish from the Bay. These contaminants persist in the environment and accumulate in aquatic food webs (SFRWRCB 2006; SFRWRCB, 2008). The Water Board has identified urban runoff from local watersheds as a pathway for pollutants of concern into the Bay, including mercury and PCBs. The Municipal Regional Stormwater Permit (MRP; SFRWRCB, 2009) contains several provisions requiring studies to measure local watershed loads of suspended sediment (SS), total organic carbon (TOC), polychlorinated biphenyl (PCB), total mercury (HgT), total methylmercury (MeHgT), nitrate-N (NO3), phosphate-P (PO4), and total phosphorus (TP) (provision C.8.e), as well as other pollutants covered under provision C.14. (e.g., legacy pesticides, PBDEs, and selenium).

Bay Area Stormwater Programs, represented by the Bay Area Stormwater Management Agencies Association (BASMAA), collaborated with the San Francisco Bay Regional Monitoring Program (RMP) to develop an alternative strategy allowed by Provision C.8.e of the MRP, known as the Small Tributaries Loading Strategy (STLS) (SFEI, 2009). An early version of the STLS provided an initial outline of the general strategy and activities to address four key management questions (MQs) that are found in MRP provision C.8.e:

> MQ1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs;
>
> MQ2. What are the annual loads or concentrations of POCs from tributaries to the Bay;
>
> MQ3. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay; and,
>
> MQ4. What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact.

Since then, a Multi-Year-Plan (MYP) has been written (BASMAA, 2011) and updated twice (BASMAA, 2012; BASMAA, 2013). The MYP provides a comprehensive description of activities that will be implemented over the next 5-10 years to provide information and comply with the MRP. The MYP provides rationale for the methods and locations of proposed activities to answer the four MQs listed above. Activities include modeling using the regional watershed spreadsheet model (RWSM) to estimate regional scale loads (Lent and McKee, 2011; Lent et al., 2012; SFEI in preparation), and pollutant characterization and loads monitoring in local tributaries beginning Water Year (WY) 2011 (McKee et al., 2012), that continued in WY 2012 (McKee et al., 2013), WY 2013 (this report), and is underway again for WY 2014.

The purpose of this report is to describe data collected during WYs 2012 and 2013 in compliance with MRP provision C.8.e., following the standard report content described in provision C.8.g.vi. The study design (selected watersheds and sampling locations, analytes, sampling methodologies and frequencies) as outlined in the MYP was developed to assess concentrations and loads in watersheds that are considered to likely be important watersheds in relation to sensitive areas of the Bay margin (MQ1):

- Lower Marsh Creek (Hg);
- North Richmond Pump Station;
- San Leandro Creek (Hg);
- Guadalupe River (Hg and PCBs);
- Sunnyvale East Channel (PCBs); and
- Pulgas Creek Pump Station.

Loads monitoring provides calibration data for the RWSM (MQ2), and is intended to provide baseline data to assess long term loading trends (MQ3) in relation to management actions (MQ4). This report is structured to allow annual updates after each subsequent winter season of data collection. It should be noted that the sampling design described in this report (and modeling design: Lent and McKee, 2011; Lent et al., 2012; SFEI in preparation) was focused mainly on addressing MQ2. Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board (and discussion at the October 2013 SPLWG meeting) have highlighted the increasing focus towards finding watersheds and land areas within watersheds for management focus (MQ4). The monitoring design described in this report is not intended to address this increasing management focus.

2. Field methods

2.1. Watershed physiography, sampling locations, and sampling methods

The San Francisco Bay estuary is surrounded by nine highly urbanized counties with a total population greater than seven million people (US Census Bureau, 2010). Although urban runoff from upwards of 300 small tributaries (note the number is dependent upon how the areas are lumped or split) flowing from the adjacent landscape represents only about 6% of the total freshwater input to the San Francisco Bay, this input has broadly been identified as a significant source of pollutants of concern (POCs) to the estuary (Davis et al., 2007; Oram et al., 2008; Davis et al., 2012; Gilbreath et al., 2012). Four watershed sites were sampled in WY 2012 and two additional watershed sites were added in WY 2013 (Figure 1; Table 1). The sites were distributed throughout the counties where loads monitoring are required by the MRP. The selected watersheds include urban and industrial land uses, watersheds where stormwater programs are planning enhanced management actions to reduce PCB and mercury discharges, and watersheds with historic mercury or PCB occurrences or related management concerns.

The monitoring design focused on winter season storms between October 1 and April 30 of each water year; the period when the majority of pollutant transport occurs in the Bay Area (McKee et al., 2003; McKee et al., 2006; Gilbreath et al, 2012). At all six sampling locations, measurement of continuous stage and turbidity at time intervals of 15 min or less was the basis of monitoring design (Table 1). At free flowing sites, stage was used along with a collection of discrete velocity measurements to generate a rating curve between stage and instantaneous discharge. Subsequently this rating curve was used to estimate a continuous discharge record over the wet season by either the STLS team or USGS depending on the sampling location (Table 1). At Richmond pump station, an optical proximity sensor (Omron, model E3F2) was used along with stage measurements and a pump efficiency curve based on the pump specifications to estimate flow. ISCO flow meters were deployed at the Pulgas Street Pump Station (Table 1). Turbidity is a measure of the “cloudiness” in water caused by suspension of particles, most of which are less than 62.5 µm in size and, for most creeks in the Bay Area, virtually always less than 250 µm (USGS data). In natural flowing rivers and urban creeks or storm drains, turbidity usually correlates with the concentrations of suspended sediments and hydrophobic pollutants. Turbidity probes were mounted in the thalweg of each sampling location on an articulated boom that allowed turbidity sampling at approximately mid-depth under most flow conditions (McKee et al., 2004).

Composite and discrete samples were collected for multiple analytes from the water column over the rising, peak, and falling stages of the hydrograph. The sampling design was developed to support the use of turbidity surrogate regression during loads computations. This method is deemed one of the most accurate methods for the computation of loads of pollutants transported dominantly in particulate phase such as suspended sediments, mercury, PCBs and other pollutants (Walling and Webb, 1985; Quémerais et al., 1999; Wall et al., 2005; Gilbreath et al., 2012). The method involves logging a continuous turbidity record in a short time interval (15 min or less during the study) and collecting a number of discrete samples to support the development of pollutants specific regressions. In this study, although not always achievable (see discussion later in the report), field crews aimed to collect 16 samples per water year during an early storm, several mid-season storms (ideally including one of the largest storms of the season) and later season storm. The use of turbidity surrogate regression and the other components of this sampling design was recommended over a range of alternative designs (Melwani et al 2010), and was adopted by the STLS (BASMAA, 2011).

Discrete samples except mercury, methylmercury and a simultaneously collected suspended sediment concentration (SSC) sample were collected using the ISCO as a pump at all the sites besides Guadalupe. Discrete mercury and methylmercury samples (including a simultaneously collected SSC sample) were collected with the D-95 at Guadalupe, Sunnyvale East Channel, North Richmond Pump Station, and San Leandro Creek (WY 2012 only), using a pole sampler at Pulgas Creek Pump Station, and by manually dipping an opened bottle from the side of the channel at San Leandro (in WY 2013 only) and Lower Marsh Creek (both WYs) (Table 1). Tubing for the ISCOs was installed using the clean hands technique, as was the 1 L Teflon bottle when used in the D-95. Composite samples, with the intent of representing average concentrations of storm runoff over each storm event sampled, were collected using the ISCO autosampler at all of the sites except Guadalupe River. At the Guadalupe site, a FISP D-95 depth integrating water quality sampler was used to collect multiple discrete samples over the hydrograph which were manually composited on-site in preparation for shipment to the laboratories.

2.2. Loads computational methods

It has been recognized since the 1980s that different sampling designs and corresponding loads computation techniques generate computed loads of differing magnitude and of varying accuracy and precision. Therefore, how can we know which methodology generates the most accurate load? In all environmental situations, techniques that maintain high resolution variability in concentration and flow data during the field collection and subsequent computation process result in high-resolution loads estimates that are more accurate no matter which loads computation technique is applied. Less accurate loads are generated by sampling designs that do not account for (or adequately describe) the concentration variability (e.g. a daily or weekly sampling protocol would not work for a semi-arid environment like the Bay Area) or that use some kind of mathematical average concentration (e.g. simple mean; geometric mean; flow weighted mean) combined with monthly annual time interval flows (again would not work in the semi-arid environment since 95% of flow occurs during storms).

Since the objective of any type of environmental data interpretation exercise is to neither over nor under interpret the available data, any loads computation technique that employs extra effort to stratify the data as part of the computation protocol will generate the most accurate loading information. Stratification can be done in relation to environmental processes such as seasonality, flow regime, or data quality. In a general sense, the more resolved the data are in relation to the processes of concentration or flow variation, the more likely it is that computations will result in loads with high accuracy and precision. The data collection protocol implemented through the Small Tributaries Loading Strategy (STLS) was designed to allow for data stratification in the following manner:

1. Early-season (“1st storm”) storm flow sampled for pollutants
2. Mid-season (“largest flood”) storm flow sampled for pollutants
3. Later-season storm flow sampled for pollutants
4. Early-, mid-, and later-season storm flow when no pollutant sampling took place
5. Dry weather flow

Loads computation techniques differ for each of these strata in relation to pollutants that are primarily transported in dissolved or particulate phase. As subsequent samples are collected each year at the STLS monitoring sites, knowledge will improve about how concentrations vary with season and flow (improvements of the definition of the strata) and thus about how to apply loads computation techniques. Therefore, with each additional annual reporting year, a revision of loads is expected for the previous water year(s). This will occur in relation to improved flow information as well as an improved understanding of concentration variation in relation to seasonal characteristics and flow.

During the study, concentrations either measured or estimated were multiplied with the continuous estimates of flow (2-15 minute interval) to compute the load on a 2 to 15 minute basis and summed to monthly and wet season loads. Laboratory measured data was retained in the calculations and assumed real for that moment in time. The techniques for estimating concentrations were applied in the following order of preference (and resulting accuracy and loads):

Linear interpolation: Linear interpolation is the primary technique used for interpolating concentrations between measured data points when storms are well sampled (Note, this method was not yet applied but will be applied when the final report for the data collection during WYs 2012, 2013, and 2014 is written – likely late 2014).

Linear Interpolation using particle ratios: Linear interpolation using particle ratios can be thought of as locally derived regression in three-dimensional space. It is superior to linear interpolation using water concentrations for pollutants which occur mainly in particulate form because it ensures that the

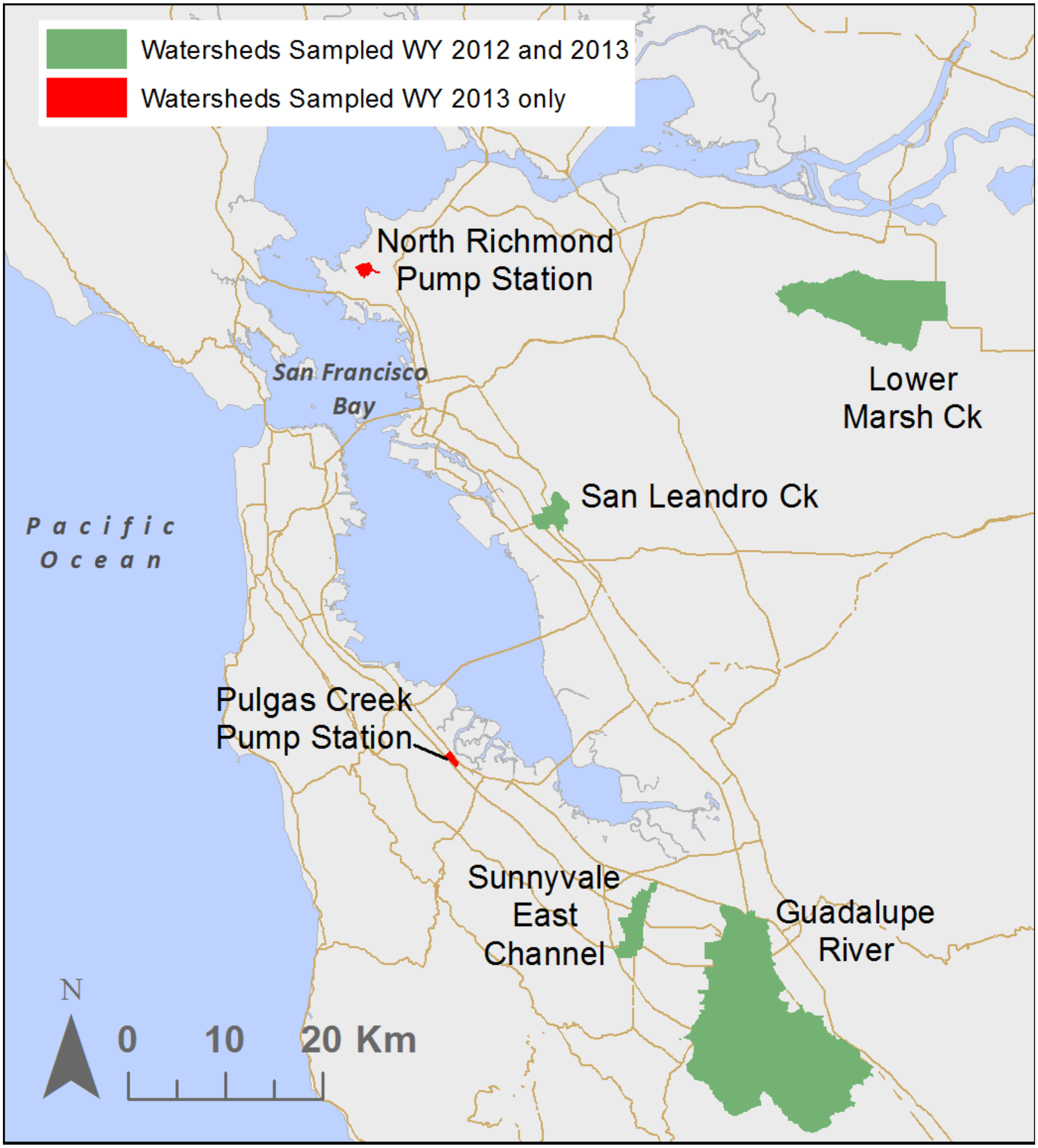


Figure 1. Water year 2012 and 2013 sampling watersheds.

Table 1. Sampling locations in relation to County programs and sampling methods at each site.

County program	Watershed name	Water years sampled	Watershed area (km²)[1]	Sampling location			Operator	Discharge monitoring method	Turbidity	Water sampling for pollutant analysis		
				City	Latitude (WGS1984)	Longitude (WGS1984)				Hg/MeHg collection	Discrete samples excluding Hg species	Composite samples
Contra Costa	Marsh Creek	2012 and 2013	99	Brentwood	37.990723	-122.16265	ADH	USGS Gauge Number: 11337600[2]	OBS-500[4]	Manual grab	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Contra Costa	North Richmond Pump Station	2013	2.0	Richmond	37.953945	-122.37398	SFEI	Measurement of pump rotations/ interpolation of pump curve	OBS-500[4]	FISP US D95[7]	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Alameda	San Leandro Creek	2012 and 2013	8.9	San Leandro	37.726073	-122.16265	SFEI WY2012 ADH WY2013	STLS creek stage/ velocity/ discharge rating	OBS-500[4]	FISP US D95[7] WY 2012 Manual grab WY 2013	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Santa Clara	Guadalupe River	2012 and 2013	236	San Jose	37.373543	-121.69612	SFEI WY2012 Balance WY 2013	USGS Gauge Number: 11169025[3]	DTS-12[5]	FISP US D95[7]	FISP US D95[7]	FISP US D95[7]
Santa Clara	Sunnyvale East Channel	2012 and 2013	14.8	Sunnyvale	37.394487	-122.01047	SFEI	STLS creek stage/ velocity/ discharge rating	OBS-500*[4] WY 2012 DTS-12[5] WY 2013	FISP US D95[7]	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
San Mateo	Pulgas Creek Pump Station	2013	0.6	San Carlos	37.504583	-122.24901	KLI	ISCO area velocity flow meter with an ISCO 2150 flow module	DTS-12[5]	Pole sampler	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]

[1]Area downstream from reservoirs.
[2]USGS 11337600 MARSH C A BRENTWOOD CA
[3]USGS 11169025 GUADALUPE R ABV HWY 101 A SAN JOSE CA
[4]Campbell Scientific OBS-500 Turbidity Probe
[5]Forest Technology Systems DTS-12 Turbidity Sensor
[6]FISP US DH-81 Depth integrating suspended hand line sampler
[7]FISP US D-95 Depth integrating suspended hand line sampler
[8]Teledyne ISCO 6712 Full Size Portable Sampler
*OBS-500 malfunctioned during WY 2012 due to low flow water depth. A DTS-12 was installed during WY 2013.

relationship between the derived concentration and varying turbidity that occurs between the two laboratory pollutant measurements results in particle ratios that at all time intervals are reasonable.

Linear Interpolation using water concentrations: Linear interpolation using water concentrations is the process by which the interpreter varies the concentrations between observed measurements using a linear time step. It is appropriately used for pollutants which occur mainly in dissolved phase because it does not incorporate any regard for varying turbidity or SSC.

Interpolation using a turbidity based regression equation with each POC: Turbidity surrogate regression can be considered the default standard for pollutants of concern that are primarily transported in a particulate form. These types of contaminants (for example PCBs and mercury) form strong linear relationships with either turbidity or SSC. Turbidity surrogate regression was applied to all unsampled flood flow conditions observed at each monitoring site.

Interpolation using a regression equation derived from two chemical species (e.g. TP:PO4): For pollutants primarily transported in dissolved phase, the turbidity regression estimator was not be appropriate. In this instance it may be possible to use an alternative surrogate such as electrical conductivity or a parent pollutant. A “chemical surrogate regression” estimator of this nature can be considered the default standard for pollutants of concern that are primarily transported in a dissolved form. This method was applied to unsampled flood flow conditions if a reliable regression was found.

Interpolation assuming a representative concentration (e.g. “dry weather lab measured” or “lowest measured”): To apply this method, an estimate of average of concentrations under certain flow conditions is combined with discharge. This is in effect a simple average estimator and is the least accurate and precise of all the loads calculation methods.

3. Continuous data quality assurance

3.1. Continuous data quality assurance methods

In 2013, a better documented method for quality assurance was developed and applied to continuous data (turbidity, stage, and rainfall) collected at the POC loads monitoring stations. These protocols were established towards the end of the season and therefore some field checks now required in the QA protocol will not be implemented until WY 2014, specifically including precision checks on the instrumentation through replicate testing of equipment at high and low reference values. Throughout the season, field staff were responsible for data verification checks after data were downloaded during site visits. The field staff reviewed the data and completed the data transmission record. During the data validation process, individual records were flagged if they didn’t meet the criteria developed in the continuous QA protocol. Datasets were evaluated in relation to the validation criteria, including: accuracy through calibration, accuracy in relation to comparison with manual measurements, dataset representativeness relative to logging interval, and finally on completeness of the dataset (Table 2 and Table 3). For more information on the quality assurance procedures developed and applied for continuous data, the reader is referred to the current version of the draft “*Quality Assurance Methods for Continuous Rainfall, Run-off, and Turbidity Data”* (McKee et al., 2013).

Table 2. Continuous data quality assurance summary for accuracy and precision for each monitoring location. "NR" indicates that the QA procedure was not completed and "NA" indicates that the QA procedure was not applicable.

	Accuracy at Calibration			Accuracy of Comparison		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Sunnyvale	NR	NR	Excellent	Excellent	Excellent	Excellent
Pulgas	NR	NR	New instrument	Excellent	NR	Poor[1]
Richmond	NR	NR	Excellent	Poor	NR	Good
Guadalupe	NA	USGS maintained	USGS maintained	NA	USGS maintained	Excellent
San Leandro	NR	NR	Within Tolerance	Excellent	Excellent	NR
Lower Marsh	NR	USGS maintained	Excellent	Excellent	USGS maintained	NR

Table 3. Continuous data quality assurance summary for representativeness and completeness for each monitoring location.

	Representativeness of the population			Completeness (Confidence in corrections)		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Sunnyvale	Excellent	Good[2]	Excellent	Excellent	Excellent	Poor[6]
Pulgas	Excellent	Excellent	Good[3]	Excellent	Poor[7]	Excellent/Poor[8]
Richmond	Excellent	Excellent	Poor[4]	Poor	Excellent	Excellent
Guadalupe	NA	USGS maintained	Excellent	NA	USGS maintained	Excellent
San Leandro	Excellent	Excellent	Excellent	Good[5]	Excellent	Poor[9]
Lower Marsh	Excellent	USGS maintained	Excellent	Excellent	USGS maintained	Excellent

[1] Manual turbidity measurements against sensor measurements had a coefficient of determination of 0.25.
[2] 4.7% of records at Sunnyvale showed a >15% change between consecutive readings, and manual stage measurements were only made in the 4th quartile.
[3] 1.9% of the population (483 records) had greater than 20 NTU absolute value change and ≥15% relative change from the preceding record; 1.3% (328 records) had greater than 20 NTU absolute value change and >50% relative change from the preceding record. Recommended action for improvement is to shorten the recording interval from 5 minutes to 1 minute.
[4] 4.2% of the population (251 records) had greater than 20 NTU absolute value change and ≥15% relative change from the preceding record; 2.9% (171 records) had greater than 20 NTU absolute value change and >50% relative change from the preceding record. Data intervals already set to minimum of 1 minute interval. Recommended action for improvement is to collect as many manual turbidity measurements as possible in order to better understand whether variability in the record is real or anomalous.
[5] Rainfall data at San Leandro Creek missing from 10/1/2012-11/6/2012, 12/6/2012-12/12/2012, and 1/4/2013-1/9/2013. Missing 10.6% of records.
[6] 31% of the period of record was missing turbidity due to the minimum stage criterion for turbidity measurement to be 0.4 ft and this amount of the record being during stages below 0.4 ft. An additional 8.3% of the turbidity record was rejected due to fouling.
[7] A large portion of the data record was on intervals greater than 15minutes.
[8] Completeness of the turbidity record was excellent during the period in which turbidity was measured, but a large portion of the wet season was missing data.
[9] 23% of records for stages > 1 ft have no corresponding turbidity record.

3.2. Continuous data quality assurance summary

Overall the continuous rainfall data were acceptable. Rain data were collected at all the sites except for Guadalupe (Note, SCVWD collects high quality rainfall data throughout the Guadalupe River watershed), and the data were collected on the same time interval as stage and turbidity. Rain gauges were cleaned before and periodically during the season, but not calibrated. All sites except for the North Richmond Pump Station compared well to nearby rain gauges. Discrepancies between the rain gauge at North Richmond Pump Station and nearby gauges during December and January resulted in the accuracy of this data set to be labeled as “poor”. All sites had rainfall totals during 5-, 10- and 60-minute intervals that aligned with 1-, 2- and 5-year rainfall returns in their respective regions.

Overall the continuous stage data were acceptable. Manual stage measurements made at Sunnyvale and San Leandro compared well with the corresponding record from the pressure transducer (R^2=0.99 at both sites). The entire stage dataset at Lower Marsh was compared to the USGS gauge on Marsh creek, and showed a regression with R^2=0.98. Percent differences between consecutive records were reasonable at all sites and the datasets were complete for the period where the equipment was installed. Manual stage measurements were not collected at either of the pump station sampling locations and could not be used to verify the accuracy or precision of those stage records, an improvement to be implemented in WY 2014.

Continuous turbidity data were rated excellent at Lower Marsh Creek and Guadalupe River. San Leandro Creek, Sunnyvale East Channel and Pulgas Creek Pump Station (qualified) all received poor quality ratings on completeness: the San Leandro Creek dataset was relatively free from spikes requiring censorship or correction but had a large portion of missing records; Sunnyvale East Channel had a full record but a large portion of data censored due to spikes; and Pulgas Creek Pump Station recorded turbidity during only three of the seven wet season months in large part due to instrumentation failures. The pump station sites both received poor ratings for representativeness given how records could fluctuate multiple times from one reading to the next. Both of these sites experience very rapidly changing conditions and may warrant unique rating criterion in the QA protocol; a topic for continued discussion and potential revision for future reporting. Pulgas Creek Pump Station also had poor repeatability between manual and sensor collected data and improvements to the monitoring set-up should be considered for next wet season.

4. Laboratory analysis and quality assurance

4.1. Sample preservation and laboratory analysis methods

All samples were labeled, placed on ice, transferred back to the respective site operator’s headquarters, and refrigerated at 4 °C until transport to the laboratory for analysis. Laboratory methods were chosen to ensure the highest practical ratio between method detection limits, accuracy and precision, and costs (BASMAA, 2011; 2012) (Table 4). In water year 2013, laboratory changes were made for the following chemical analyses:

- Total Mercury and total methylmercury from Moss Landing Marine Laboratory to Caltest
- Nutrients and SSC from East Bay MUD to Caltest

- Pyrethroids from AXYS Analytical Laboratory to Caltest
- Selenium, copper, and hardness from Brooks Rand Laboratory to Caltest

An inter-comparison study was designed to assess any impacts of laboratory change during the study. A subset of samples were collected in replicate in the field and sent to the previous laboratory and replacement laboratory. Acceptance limits for precision and recovery in QC samples (e.g., for matrix spikes or reference materials) in published methods provide practical guides for the expected

Table 4. Laboratory analysis methods

Analyte	Method	Field Filtration	Field Acidification	Laboratory
Carbaryl	EPA 632M	no	no	DFG WPCL
Fipronil	EPA 619M	no	no	DFG WPCL
Suspended Sediment Concentration	ASTM D3977-97B	no	no	Caltest Analytical Laboratory
Total Phosphorus	SM20 4500-P E	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Nitrate	EPA 353.2 / SM20 4500-NO3 F	yes	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Dissolved OrthoPhosphate	SM20 4500-P E	yes	no	Caltest Analytical Laboratory
PAHs	AXYS MLA-021 Rev 10	no	no	AXYS Analytical Services Ltd.
PBDEs	AXYS MLA-033 Rev 06	no	no	AXYS Analytical Services Ltd.
PCBs	AXYS MLA-010 Rev 11	no	no	AXYS Analytical Services Ltd.
Pyrethroids	EPA 8270Mod (NCI-SIM)	no	no	Caltest Analytical Laboratory
Total Methylmercury	EPA 1630M Rev 8	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Total Mercury	EPA 1631EM Rev 11	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Copper[1]	EPA 1638M	no	no	Caltest Analytical Laboratory
Selenium[1]	EPA 1638M	no	no	Caltest Analytical Laboratory
Total Hardness[1]	SM 2340	no	no	Caltest Analytical Laboratory
Total Organic Carbon	SM20 5310B	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Toxicity[3]	See 2 below	no	no	Pacific Eco-Risk Labs

[1] Dissolved selenium and dissolved copper were field filtered at the Lower Marsh Creek and San Leandro Creek stations in water year 2013. Dissolved selenium and dissolved copper field filtered for Lower Marsh Creek only in water year 2012. Field filtered samples are also field preserved.
[2] Hardness is a calculated property of water based on magnesium and calcium concentrations. The formula is: Hardness (mg/L) = (2.497 [Ca, mg/L] + 4.118 [Mg, mg/L])
[3] Toxicity testing includes: chronic algal growth test with *Selenastrum capricornutum (*EPA 821/R-02-013)chronic survival & reproduction test with *Ceriodaphnia dubia* (EPA 821/R-02-013), chronic survival and growth test with fathead minnows (EPA 821/R-02-013), and10-day survival test with *Hyalella Azteca (*EPA 600/R-99-064M)

agreement between samples analyzed by different labs; differences between labs will reflect the aggregate of uncertainty for each measurement (the propagated error would be the square root of the sum of the squared errors), and thus may often be larger than the accepted limits of intra- (single) lab variation. Differences among locations or over time, that were smaller than these propagated errors, could not be distinguished from measurement variability, so results (e.g., calculated loads) should be interpreted with awareness of these uncertainties.

Mercury and methylmercury samples were analyzed during the inter-comparison study. Comparability for total mercury samples was good, averaging 26% RPD (similar to the expected 25% RPD for within lab replicates) and ranging from 2 to 42% RPD for individual pairs, with the previous laboratory reporting higher concentrations for all inter-compared sample pairs. Methylmercury comparability was even better, averaging 11% RPD (10.7 and 11.1% RPD on individual sample pairs), again with the previous laboratory reporting slightly higher concentrations.

Comparability of nutrient and conventional water quality parameters was usually good except for SSC. RPDs between nitrate results from the labs ranged 2 to 6% (average 4%), and orthophosphate results were identical within rounding error (reported to the nearest 0.01 mg/L). Total phosphorous was slightly more variable but averaged only 6% RPD (4 to 7% range). Only SSC showed a wide degree of variation, with RPDs ranging 0 to 60% (average 25%), illustrating some of the challenges of consistently representatively sampling particulate matter in stormwater flows.

For pyrethroids, the results were fairly similar for the most abundant compound, bifenthrin (17% RPD), with somewhat poorer agreement for the next most abundant compound, permethrin with 40% RPD. For two independent measurements each with up to 35% error, the propagated error would be the square root of the sum of the squared errors (i.e., SQRT[$0.35^2 + 0.35^2$]), approximately 49%, so 40% RPD was within this range of expected error. Comparability could not be assessed quantitatively (i.e., no RPDs were calculated) for the remaining pyrethroids. MDLs from the previous laboratory were mostly in the range 0.25-5 ng/L, with most samples reported as non-detect or as estimated results near MDL/below RL. Therefore RPDs (even if calculated) could not be quantitative.

Hardness, copper, and selenium were also analyzed. Although hardness reported by the current laboratory was censored due to poor matrix spike recovery (error 4 times over the 5% target; the error tolerance on hardness measurements are tighter due to the usual ease of good precision and accuracy on those measurements), raw results were compared to see if the bias reported in QC samples was also reflected in comparability between laboratories. The RPD for hardness was 16%, with the current laboratory reporting lower concentrations; a similar low bias is seen in their matrix spike samples, which reported 21% lower than their expected values. The concurrence between these IC results and the current laboratory’s MS results suggests a consistent low bias for hardness, so any use of the currently censored data should be made with full awareness and acknowledgement of this likely bias. Comparability on copper was much better, averaging 7% RPD (5 and 12% respectively for the total and dissolved samples compared), and similarly the comparability on selenium was quite good, averaging 6% (0.5 and 11% for the total and dissolved fractions of compared samples).

Where differences being sought are similar in magnitude to the uncertainty in precision around individual measurements, a large number of measurements may be needed to verify the significance of possible differences (or lack thereof) seen. When the uncertainty arises from bias, comparison to other laboratories' results (either through inter-comparison exercises or certified reference materials[1]) can provide an indication of the possible bias. The inter-comparability data provide greater confidence in individual measurements where there is better agreement; the results are less likely to reflect an artifact of any particular laboratory's sample handling and quantitation methods. Thus for this study, there is generally better confidence in the measurement of inorganic pollutants and water quality parameters (other than SSC). Overall, the results from the IC study (from a relatively small sub-set of samples) did not provide evidence to indicate non-comparability between the new laboratories for most analytes. Due to sample concentrations near MDL for pyrethriods, evidence is weaker and there was some concern with the SSC comparability; SSC inter-comparisons are likely most influenced among all the analytes by grain size and field sub-sampling techniques in addition to laboratory sample treatment. At this time, the results from the IC study have not been factored into loads computations; this will occur during the completion of the final report estimated to occur in late 2014.

4.2. Quality assurance methods for pollutants of concern concentration data

4.3.1. Sensitivity

The sensitivity review evaluated the percentage of field samples that were non-detects as a way to evaluate if the analytical methods employed were sensitive enough to detect expected environmental concentrations of the targeted parameters. In general, if more than 50% of the samples were ND then the method may not be sensitive enough to detect ambient concentrations. However, review of historical data from the same project/matrix/region (or a similar one) helped to put this evaluation into perspective; in most cases the lab was already using a method that is as sensitive as is possible.

4.3.2. Blank Contamination

Blank contamination review was performed to quantify the amount of targeted analyte in a sample from external contamination in the lab or field. This metric was performed on a lab-batch basis. Lab blanks within a batch were averaged. When the average blank concentration was greater than the method detection limit (MDL), the field samples, within this batch, were qualified as blank contaminated. If the field sample result was less than 3 times the average blank concentration (including those reported as ND) those results were "censored" and not reported or used for any data analyses.

4.3.3. Precision

Rather than evaluation by lab batch, precision review was performed on a project or dataset level (e.g., a year or season's data) so that the review took into account variation across batches. Only results that were greater than 3 times the MDL were evaluated, as results near MDL were expected to be highly

[1] Although certified reference materials provide one indicator of possible bias, they in themselves provide no absolute guarantee of a particular measurement's accuracy; the certified values are consensus values that often have very wide confidence bands. This may depend on the particular labs participating in the certification and the methods used by those labs. Furthermore, concentrations of analytes and interfering matrices may differ from those in samples from a particular study.

variable. The overarching goal was to review precision using sample results that were most similar in characteristics and concentrations to field sample results. Therefore the priority of sample types used in this review was as follows: lab-replicates from field samples, or field replicates (but only if the field replicates are fairly homogeneous - unlikely for wet-season runoff event samples unless collected simultaneously from a location). Replicates from CRMs, matrix spikes, or spiked blank samples were reviewed next with preference to select the samples that most resembled the targeted ambient samples in matrix characteristics and concentrations. Results outside of the project management quality objective (MQO) but less than 2 times the MQO (e.g., ≤50% if the MQO RPD is ≤25%) were qualified; those outside of 2 times the MQO were censored.

4.3.4. Accuracy

Accuracy review was also performed on a project or dataset level (rather than a batch basis) so that the review takes into account variation across batches. Only results that were greater than 3 times the MDL were evaluated. Again, the preference was for samples most similar in characteristics and concentrations to field samples. Thus the priority of sample types used in this review was as follows: Certified Reference Materials (CRMs), then Matrix Spikes (MS), then Blank Spikes. If CRMs and MS were both reported in the same concentration range, CRMs were preferred because of external validation/certification of expected concentrations, as well as better integration into the sample matrix (MS samples were often spiked just before extraction). If both MS and blank spike samples were reported for an analyte, the MS was preferred due to its more similar and complex matrix. Blank spikes were used only when preferred recovery sample types were not available (e.g., no CRMs, and insufficient or unsplittable material for creating an MS). Results outside the MQO were flagged, and those outside 2 times the MQO (e.g., >50% deviation from the target concentration, when the MQO is ≤25% deviation) were censored for poor recovery.

4.3.5. Comparison of dissolved and total phases

This review was only conducted on water samples that reported dissolved and particulate fractions. In most cases the dissolved fraction was less than the particulate or total fraction. Some allowance is granted for variation in individual measurements, e.g. with an MQO of RPD<25%, a dissolved sample result might easily be higher than a total result by that amount.

4.3.6. Average and range of field sample versus previous years

Comparing the average range of the field sample results to comparable data from previous years (either from the same program or other projects) provided confidence that the reported data do not contain egregious errors in calculation or reporting (errors in correction factors and/or reporting units). Comparing the average, standard deviation, minimum and maximum concentrations from the past several years of data aided in exploring data, for example if a higher average was driven largely by a single higher maximum concentration.

4.3.7. Fingerprinting summary

The fingerprinting review evaluated the ratios or relative concentrations of analytes within an analysis. For this review, we looked at the reported compounds to find out if there are unusual ratios for individual samples compared to expected patterns from historic datasets or within the given dataset.

Since analyses of organic contaminants at trace levels are often susceptible to biases that may not be detected by conventional QA measures, additional QA review is necessary to ensure the integrity of the reported data. Based on knowledge of the chemical characteristics and typical relative concentrations of organic contaminants in environmental samples, concentrations of the target contaminants are compared to results for related compounds to identify potentially erroneous data. Compounds that are more abundant in the original technical mixtures and are more stable and recalcitrant in the environment are expected to exist in higher concentrations than the less abundant or less stable isomers. For example, PCB congener concentrations follow general patterns of distribution based on the original concentrations in Aroclor mixtures. If an individual congener occurs at concentrations much higher than usual relative to more abundant congeners, the result warrants further investigation.

Furthermore, several contaminants chemically transform into other toxic compounds and are usually measured within predicted ranges of concentrations compared to their metabolites (e.g. heptachlor epoxide/heptachlor), so deviations from such expectations are also further investigated. However, great care should be exercised in using information on congener ratios of common Aroclor mixtures and other such heuristic methods, for some of the same reasons that interpreting environmental PCBs only as mixtures of Aroclors has limitations. Over-reliance on such patterns in data interpretation may lead to inadvertent censoring of data, e.g., for contributions from unknown or unaccounted sources.

When results are reported outside the range of expected relative concentrations, and the laboratory cannot identify the source of variability, values are qualified to indicate uncertainty in the results. If the reported values do not deviate much from the expected range, they are generally allowed to stand and are included in calculations of “sums” for their respective compound classes. However, if the reported concentrations deviate greatly from the expected range and are clearly higher than observed in past analyses or current sample splits, it can be reasonably concluded that the results are erroneous.

5. Results

The following sections present synthetic results from the six monitored tributaries. In this section, a summary of data quality is initially presented. This is then followed by sub-sections that synthesize climate and flow across the six locations, concentrations of POCs across the six locations, loads across six locations, and a graphical summary of particle concentrations across the six locations.

5.1. Project Quality Assurance Summary

The section below reports on WY 2013 data; for the WY 2012 quality assurance summary, refer to section 4.1 in McKee et al., 2013. Attachment 1 provides a detailed QAQC summary for WY 2013 data.

The PCB data were acceptable. MDLs were sufficient for the majority of PCBs with 22% (16 out of 71 congeners) having some non-detects (ND), but none were extensive. A number of PCB congeners were found in laboratory blanks. About 27% (19 out of 71) of the congeners had some contamination in at least one method blank. PCB congeners 18, 28, 31, 44, 49, 52, 66, 70, 87, 95, 118, and 153 had 3% of grab sample results flagged with the censoring contamination qualifier of “VRIP” (results with reported concentrations <3x the blank results (by batch) being censored for contamination). Precision and accuracy metrics were within MQOs.

Overall the total mercury and total methylmercury results were acceptable. MDLs were sufficient with only one ND for methylmercury. Total mercury and methylmercury were not detected in lab blanks, although total mercury was found in one field blank at .004 µg/L, about 20 times above the MDL, but still ~5 times lower than the average concentration for field samples in this data set. Precision and accuracy metrics were within MQOs. Methylmercury concentrations were generally in the range of 1% of total mercury concentrations which is fairly typical. No additional qualifiers were needed on the data set.

The nutrient data were generally acceptable. MDLs were sufficient to get quantitative results for most analytes at all stations. Nitrate had 7% non-detects and suspended sediment concentration had 3% non-detects. No blank contamination was found in either the method blanks or equipment blanks (3 batches). Field blanks were analyzed for 21 batches with blank contamination found for nitrate and phosphorus as in one batch each. Precision and accuracy metrics were within MQOs.

The carbaryl and fipronil data were acceptable. MDLs were sufficient with carbaryl having ≥50% NDs. Blank contamination was not found in either the method blanks or the field blanks. Precision and accuracy metrics were within MQOs.

The PAH dataset was acceptable with some minor QA issues. MDLs were sufficient for most of the PAHs, with <50% non-detects for 76% of the target PAHs; Acenaphthene, Acenaphthylene, Benz(a)anthracene, Dibenz(a,h)anthracene , Dibenzothiophene, and Fluorene had >50% NDs. Thirteen PAHs were found in at least one of the three lab blanks; subsequently Benz(a)anthracene, Benz(a)anthracenes/Chrysenes, C4- , Biphenyl, Dibenzothiophene, Fluorene, Methylnaphthalene, 1-, Naphthalene, and Trimethylnaphthalene, 2,3,5- had results flagged with the censoring qualifier VRIP for being <3x the average blank concentration. Precision was good with <35% RSD on lab or blank spike replicates for all analytes. Accuracy was evaluated using recoveries for the 43 PAHs in the laboratory control samples and were generally good, with only Tetramethylnaphthalene, 1,4,6,7- (40%) having a recovery averaging >35%.

Overall the PBDE data were acceptable. MDLs were sufficient with 29 of the 49 reported PBDE congeners having some level of non-detect, and 27% having ≥50% NDs. PBDE congeners 17, 28, 47, 49, 85, 99, 100, 138, 153, 154, 183 and 209 had some contamination in at least one method blank, but only PBDE 183 had 6% of its samples censored. Replicates on field samples were used to evaluate precision and were generally good, less than the target 35% average RSD, except for PBDE 8 and 12, which were flagged with the non-censoring qualifier. Accuracy metrics were within MQOs.

Overall the pyrethroids data were acceptable. MDLs were sufficient with 12 of the 13 pyrethroids reported having some level of non-detect (ranging from 5 to 95% non-detects) and 50% of the pyrethroids reported having ≥50% NDs (Allethrin, Deltamethrin/Tralomethrin, Diazinon, Fenpropathrin, Tetramethrin and T-Fluvalinate). Blank contamination was not found in any of the method blanks. Field blanks were examined, but not used in the evaluation, with blank contamination found in one of the field blanks for Chlorpyrifos and Diazon at a concentration equal to the MDL. Matrix spikes were used to assess accuracy with recovery errors less than the target 35% for all reported analytes, except Allethrin, Deltamethrin/Tralomethrin, and Tetramethrin, which were flagged with a non-censoring qualifier. Replicates on matrix spikes were used to evaluate precision and were generally good, less than the target 35% average RSD, except Allethrin and Cyhalothrin, lambda total, which were flagged with a non-censoring qualifier.

Overall the other trace elements dataset was acceptable. MDLs were sufficient with only dissolved selenium having non-detects (1 out of 21 samples; 5% ND). No blank contamination was observed except in two of the equipment blanks for total copper; one at a concentration equal to the MDL (0.08 µg/L), the other at less than two times the method blank (0.125 µg/L). Precision and accuracy metrics were within MQOs except for the metric accuracy for Hardness (recovery error 21%), which was flagged with a censoring qualifier. The ratio of dissolved to total concentrations can help characterize the sources and environmental processes of contaminants, and ratios >100% (i.e., dissolved concentrations greater than totals) may indicate some analytical problems with one or both fractions. Dissolved copper results ranged from 4% to 69% of the total results, with the majority being less than 50%. Dissolved selenium results ranged from 57% to 102% of the total results; dissolved and total selenium results for San Leandro Creek on 11/21/2012 were both 0.19 µg/L. Lower Marsh Creek selenium dissolved and total results from 4/5/2013 were 0.51 and 0.5 µg/L, respectively.

5.2. Climate and flow at the sampling locations during water years 2012 and 2013

The climatic conditions under which observations are made of pollutant concentrations in flowing river systems have a large bearing on concentrations and loads observed. It has been argued that a 30 year period is needed in California to capture the majority of climate related variability of a single site (McKee et al., 2003). Given monitoring programs for concentrations or loads do not normally continue for such a long period, the objective of sampling is usually to try to capture sufficient components of the full spectrum of variability to make inferences from a smaller dataset. In general, high magnitude (high intensity or long duration) events occur infrequently and thus are usually poorly represented in datasets yet for most pollutants, these types of events usually transport the majority of a decadal scale load. This occurs because the discharge-load relation is described by a power function and therefore storms and wet years with larger discharge have a profound influence on the estimate of mean annual load for a given site and will likely confound any comparisons of loads between sites unless adequately characterized. However, if it is assumed that this is consistently true for all sites, comparisons across sites will be more valid.

Conceptually, watersheds that are more impervious, or smaller in area, or have lower pollutant production variability (or sources) should exhibit lower inter-annual variability (lower slope of the power function) and therefore require less sampling to adequately quantify pollutant source-release-transport processes (the exemplary example in this group is Marsh Creek in relation to PCBs). In contrast, a longer sampling period spanning a wider climatic variability will be required to adequately describe pollutant source-release-transport processes in watersheds that are larger, or less impervious, or have large and known pollutant sources. The quintessential example of this category within this study is Guadalupe River in relation to Hg sources, release mechanisms, and loads but San Leandro Creek (both Hg and PCBs) and Sunnyvale East channel and Pulgas Creek (PCBs) may also fall into this category.

Unfortunately, during the study to date, winter seasons have been very dry relative to average annual conditions with all observations to-date made during years of <89% mean annual precipitation or flow (Table 5). For example, Lower Marsh Creek experienced just 22% of mean annual runoff in WY 2012 and 73% of mean annual run-off in WY 2013. However, there have been some notable storms, particularly those occurring during late November and December of WY 2013. For example, approximately 65% of the total wet season rainfall fell on Sunnyvale East Channel in the span of less than one month. Loads of pollutants were disproportionately transported during such events; at Sunnyvale East Channel, 88%, 92% and 83% of the total wet season sediment, PCBs and mercury loads were transported during those larger November and December storms. However, despite these larger individual storm events, at this time, any effort to estimate long-term averages for each site will likely result in estimates that are biased low due to observations during relatively dry and therefore benign flow production, sediment erosion and transport conditions.

Table 5. Climate and flow during sampling years to-date at each sampling location.

		Marsh Creek[2]	North Richmond Pump Station[3]	San Leandro Creek[4]	Guadalupe River[5]	Sunnyvale East Channel[6]	Pulgas Creek Pump Station[7]
Rainfall (mm) (% mean annual)	WY 2012	321 (70%)	No data	486 (75%)	179 (47%)	224 (58%)	No data
	WY 2013	278 (61%)	508 (89%)	342* (52%)	223 (59%)	259* (67%)	378* (78%)
	Mean Annual	457	570	652	378	387	488
Runoff (Mm^3) (% mean annual)	WY 2012	1.87 (22%)	No data	5.47	38.0 (68%)	1.07	No data
	WY 2013	6.23 (73%)	0.76	8.81	45.45 (82%)	1.79	0.21
	Mean Annual	8.51	No data	No data	55.6	No data	No data

[1] Unless otherwise stated, averages are for the period Climate Year (CY) (Jul-Jun) (rainfall) or Water Year (WY) (Oct-Sep) (runoff) 1971-2010.
[2] Rainfall gauge: Concord Wastewater treatment plant (NOAA gauge number 041967) (CY 1991-2013); Runoff gauge: Marsh Creek at Brentwood (gauge number 11337600) (WY 2001-2013).
[3] Rainfall gauge: This study with mean annual from modeled PRISM data; Runoff gauge: This study.
[4] Rainfall gauge: Upper San Leandro Filter (gauge number 049185); Runoff gauge: This study.
[5] Rainfall gauge: San Jose (NOAA gauge number 047821); Runoff gauge: Guadalupe River at San Jose (gauge number 11169000) and at Hwy 101 (gauge number 11169025).
[6] Rainfall gauge: Palo Alto (NOAA gauge number 046646); Runoff gauge: This study
[7] Rainfall gauge: Redwood City NCDC (gauge number 047339-4); Runoff gauge: This study.
* indicates data missing for the latter few months of the season

5.3. Concentrations of pollutants of concern during sampling to-date

Understanding the concentrations of pollutants in the watersheds is important to both directly answering one of the Small Tributary Loading Strategy management questions (MQ2) as well as forming the basis from which to answer all of the other key management questions identified by the Strategy. Sampling to-date has provided data that, in some cases, indicate surprisingly high concentrations (e.g. Hg in San Leandro Creek; PCBs in Sunnyvale East Channel; PBDEs in North Richmond Pump Station); other cases indicate surprisingly low concentrations (Hg in Marsh Creek). In some cases non-detects and quality assurance issues continue to confound robust interpretations. This section explores those issues through synthesis of data collected across all six sampling locations to date to provide support for rationale for continued sampling in relation to answering management questions.

Concentrations of pollutants typically vary over the course of a storm, between storms of varying magnitudes, and are dependent on related discharge, sediment and source-related transport processes. Thus, it is important to sample at a wide range flow conditions both within a storm and over a wide range of storm magnitudes to adequately characterize concentrations of pollutants in a watershed. The monitoring design for this project aims to collect pollutant concentration data from 12 storms over the span of three years, with priority pollutants sampled at an average of four samples per storm for a total of 48 samples collected during the monitoring term. Sampling at the six locations to date has included sampling between one and six storm events at each location. Given the small sample size and varying sample sizes between sites, the following synthesis should be considered qualitative at this time; data collection during WY 2014 will likely provide further insights into pollutant characteristics at single sites and between sites.

Overall, detections of concentrations in the priority pollutants (suspended sediment, total PCBs, total mercury, total methylmercury, total organic carbon, total phosphorous, nitrate, and phosphate) were all 94% or better, as were detections of several of the “tier II” pollutants (total and dissolved copper and selenium, PAHs and PBDEs) (Table 6). Numerous pyrethroids were not detected at any of the sites, whereas Delta/Tralomethrin, Cypermethrin, Cyhalothrin lambda, Permethrin, Bifenthrin as well as Carbaryl and Fipronil were all detected in one or more samples at each sampling location (except Pulgas Creek Pump Station where Fipronil was not detected in the one sample to-date).

The two sampling locations added this year (North Richmond and Pulgas Creek pump stations), have the lowest mean SSC; whereas pollutant concentrations are relatively high for these watersheds (e.g. PCBs at Pulgas Creek Pump Station). As a result, the particle ratio (turbidity or SSC to pollutant; discussed further in section 5.5) was higher relative to other watersheds with similar pollutant concentrations but greater SSC. Given the high imperviousness and small size of these watersheds, although few storms have been sampled at these locations, it is unlikely great variation in SSC will be observed in future sampling efforts.

The maximum PCB concentration of the dataset to date (176 ng/L) was collected in Sunnyvale East Channel, which also has the greatest mean PCB concentration of the six locations; consistent with the high ranking assigned to Sunnyvale East Channel based on the WY 2011 reconnaissance study of 17 watersheds distributed across four Bay Area counties (McKee et al., 2012). However, sampling at Pulgas Creek Pump Station has so far captured only one relatively small storm event; future monitoring at this location will likely indicate higher PCB concentrations until management actions take effect. Guadalupe River has mercury mines in the upper watershed and is a known mercury source to the San Francisco Bay, explaining the high mercury and, possibly, methylmercury concentrations in this watershed. Less well understood is San Leandro Creek, which has mercury and methylmercury concentrations nearly as high as Guadalupe River. Continued sampling under more variable storm and climatic conditions in San Leandro Creek may improve our understanding of source-release-transport processes of mercury in this watershed. It is also worth noting (with regard to the tier I priority analytes) that phosphorus

Table 6. Synthesis of concentrations of pollutants of concern based on all samples collected to-date at each sampling location.

		Marsh Creek		North Richmond Pump Station		San Leandro Creek		Guadalupe River		Sunnyvale East Channel		Pulgas Creek Pump Station	
Analyte Name	**Unit**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**
SSC	mg/L	81 (99%)	243 (27.5)	41 (95%)	45.7 (8.48)	81 (94%)	145 (18.5)	82 (100%)	161 (18.3)	62 (97%)	302 (66.1)	15 (100%)	33.3 (8.54)
∑PCB	ng/L	22 (100%)	1.25 (0.258)	12 (100%)	12.0 (2.05)	28 (100%)	9.45 (1.50)	23 (100%)	14.0 (3.63)	18 (100%)	51.3 (12.9)	4 (100%)	34.7 (10.1)
Total Hg	ng/L	25 (100%)	45.8 (11.5)	12 (100%)	27.7 (7.10)	28 (100%)	145 (35.7)	24 (100%)	210 (50.1)	18 (100%)	52.8 (12.9)	6 (100%)	10.5 (2.82)
Total MeHg	ng/L	19 (95%)	0.306 (0.076)	6 (100%)	0.118 (0.029)	18 (100%)	0.438 (0.099)	17 (100%)	0.438 (0.082)	12 (92%)	0.251 (0.061)	6 (100%)	0.178 (0.041)
TOC	mg/L	24 (100%)	7.13 (0.416)	12 (100%)	7.46 (0.970)	28 (100%)	7.13 (0.453)	24 (100%)	7.55 (0.657)	18 (100%)	6.10 (0.369)	4 (100%)	10.3 (2.26)
NO3	mg/L	24 (96%)	0.579 (0.045)	12 (100%)	1.13 (0.245)	29 (100%)	0.429 (0.094)	24 (83%)	0.919 (0.150)	18 (100%)	0.287 (0.022)	4 (100%)	0.358 (0.051)
Total P	mg/L	20 (100%)	0.438 (0.054)	12 (100%)	0.276 (0.013)	25 (100%)	0.34 (0.035)	20 (100%)	0.434 (0.044)	19 (100%)	0.422 (0.078)	4 (100%)	0.15 (0.035)
PO4	mg/L	24 (100%)	0.098 (0.008)	11 (100%)	0.168 (0.013)	29 (100%)	0.09 (0.005)	24 (100%)	0.105 (0.007)	18 (100%)	0.102 (0.005)	4 (100%)	0.066 (0.010)
Hardness	mg/L	4 (100%)	189 (8.86)	-	-	7 (100%)	46.0 (6.55)	4 (100%)	136 (9.31)	2 (100%)	56.3 (4.90)	-	-
Total Cu	µg/L	6 (100%)	16.7 (4.10)	3 (100%)	15.3 (2.94)	7 (100%)	19.6 (4.36)	6 (100%)	19.8 (3.74)	4 (100%)	20.0 (4.16)	1 (100%)	30.0 (-)
Dissolved Cu	µg/L	6 (100%)	2.868 (0.792)	3 (100%)	6.367 (1.819)	7 (100%)	6.459 (0.981)	6 (100%)	4.52 (0.852)	4 (100%)	6.79 (2.70)	1 (100%)	20.0 (-)
Total Se	µg/L	6 (100%)	0.783 (0.128)	3 (100%)	0.397 (0.098)	7 (100%)	0.213 (0.027)	6 (100%)	1.46 (0.392)	4 (100%)	0.450 (0.041)	1 (100%)	0.180 (-)
Dissolved Se	µg/L	6 (100%)	0.694 (0.111)	3 (100%)	0.363 (0.098)	7 (100%)	0.149 (0.018)	6 (100%)	1.21 (0.42)	4 (100%)	0.343 (0.018)	1 (100%)	0.17 (-)
Carbaryl	ng/L	6 (33%)	4.83 (3.08)	3 (100%)	23.7 (8.41)	7 (29%)	3.43 (2.26)	6 (83%)	27.1 (9.50)	4 (75%)	12.8 (4.77)	1 (100%)	204 (-)
Fipronil	ng/L	6 (100%)	11.6 (1.52)	3 (33%)	1.33 (1.33)	7 (86%)	6.14 (1.42)	6 (100%)	10.1 (2.34)	4 (75%)	6.00 (2.45)	1 (0)	-
∑PAH	ng/L	3 (100%)	267 (120)	3 (100%)	952 (397)	3 (100%)	3327 (1142)	4 (100%)	614 (194)	2 (100%)	1322 (32.8)	4 (100%)	614 (194)

		Marsh Creek		North Richmond Pump Station		San Leandro Creek		Guadalupe River		Sunnyvale East Channel		Pulgas Creek Pump Station	
Analyte Name	**Unit**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**	**Number (% detect)**	**Mean (std. error)**
∑PBDE	ng/L	3 (100%)	29.2 (13.9)	3 (100%)	2340 (2340)	4 (100%)	44.6 (18.0)	3 (100%)	39.1 (16.5)	2 (100%)	19.8 (15.0)	4 (100%)	45.8 (24.9)
Delta/ Tralo-methrin	ng/L	6 (83%)	1.70 (0.820)	3 (100%)	2.52 (0769)	6 (67%)	0.652 (0.308)	6 (50%)	0.737 (0.372)	3 (67%)	2.47 (1.23)	1 (0%)	-
Cypermethrin	ng/L	6 (83%)	14.6 (10.9)	3 (100%)	3.18 (0.651)	7 (29%)	0.214 (0.159)	6 (50%)	0.917 (0.547)	4 (50%)	2.10 (1.28)	1 (100%)	0.900 (-)
Cyhalothrin lambda	ng/L	6 (83%)	1.37 (0.551)	3 (100%)	0.767 (0.273)	6 (33%)	0.693 (0.635)	6 (67%)	0.483 (0.227)	3 (67%)	1.23 (0.722)	1 (0%)	-
Permethrin	ng/L	6 (83%)	7.70 (2.75)	3 (100%)	12.0 (2.88)	7 (71%)	4.86 (1.73)	6 (67%)	10.4 (3.95)	4 (100%)	24.1 (8.78)	1 (100%)	2.90 (-)
Bifenthrin	ng/L	6 (100%)	91.5 (38.1)	3 (100%)	5.98 (1.23)	7 (86%)	10.3 (4.07)	6 (83%)	5.64 (1.97)	4 (75%)	8.68 (3.68)	1 (100%)	1.30 (-)

Analyzed but not detected: Fenpropathrin, Esfenvalerate/ Fenvalerate, Cyfluthrin, Allethrin, Prallethrin, Phenothrin, and Resmethrin
All Hardness results in WY 2013 were censored.

concentrations in most of the six watersheds appear greater than elsewhere in the world under similar land use scenarios, perhaps attributable to geological sources (McKee and Krottje, 2005).

Selenium and PBDE concentrations, two analytes being collected at a lesser frequency in this study (intended only for characterization) are particularly notable. In the Guadalupe River, mean selenium concentrations were 2-8 fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Maximum PBDE concentrations in North Richmond Pump Station were 37- to 96-fold greater than the PBDE maxima observed in the five other locations of this current study. These are the highest PBDE concentrations measured in Bay area stormwater to-date (see section 8.2 for details).

Concentration sampling to date at the six locations have in part confirmed previously known or suspected pollutant sources (e.g. mercury in Guadalupe, PCBs in Sunnyvale East Channel). Concentration results to date have also raised some questions about certain pollutants in certain watersheds (e.g. upper versus lower watershed Hg concentrations in San Leandro Creek, PBDE concentrations in North Richmond Pump Station). More sampling under a broader range of storm events is necessary to more confidently characterize pollutants in those watersheds. With a more targeted sampling approach in future water years based on storm variability and data that are still lacking to answer management questions adequately (see section 6), it is expected that this monitoring study will produce a robust characterization of pollutants in these watersheds.

5.4. Loads of pollutants of concern computed for each sampling location

One of the primary goals of this project and key management questions of the Small Tributary Loading Strategy was to estimate the annual loads of POCs from tributaries to the Bay (MQ2). In particular, large loads of POCs entering sensitive Bay margins are likely to have a disproportionate impact on beneficial uses (Greenfield and Allen, 2013). As described in the climatic section (5.2), given the relationship between climate (manifested as either rainfall and resulting discharge) and watershed loads follows a power function, estimates of long-term average loads for a given watershed are highly influenced by samples collected during wetter than average conditions and rare high magnitude storm events. Comparing loads estimates between the sites is currently confounded by small sample datasets during climatically dry years. At this time, comparison should therefore be considered qualitative; with subsequent years of sampling an attempt at computing long-term average loads for each sampling location will likely be made. Accepting these caveats, the following observations are made on the total wet season loads estimates at the six locations.

Comparison of total loads between watersheds is largely driven by drainage area of each watershed. In terms of total wet season loads from each of the six watersheds, the largest watershed sampled is the Guadalupe River, which also has the largest load for every pollutant estimated in this study. Conversely, Pulgas Creek Pump Station is the smallest watershed in the study and has the lowest total wet season load (except for TOC in which the load is similar to North Richmond Pump Station) (Table 7). As another example, methylmercury in San Leandro Creek (8.9 km2) and Guadalupe River (236 km2) have similar concentrations but Guadalupe River discharges 10x the total mass of methylmercury given the much greater overall discharge of runoff volume and sediments.

Table 7. Loads of pollutants of concern during the sampling years to-date at each sampling location.

Site	Water Year	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)	Mean annual loads confidence	Main issues
Marsh Creek	2012	1.39	226	9,467	1.21	44.4	0.454	833	155	480	Moderate (PCBs) Low (Hg)	Lack of data on storms that cause run-off through the upper watershed reservoir.
	2013	5.82	2,600	39,682	16.2	594	1.90	3,491	652	4,020		
North Richmond Pump Station	2012	-	-	-	-	-	-	-	-	-	Moderate	Limited data on first flush conditions and generally during more intense storms. Surprisingly elevated PDBE concentrations.
	2013	0.763	34.4	5,709	7.90	16.1	0.113	863	130	211		
San Leandro Creek	2012	3.99	114	26,560	11.7	137	0.772	1,515	367	843	Low	Lack of a robust discharge rating curve; lack of sampling during reservoir release and during more intense storms.
	2013	8.81	218	58,674	22.6	280	1.52	3,348	811	1,671		
Guadalupe River	2012	25.8	2,116	146,483	113	2,033	8.20	16,347	2,243	7,042	High (PCBs) Low (Hg)	Lack of high intensity storms samples for Hg.
	2013	35.5	4,352	237,227	334	5,603	15.2	22,482	3,440	12,099		
Sunnyvale East Channel	2012	1.07	36.7	6192	14.6	18.4	0.181	263	114	241	Low	Few storms sampled.
	2013	1.79	672.5	10352	73.1	109	0.538	440	190	865		
Pulgas Creek Pump Station	2012	-	-	-	-	-	-	-	-	-	Low	Few storms sampled.
	2013	0.206	11.2	5967	9.3	3.2	0.050	75.6	32.4	34.3		

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12 and 10/19/12 – 4/18/13.

[b] North Richmond Pump Station (WY 2013 only) and Guadalupe River (WY 2012 and 2013) wet season loads are reported for the full period of record each water year (10/01/11 – 4/30/12 for WY 2012 and 10/01/12 – 4/30/13 for WY 2013).

[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 11/01/12 – 4/18/13.

[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 10/01/12 – 4/30/13.

[e] Pulgas Creek Pump Station South WY 2013 wet season loads are estimates provided for the entire wet season (10/01/12 – 4/30/13) however monitoring only occurred during the period 12/17/2012 – 3/15/2012. Monthly loads for the non-monitored period were extrapolated using regression equations developed for the monthly rainfall and corresponding monthly (or partial month) contaminant load.

Comparison of total wet season loads between water years at the sites with two years of data highlighted how loads estimates can be highly variable even during two drier than average years. Additionally, the size and intensity of the storm events in the different regions where the sampling sites are located greatly impacted the load variation from year to year and between sampling locations. For example PCBs and mercury in San Leandro Creek and Guadalupe River were approximately 2x greater in WY 2013 than WY 2012, whereas loads of those same pollutants were 5 – 20x larger in WY 2013 in Lower Marsh Creek and Sunnyvale East Channel, where the late November and December 2012 storms were moderately large events. Even when normalized to total discharge (in other words, the flow-weighted mean concentration [FWMC]), Sunnyvale East Channel transported 11x as much sediment in WY 2013 than WY 2012, whereas the FWMC of suspended sediment in San Leandro Creek was the same in both water years. This observation suggests that any attempt at this time to estimate long-term loads for Sunnyvale East channel will be biased low. In this manner, the relationship between FWMC and discharge (either at the annual or individual flood scale) can be used as an indicator of when enough data has been collected to characterize the site adequately to answer our management questions.

In light of these climatic considerations as well as the known data quality considerations and challenges at each of the sampling locations, the two far-right columns in Table 7 note our current level of confidence in the mean annual loads estimates as well as the main issues at each site which warrant the confidence level rating. Future sampling at each of these locations should seek to alleviate these issues and to raise the quality of the data in relation to answering management questions.

5.5. Comparison of regression slopes and normalized loads estimates between watersheds

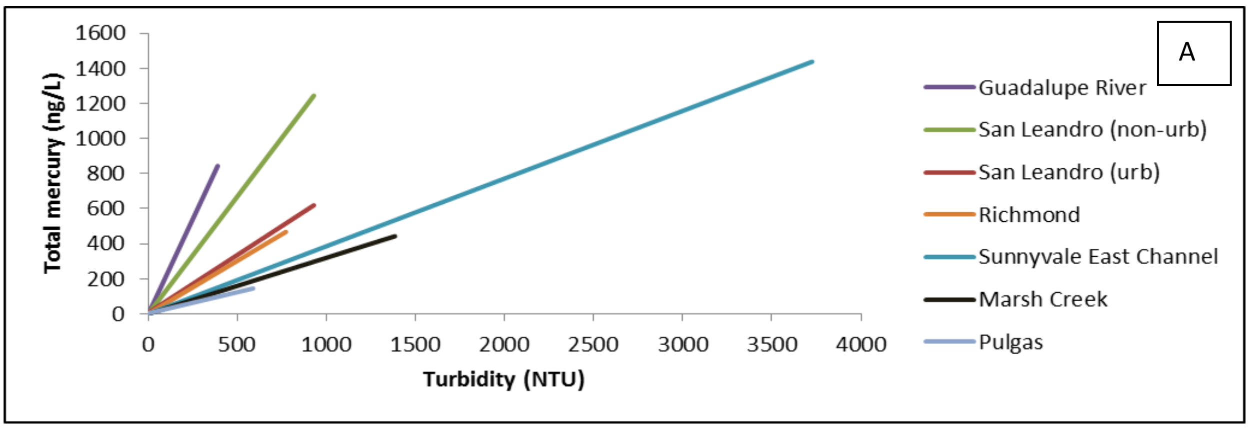
One of our key activities in relation to the small tributary loading strategy is improving our understanding of which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from pollutants of concern (MQ1) and therefore potentially represent watersheds where management actions should be implemented to have the greatest beneficial impact (MQ4). Unfortunately, the comparison of loading estimates between watersheds in relation to these key management needs is confounded by variations in climate and how well samples collected to date represent source-release-transport processes for each watershed and pollutant (see section 5.2). With these caveats accepted, a preliminary comparison based on data collected during water year 2012 and 2013 was provided in this section. It is anticipated that these comparisons will change as additional data are collected in WY 2014, and, should data be sufficient, the best comparisons will be made in next year's report update based on (where/if possible) climatically averaged data.

Multiple factors influence the treatability of pollutant loads in relation to impacts to San Francisco Bay. Conceptually a large load of pollutant transported on a relatively small mass of sediment is more treatable than less polluted sediment. Therefore, the graphical function between either sediment concentration or turbidity provides a first order mechanism for ranking relative treatability of watersheds (Figure 2A). This method is valid for pollutants that are dominantly transported in a particulate form (total mercury and the sum of PCBs are examples) and when there is relatively little variation in the particle ratios between water years or storms (note data presented at the October 2013

SPLWG meeting demonstrated that this assumption is sometimes violated and influences our perception of relative ranking).

These issues accepted, based on the ratios between turbidity and Hg, runoff derived from less urbanized portions of San Leandro Creek watershed and run-off from the Guadalupe River watershed exhibit the greatest particle ratios for total mercury (Figure 2). Sunnyvale East Channel, Marsh Creek and Pulgas Creek Pump Station appear to have relatively low particle ratios for total mercury, although, Marsh Creek has not been observed under wet conditions when the possibility of mercury release from historic mining sources exists and an insufficient number of samples have yet been collected from Pulgas Creek Pump Station to be confident that the mercury transport processes are adequately characterized. With the exception of the addition of two more sampling stations (North Richmond Pump Station and Pulgas Creek Pump Station), the relative nature of these rankings has not changed in relation to the previous report (McKee et al., 2013).

In contrast, for the sum of PCBs, Pulgas Creek Pump Station and Sunnyvale East Channel exhibit the highest particle ratios among these six watersheds, with urban sourced run-off from Guadalupe River and North Richmond Pump Station ranked 3rd and 4th as indicated by the turbidity-PCB graphical relation



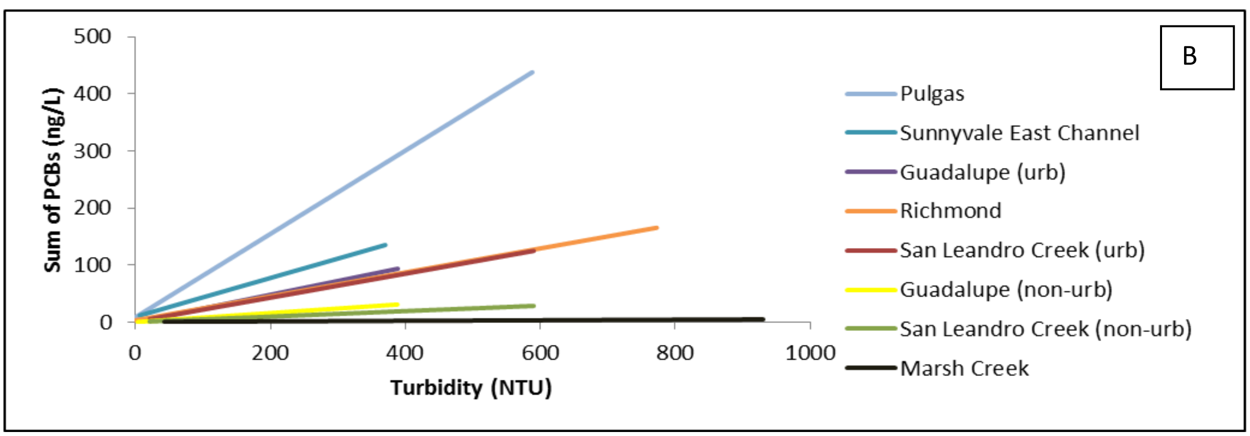


Figure 2. Comparison of regression slopes between watersheds based on data collected during sampling to-date A) total Mercury and B) PCBs (Note Sunnyvale, Richmond and Pulgas includes data for water year 2013 only; Pulgas turbidity maximum is storm maximum not record maximum). Note these comparisons will likely change once additional data are collected in subsequent water years.

(Figure 2). Marsh Creek exhibits very low particle ratios for PCBs, an observation that is unlikely to change with additional samples given the likelihood of relatively low pollutant sources and relatively low variability of release-transport processes. Unlike Hg, new data collected during WY 2013 did alter the relative PCB rankings based on this graphical analysis providing an example of the influence of either low sample numbers or the random nature of sample capture on the resulting interpretation of particle ratios (as discussed in the October 2013 SPLWG meeting). Given the relatively large confidence intervals (not shown) and the relatively low numbers of samples collected to-date during relatively dry years, the relative nature of these regression equations may change in the future as more samples are collected.

Another influence on potential treatability is the size of the watershed. Conceptually, a large load that is transported from a relatively small watershed and therefore in association with a relatively small volume of water is more manageable (efforts to manage flows from the North Richmond Pump Station watershed exemplify this type of opportunity). Thus, area normalized loads (yields) provide another useful mechanism for first order ranking of watersheds (Table 8) in relation to ease of management. This method is much more highly subject to climatic variation than the turbidity function/particle ratio method for ranking and would ideally be done on climatically averaged loads (not yet done). Despite quite large differences in unit runoff between the watersheds during water year 2012 and 2013, in a general sense, the relative rankings for PCBs exhibit a similar ranking to the particle ratio method; Pulgas Creek Pump Station watershed ranked highest and Marsh Creek watershed ranked lowest. However the relative ranking of the other watersheds is not similar. In the case of mercury, Guadalupe River, San Leandro Creek, and Richmond pump station exhibit the highest currently estimated yields corroborating the evidence from the particle ratio method. However, it is anticipated that the relative nature of the area-normalized loads will be subject to greater change in the event that sampling during WY 2014 captures rainstorms of greater magnitude and less frequent recurrence interval. In particular, the relative rankings for suspended sediment loads normalized by unit area could change substantially with the addition of data from a water year that is closer to or exceeds the climatic normal for each watershed; total phosphorus unit loads would also respond in a similar manner. For pollutants such as PCBs and total Hg that are found in specific source areas such as industrial and mining areas (Hg only) of these watersheds, release processes will likely be influenced by both climatic factors and sediment transport off impervious surfaces; also factors that are not likely well captured by the sampling to date that has occurred under relatively dry conditions.

6. Conclusions and next steps

6.1. Current and future uses of the data

The monitoring program implemented during the study was designed primarily to improve estimates of watershed-specific and regional loads to the Bay (MQ2) and secondly, to provide baseline data to support evaluation of trends towards concentration or loads reductions in the future (conceptually one or two decades hence) (MQ3) (see introduction section) in compliance with MRP provision C.8.e. (SFRWRCB, 2009). Multiple metrics have been developed and presented in this report to support these management questions:

- Pollutant loads: Pollutant loading estimates can help measure relative delivery of pollutants to sensitive Bay margin habitats and support calibration and verification of the Regional Watershed Spreadsheet Model and resulting regional scale loading estimates.
- Flow Weighted Mean Concentrations: FWMC can help to identify when sufficient data has been collected to adequately characterize watershed processes in relation to a specific pollutant in the context of management questions.
- Sediment-pollutant particle ratios: Particle ratios can help identify relative watershed pollution levels on a particle basis and relates to treatment potential.
- Pollutant area yields: Pollutant yields can help identify pollutant sources and relates to treatment potential.
- Correlation of pollutants: Finding co-related pollutants helps identify those watersheds with multiple sources and provides additional cost/benefit for management actions.

As discussed briefly in the introduction (section 1), as management effort focuses more and more on locating high leverage watersheds and patches within watersheds, the monitoring (and modeling) design will need to evolve.

Table 8. Area normalized loads (yields) ranked in relation to PCBs based on free flowing areas downstream from reservoirs (See Table 1 for areas used in the computations). Note these yield estimates are based on the average of data from water year 2012 and 2013. Quantitative comparison between watersheds is confounded by dry climatic conditions and differing unit runoff. With additional years of sampling, climatically-averaged area-normalized loads may be generated.

	Unit runoff (m)	SS (t/km^2)	TOC (mg/m^2)	PCBs (µg/m^2)	HgT (µg/m^2)	MeHgT (µg/m^2)	NO3 (mg/m^2)	PO4 (mg/m^2)	Total P (mg/m^2)
Pulgas Creek Pump Station [e]	*0.35*	*19.1*	*10218*	*15.9*	*5.53*	*0.0858*	*130*	*55.6*	*58.8*
North Richmond Pump Station [b]	0.39	17.6	2913	4.03	8.22	0.0575	440	66.2	107
Sunnyvale East Channel [d]	0.10	24.0	559	2.96	4.31	0.0243	23.7	10.3	37.4
San Leandro Creek [c]	0.72	18.7	4788	1.93	23.4	0.129	273	66.1	141
Guadalupe River [b]	0.13	13.7	813	0.947	16.2	0.0496	82.3	12.0	40.6
Marsh Creek [a]	0.04	16.9	294	0.104	3.82	0.0141	25.9	4.83	26.9

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12 and 10/19/12 – 4/18/13.
[b] North Richmond Pump Station (WY 2013 only) and Guadalupe River (WY 2012 and 2013) wet season loads are reported for the full period of record each water year (10/01/11 – 4/30/12 for WY 2012 and 10/01/12 – 4/30/13 for WY 2013).
[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 11/01/12 – 4/18/13.
[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 10/01/12 – 4/30/13.
[e] Pulgas Creek Pump Station South WY 2013 wet season loads are estimates provided for the entire wet season (10/01/12 – 4/30/13) however monitoring only occurred during the period 12/17/2012 – 3/15/2012. Monthly loads for the non-monitored period were extrapolated using regression equations developed for the monthly rainfall and corresponding monthly (or partial month) contaminant load.

6.2. What data gaps remain at current loads stations?

With regard to addressing the main management endpoints (single and regional watershed loads and baseline data for trends) that caused the monitoring design described by the MYP (BASMAA, 2011) and updated twice [BASMAA, 2012; BASMAA, 2013], an important question that managers are asking is how to determine when sufficient data have been collected. Several sub-questions are important when trying to make this determination. Are the data representative of climatic variability; have storms and years been sampled well enough relative to expected climatic variation? Is the data representative of the source-release-transport processes of the pollutant of interest? In reality, these two factors tend to juxtapose and after two years of monitoring, some data gaps remain for each of the monitoring locations.

- Guadalupe River watershed has been sampled at the Hwy 101 location during eight water years (WY 2003-2006, 2010-2013) to-date, but data are still lacking to adequately describe high intensity upper watershed rain events when mercury may still be released from sources in relation to historic mining activities. This type of information could help estimate the upper range of mercury loads from the mercury mining district and continue to help focus management attention. Further data collection in Guadalupe River watershed should focus on high intensity storms only; further sampling of relatively frequent smaller runoff events is unnecessary. The current sampling design is not cost-effective for gathering improved information to support management decisions in this watershed.
- San Leandro Creek watershed has been sampled for two WYs to-date. San Leandro Creek, received poor quality ratings on the quality of discharge information and completeness of turbidity data. The largest weakness is the lack of velocity measurements to adequately describe the stage-discharge rating curve and generate a continuous flow record. Additional velocity measurements are necessary to increase the accuracy and precision of discharge data for the site and support the computation of loads. There is currently no information on pollutant concentrations during reservoir releases yet volumetrically, reservoir release during WYs 2012 and 2013 has been proportionally large. Sample collection during release would help elucidate pollutant load contributions from the reservoir. Data collection during more intense rainstorms are also desirable for this site given the complex sources of PCBs and mercury in the watershed and the existence of areas of less intense land use and open space lending to likely relatively high inter-annual variability of water and sediment production.
- Marsh Creek watershed has been sampled for two WYs to-date. Continuous turbidity data were rated excellent at Lower Marsh Creek; no changes to monitor design for turbidity are necessary. Ample lower watershed stormwater runoff data are available at Lower Marsh Creek, but this site is lacking information on high intensity upper watershed rain events where sediment mobilization from the historic mercury mining area could occur. Sampling during WY 2014 would ideally be focused on storms of greater intensity preferably when spillage is occurring from the upstream reservoir. Beyond WY 2014, the sampling design should be revisited with the objective of increased cost efficiency for data gathering to support management questions.
- North Richmond Pump Station watershed has been sampled for just one year (although data exists from a previous study [Hunt et al., 2012]). Although some data exist, further data in

relation to early season (seasonal 1st flush or early season storms) would help estimate loads averted from diversion of early season storms to wastewater treatment. Further data collection in relation to high concentrations of PBDEs is necessary to verify the existence of PBDEs source in this watershed. Providing these types of data can be collected during WY 2014, an alternative sampling design could be considered.

- At Pulgas Creek Pump Station and Sunnyvale East Channel (two locations with much below average rainfall during sampling to date), more storm event water quality monitoring is needed for establishing confidence in particle ratios, pollutant loads, FWMCs, and yields. Sunnyvale East Channel and Pulgas Creek Pump Station received poor quality ratings on completeness of turbidity data: Sunnyvale East Channel had a full record but a large portion of data censored due to spikes and Pulgas Creek Pump Station recorded turbidity during only three of the seven wet season months in large part due to instrumentation failures. The Pulgas Creek sampling location also received a low rating on representativeness given how turbidity records could fluctuate multiple times from one reading to the next. Pulgas Creek Pump Station also had poor repeatability between manual and sensor collected data and improvements to the monitoring set-up should be considered for next wet season. Improvements have been recommended for the WY 2014 winter season for both sampling sites. The existing sampling design (with ongoing annual improvements as lessons are learned) may be warranted for these two watersheds for additional years.

6.3. Next Steps

Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board (and discussion at the October 2013 SPLWG meeting) have highlighted the increasing focus towards finding watersheds and land areas within watersheds for management focus (MQ4). The monitoring design described in this report is likely not appropriate for this increasing management focus. During the first quarter of 2014, the STLS will be reviewing lessons learned to-date and will be developing recommendations for alternative monitoring designs and sampling locations (in concert with the RWSM modeling design). Based on recent findings, there is evidence to support effort reduction at Lower Marsh Creek and Guadalupe River as well as development of monitoring decision points for determining when sufficient data has been collected to address MQ2 (single watershed and regional pollutant loads), and to provide baseline data to support MQ3 (future trends in relation to management actions). Additional information is needed for Pulgas Creek Pump Station, Sunnyvale East Channel, North Richmond Pump Station and San Leandro Creek, especially during early season/high-intensity rain events. If the right climatic conditions and field work focus occurs during WY 2014, these data gaps may be addressed sufficiently. A revised monitoring design will need to be robust enough to continue to support MQ 1, 2, and 3 for PCBs and Hg and emerging pollutants of interest as well as increasing information to support MQ4.

There are various alternative monitoring designs that are more cost-effective for the addressing the increasing focus in the second MRP permit term towards finding watersheds and land areas within watersheds for management attention while still supporting the other STLS management questions. The challenge for the STLS and SPWLG is finding the right balance between the different alternatives within budget constraints. Options include:

- Loads monitoring
    - Changing to a rotating site approach (e.g. all six monitoring locations are maintained for stage and turbidity but each monitored fewer years for pollutants)
    - Changing monitoring frequency (e.g. opportunistic sampling for specific events with overall reduction in effort but increased informational outcomes)
    - Reducing the number of sites (currently six)
    - Adding new sites of specific interest (e.g. to determine load magnitude in relation to upstream pollution or downstream beneficial use impact)
    - Dropping loads monitoring completely
- Reconnaissance monitoring design
    - Make improvements to the WY 2011 design:
        - Increase the number of samples from 4-7 to 8-14 per site
        - Selectively add measurements of stage and possibly velocity
    - Focus on sampling a subset of feasible pump stations downstream from industrial land use (73 possible locations identified). Pump stations have the advantage of forcing unidirectional flow very near the Bay margin but have disadvantages in terms of complex flow patterns, confined space, permission or limited access during work hours. Lessons learned at the North Richmond and Pulgas Creek Pump Stations during the current study will be valuable.
    - Rotate in single land use/ source area “high opportunity” sites.

It is likely that a sampling design that simultaneously addresses all four STLS management questions will require a compromise between the different monitoring options (i.e. some loads monitoring effort retained). However, the advantage of the reconnaissance sampling design is flexibility and given recent advances on the development of the RWSM (SFEI in preparation) have indicated the value of the data collected previously using the reconnaissance design (McKee et al., 2012), it seems likely that the reconnaissance design may end up being the most cost-effective. Data and information gathered over the last 10+ years guided by the SPLWG and STLS will continue to help guide the development of a cost effective monitoring design to adapt to changing management needs.

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8. Detailed information for each sampling location

8.1. Marsh Creek

8.1.1. Marsh Creek flow

The US geological survey has maintained a flow record on Marsh Creek (gauge number 11337600) since October 1, 2000 (13 WYs). Peak annual flows for the previous 13 years have ranged between 168 cfs (1/22/2009) and 1770 cfs (1/2/2006). For the same period, annual runoff has ranged between 3.03 Mm3 (WY 2009) and 26.8 Mm3 (WY 2006). In the Bay Area, at least 30 years of observations are needed at a particular site to get a reasonable understanding of climatic variability (McKee et al., 2003). Since, at this time, Marsh Creek has a relatively short history of gauging, flow record on Marsh Creek were compared with a reasonably long record as an adjacent monitoring station near San Ramon. Based on this comparison, WY 2006 may be considered representative of very rare wet conditions (upper 10th percentile) and WY 2009 is perhaps representative of moderately rare dry conditions (lower 20th percentile) based on records that began in WY 1953 at San Ramon Creek near San Ramon (USGS gauge number 11182500).

A number of relatively minor storms occurred during WY 2012 and 2013 (Figure 3). In WY 2012, flow peaked at 174 cfs on 1/21/2012 at 1:30 am and then again 51 ½ hours later at 143 cfs on 1/23/2012 at 5:00 am. Total runoff during the whole of WY 2012 (October 1st to September 30th) was 1.87 Mm^3. During water year 2013, flow peaked at 1300 cfs at 10:00 am on 11/30/2012; total run-off for the water year was 6.26 Mm^3 based on preliminary USGS data and was much greater relative to the first year of monitoring. Although the peak discharge for WY 2013 was the second highest since records began in WY 2001, total annual flow ranked eighth in the last 13 years. Thus, discharge of these magnitudes for both water years of observations to-date are likely exceeded most years in this watershed. Rainfall data corroborates this assertion; rainfall during WY 2012 and 2013 respectively was 70% and 71% of mean annual precipitation (MAP) based on a long-term record at Concord Wastewater treatment plant (NOAA gauge number 041967) for the period Climate Year (CY) 1992-2013. Marsh Creek has a history of mercury mining in the upper part of the watershed. The Marsh Creek Reservoir is downstream from the historic mining area but upstream of the current gauging location. During water years 2012 and 2013, discharge through the reservoir occurred on March, November, and December 2012.

8.1.2. Marsh Creek turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. During WY 2012, turbidity peaked at 532 NTU during a late season storm on 4/13/12 at 7 pm. Relative to flow magnitude, turbidity remained elevated during all storms and was the greatest during the last storm despite lower flow. During WY 2013, turbidity peaked at 1384 NTU during the December storm series on 12/02/12 at 7:05 pm. These observations, and observations made previously during the RMP reconnaissance study (maximum 3211 NTU; McKee et al., 2012), provide evidence that during larger storms and wetter years, the Marsh Creek watershed is capable of much greater sediment erosion and transport than occurred during observations in WY 2012 and 2013, resulting in greater turbidity and concentrations of suspended sediment. The OBS-500 instrument utilized at this sampling location with a range of 0-4000 NTU will likely be exceeded during medium or larger storms.

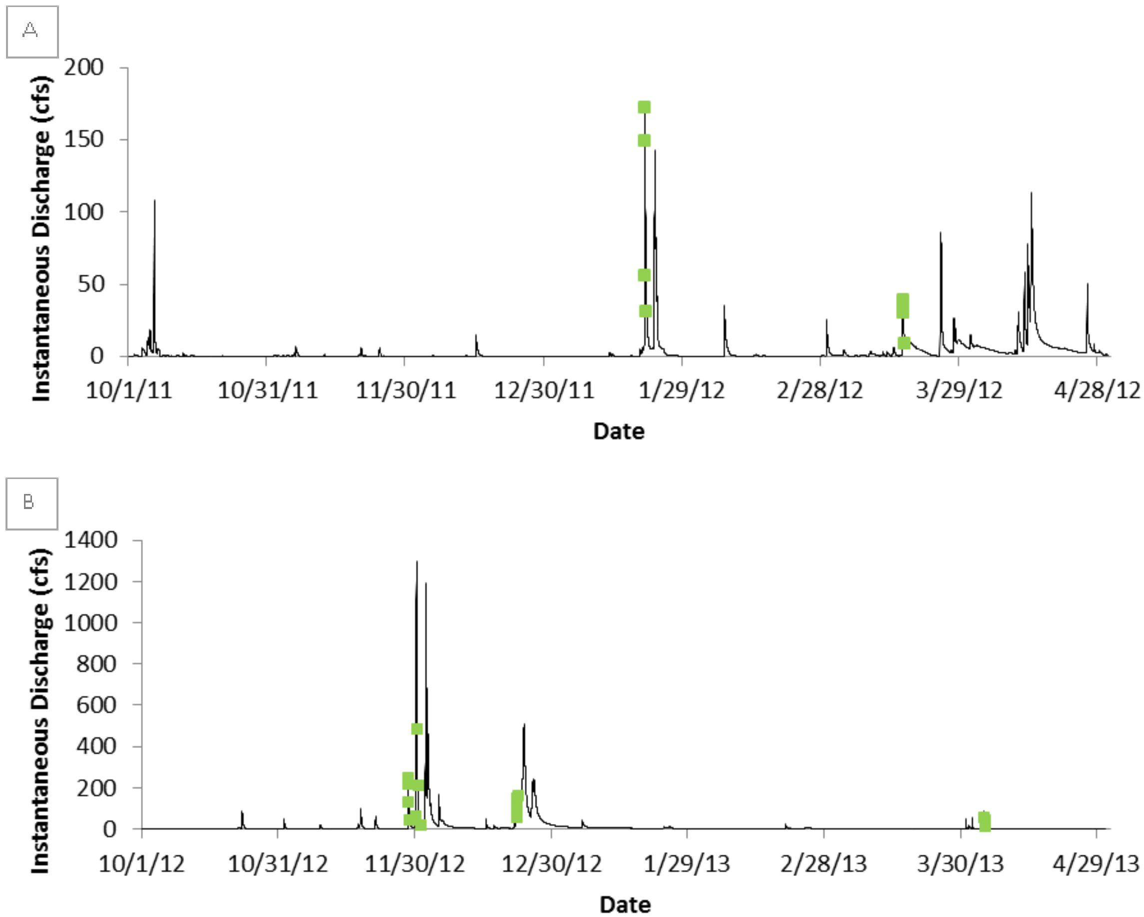


Figure 3. Flow characteristics in Marsh Creek during water year 2012 (A) based on published data and for the water year 2013 (B) based on preliminary 15 minute data provided by the United States Geological Survey, gauge number 11337600) with sampling events plotted in green. Note, USGS normally publishes finalized data for the permanent record in the spring following the end of each water year.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. SSC peaked at 1312 mg/L during the 4/13/12 late season storm and at 1849 mg/L on 12/02/12 at the same time as the peaks in turbidity. During WY 2012, relative to flow magnitude, SSC remained elevated during all storms and was the greatest during the last storm despite lower flow. A similar pattern was also observed during WY 2013. Turbidity and computed SSC peaked during a smaller storm in December rather than the largest storm which occurred in late November. Turbidity remained relatively elevated from an even smaller storm that occurred on December 24th. These observations of increased sediment transport as the season progresses relative to flow in addition to the maximum SSC observed during the RMP reconnaissance study of 4139 mg/L (McKee et al., 2012), suggest that in wetter years, greater SSC can be expected.

8.1.3. Marsh Creek POC concentrations summary (summary statistics)

In relation to the other five monitoring locations, Marsh Creek is representative of a relatively rural watershed with lower levels of urbanization but potentially impacted by mercury residues from historic mining upstream. Summary statistics (Table 9) were used to provide useful information to compare Marsh Creek water quality to other Bay Area streams. The comparison of summary statistics to knowledge from other watersheds and conceptual models of pollutant sources and transport processes provided a further check on data quality. The maximum PCB concentration (4.32 ng/L) was similar to background concentrations normally found in relatively nonurban areas while maximum mercury concentrations (252 ng/L) were similar to concentrations found in mixed land use watersheds (Lent and McKee, 2011). Maximum MeHg concentrations (0.407 ng/L during WY 2012 and 1.2 ng/L during WY 2013 were greater than the proposed implementation goal of 0.06 ng/l for methylmercury in ambient water for watersheds tributary to the Central Delta (Wood et al., 2010: Table 4.1, page 40). Nutrient concentrations appear to be reasonably typical of other Bay Area watersheds (McKee and Krottje, 2005). As is typical in the Bay Area, phosphorus concentrations appear greater than elsewhere in the world under similar land use scenarios, an observation perhaps attributable to geological sources (McKee and Krottje, 2005). For pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients), concentrations exhibited the typical pattern of median < mean with the exception of organic carbon during both years.

A similar style of first order quality assurance is also possible for analytes measured at a lower frequency. Pollutants sampled at a lesser frequency using composite sampling design (see methods section) and appropriate for characterization only (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) were quite low and similar to concentrations found in watersheds with limited or no urban influences. It was surprising to see PBDE concentrations so much greater in the second year of sampling relative to the first year, possibly just an artifact of the randomness sample capture and small sample numbers. Carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L, Moran, 2007) (Carbaryl: DL - 700 ng/L, Ensiminger et al., 2012). Pyrethroid concentrations of Delta/Tralo-methrin were similar to those observed in Zone 4 Line A, a small 100% urban tributary in Hayward, whereas concentrations of Permethrin and Cyhalothrin lambda were about 10-fold and 2-fold lower and concentrations of Bifenthrin were about 5-fold higher; cypermethrin was not detected in Z4LA (Gilbreath et al., 2012). It was a little surprising to see cypermethrin concentrations more than 4-fold lower in WY 2013 relative to WY 2012. Again, this may just be an artifact of the randomness of sample capture. In summary, the statistics indicate pollutant concentrations typical of a Bay Area non-urban stream and there is no reason to suspect data quality issues.

8.1.2. Marsh Creek toxicity

Composite water samples were collected at the Marsh Creek station during two storm events in Water Year 2012 and four storm events in Water Year 2013. No significant reductions in the survival, reproduction and growth of three of four test species were observed during WY 2012. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during both WY 2012 storm events. Water Year 2013 had complete mortality of *Hyalella Azteca* between 5 and 10 days of exposure to storm water (0% survival compared to a 100% laboratory survival rate) during all four storm events. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of sediments in receiving waters. Additionally,

Table 9. Summary of laboratory measured pollutant concentrations in Marsh Creek during WY 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**Unit**	**Samples taken (n)**	**Proportion detected (%)**	**Min**	**Max**	**Median**	**Mean**	**Standard Deviation**	**Samples taken (n)**	**Proportion detected (%)**	**Min**	**Max**	**Median**	**Mean**	**Standard Deviation**
SSC	mg/L	27	96%	ND	930	180	297	276	54	100%	3.3	1040	167	217	230
∑PCB	ng/L	7	100%	0.354	4.32	1.27	1.95	1.61	15	100%	0.240	3.46	0.676	0.927	0.856
Total Hg	ng/L	8	100%	8.31	252	34.6	74.3	85.2	17	100%	1.90	120	19.0	32.5	33.9
Total MeHg	ng/L	5	100%	0.085	0.407	0.185	0.218	0.120	14	94%	ND	1.20	0.185	0.337	0.381
TOC	mg/L	8	100%	4.6	12.4	8.55	8.34	2.37	16	100%	4.30	9.50	6.55	6.52	1.60
NO3	mg/L	8	100%	0.470	1.10	0.635	0.676	0.202	16	94%	ND	1.0	0.53	0.53	0.22
Total P	mg/L	8	100%	0.295	1.10	0.545	0.576	0.285	12	100%	0.140	0.670	0.305	0.346	0.166
PO4	mg/L	8	100%	0.022	0.120	0.056	0.065	0.030	16	100%	0.046	0.180	0.110	0.114	0.036
Hardness	mg/L	2	100%	200	203	189	202	2.12	-	-	-	-	-	-	-
Total Cu	µg/L	2	100%	13.8	27.5	20.6	20.6	9.70	4	100%	3.80	30.0	12.5	14.7	11.0
Dissolved Cu	µg/L	2	100%	4.99	5.62	5.31	5.31	0.445	4	100%	1.30	2.40	1.45	1.65	0.520
Total Se	µg/L	2	100%	0.647	0.784	0.716	0.716	0.097	4	100%	0.525	1.40	0.670	0.816	0.395
Dissolved Se	µg/L	2	100%	0.483	0.802	0.643	0.643	0.226	4	100%	0.510	1.20	0.585	0.720	0.323
Carbaryl	ng/L	2	50%	-	-	-	16.0	-	4	25%	ND	13.0	0	3.25	6.50
Fipronil	ng/L	2	100%	7.00	18.0	12.5	12.5	7.78	4	100%	10.0	13.0	10.8	11.1	1.44
∑PAH	ng/L	1	100%	-	-	-	494	-	2	100%	85.7	222	154	154	96
∑PBDE	ng/L	1	100%	-	-	-	20.0	-	2	100%	11.2	56.4	33.8	33.8	32.0
Delta/ Tralo-methrin	ng/L	2	100%	0.954	5.52	3.23	3.23	3.23	4	75%	ND	2.20	0.750	0.925	0.943
Cypermethrin	ng/L	2	50%	-	-	-	68.5	-	4	100%	1.80	13.0	2.15	4.78	5.49
Cyhalothrin lambda	ng/L	2	50%	-	-	-	2.92	-	4	100%	0.500	3.20	0.800	1.33	1.27
Permethrin	ng/L	2	100%	3.81	17.3	10.6	10.6	9.54	4	75%	ND	12.0	6.55	6.28	6.11
Bifenthrin	ng/L	2	100%	25.3	257	141	141	163	4	100%	27.0	150	45.0	66.8	56.2

Analyzed but not detected: Fenpropathrin, Esfenvalerate/ Fenvalerate, Cyfluthrin, Allethrin, Prallethrin, Phenothrin, and Resmethrin
Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at Marsh Creek was two.
All Hardness results in WY 2013 were censored.

one Water Year 2013 sample showed a significant reduction in fathead minnow survival (57.5% compared to a 90% laboratory survival). No significant effects were observed for the crustacean *Ceriodaphnia dubia* or the algae *Selenastrum capricornutum* during these storms.

8.1.3. Marsh Creek preliminary loading estimates

Site-specific methods were developed for computed loads (Table 10). Preliminary loads estimates generated for WY 2012 and reported by McKee et al. (2013) have now been revised based on additional data collected in WY 2013 and an improving understanding of pollutant transport processes for the site. Preliminary monthly loading estimates correlate well with monthly discharge (Table 11). There are no data available for October and November 2011 because monitoring equipment was not installed until the end of November. Monthly discharge was greatest in December 2012 as were the monthly loads for each of the pollutants regardless of transport mode (dominantly particulate or dissolved). The discharge was relatively high for December given the rainfall, an indicator that the watershed was reasonably saturated by this time. The sediment loads are well-aligned with the total discharge and the very high December 2012 sediment load appears real; the watershed became saturated after late November rains such that early December and Christmas time storms transported a lot of sediment. Monthly loads of total Hg appear to correlate with discharge for all months; this would not be the case if there was variable release of mercury from historic mining sources upstream associated with climatic and reservoir discharge conditions. At this time, all load estimates should be considered preliminary. Additionally (and, in this case, more importantly), if data collected during WY 2014 is able to capture periods when saturated and high rainfall conditions occur along with reservoir releases, new information may emerge about the influence, if any, of Hg pollution associated with historic mining. In any case, WY 2014 data will be used to improve our understanding of rainfall-runoff-pollutant transport processes for all the pollutants and used to recalculate and finalize loads for WYs 2012 and 2013. Regardless of these improvements however, given the very dry flow conditions of WY 2012 and 2013 (see discussion on flow above), preliminary loads presented here may be considered representative of dry conditions.

Table 10. Regression equations used for loads computations for Marsh Creek during water years 2012 and 2013. Note that regression equations will be reformulated with each future wet season of storm sampling.

Analyte	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	1.3	33	0.45	Regression with turbidity
Total PCBs (ng/NTU)	0.0089		0.84	Regression with turbidity
Total Mercury (ng/NTU)	0.32		0.65	Regression with turbidity
Total Methylmercury (ng/L)	0.327			Flow weighted mean concentration
Total Organic Carbon (mg/L)	6.82			Flow weighted mean concentration

Analyte	Slope	Intercept	Correlation coefficient (r^2)	Notes
Total Phosphorous (mg/NTU)	0.0016	0.19	0.57	Regression with turbidity
Nitrate (mg/L)	0.6			Flow weighted mean concentration
Phosphate (mg/L)	0.112			Flow weighted mean concentration

Table 11. Preliminary monthly loads for Marsh Creek during water years 2012 and 2013.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	33	-	-	-	-	-	-	-	-	-
	11-Nov	26	-	-	-	-	-	-	-	-	-
	11-Dec	6	0.0252	1.57	172	0.00493	0.180	0.00823	15.1	2.82	5.63
	12-Jan	51	0.318	68.3	2,169	0.389	14.2	0.104	191	35.6	130
	12-Feb	22	0.0780	6.59	532	0.0269	0.983	0.0255	46.8	8.74	19.5
	12-Mar	60	0.361	31.8	2,458	0.133	4.87	0.118	216	40.4	91.9
	12-Apr[a]	59	0.606	118	4,136	0.658	24.1	0.198	364	67.9	233
	Wet season total	198	1.39	226	9,467	1.21	44.4	0.454	833	155	480
2013	12-Oct[b]	23	0.0875	10.0	596	0.0474	1.73	0.0286	52.5	9.79	25.0
	12-Nov	96	0.989	248	6,745	1.45	53.1	0.323	593	111	448
	12-Dec	75	4.00	2,297	27,291	14.6	534	1.31	2,401	448	3,384
	13-Jan	15	0.428	24.1	2,920	0.0660	2.41	0.140	257	48.0	92.5
	13-Feb	6	0.142	5.98	970	0.00825	0.302	0.0465	85.3	15.9	28.3
	13-Mar	9	0.0721	3.79	492	0.00932	0.341	0.0236	43.2	8.07	15.2
	13-Apr[c]	19	0.098	10.8	667	0.0506	1.85	0.0320	58.7	11.0	27.5
	Wet season total	243	5.82	2,600	39,682	16.2	594	1.90	3,491	652	4,020

[a] April 2012 monthly loads are reported for only the period April 01-26. In the 4 days missing from the record, <0.03 inches of rain fell in the lower watershed.

[b] October 2012 monthly loads are reported for only the period October 19-31. In the 18 days missing from the record, <0.05 inches of rain fell in the lower watershed.

[c] April 2013 monthly loads are reported for only the period April 01-18. In the 12 days missing from the record, no rain fell in the lower watershed.

8.2. North Richmond Pump Station

8.2.1. North Richmond Pump Station flow

Richmond flow and discharge estimates were calculated during periods of active pumping at the station from October 1, 2012 to April 30, 2013. Flow and discharge estimates include all data collected when where the pump rate was operating at is greater than 330 RPM. This rate is generally reached 30 seconds after pump ignition. For the purposes of this study, flows at less than 330 RPM were considered negligible due to limitations of the pump efficiency curve. This assumption would have resulted in slight underestimation of active flow from the station particularly during shorter duration pump outs but this under estimate was minor relative to storm and annual flows. The annual estimated discharge from the station was 0.76 Mm^3 for WY 2013 (Table 14). A discharge estimate at the station for WY 2011 was 1.1 Mm^3 (Hunt et al., 2012). The rainfall to run-off ratios between the two studies was similar supporting the hypothesis that the flows and resulting load estimates from the previous study remain valid. October 2012 exhibited a lower discharge per unit rainfall, perhaps caused by a dry watershed. Water quality samples were collected during three storm events (Figure 4). Most pump-outs had one operating pump except for a few storm events where two pumps were in operation.

A number of relatively minor storms occurred during WY 2013 except during the period late November to mid-December when 15 inches of rain fell in North Richmond (74% of October-April rainfall). During water year 2013, peak flow of 210 cfs occurred on December 2, 2013 after approximately 3.8 inches of rain fell over a 63 hour period. Approximately 20 inches of rain fell during Water Year 2013. Rainfall during 2013 was 89% mean annual precipitation (MAP) based on a long-term record PRISM data record (modeled PRISM data) for the period Climate Year (CY) 1970-2000. Thus it appears WY 2013 was slightly drier than average.

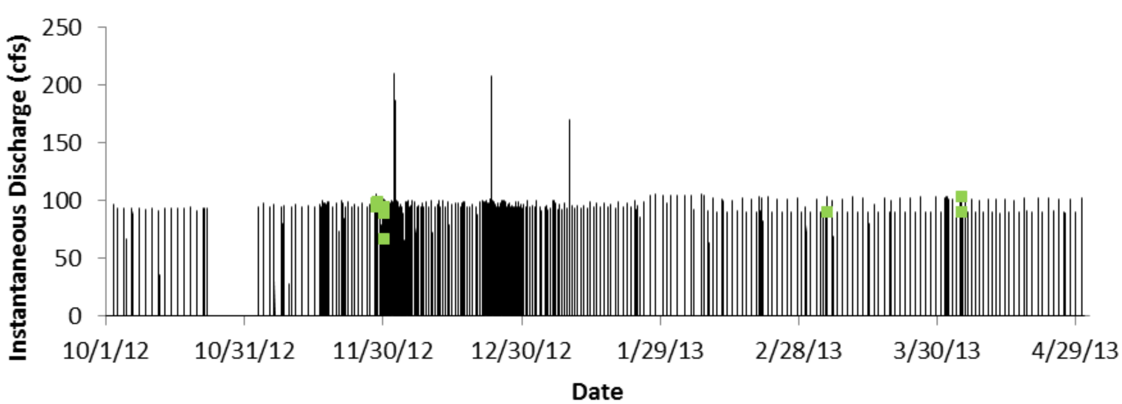


Figure 4. Preliminary flow characteristics at North Richmond Pump Station during Water Year 2013 with sampling events plotted in green. Note, flow information may be updated in the future as we continue to refine how we interpret the well depth, pump RMP, pump efficiency curves, and well geometry information.

8.2.2. North Richmond Pump Station turbidity and suspended sediment concentration

Maximum turbidity during Water Year 2013 was measured at 772 NTU which occurred during a dry flow pump out on January 24, 2013 following a low magnitude storm event of 0.22 inches on January 23. Maximum turbidity during other storm events ranged up to 428 NTU. The pattern of turbidity variation over the wet season was remarkably similar to that observed during WY 2011 in the previous study (Hunt et al., 2012). The turbidity dataset collected by Hunt et al. (2012) was noisy and contained unexplainable turbidity spikes that were censored. The similarities between the WY 2011 and 2013 datasets suggest that the WY 2011 data set was not over censored and therefore that pollutant loads based on both flow and turbidity computed by Hunt et al. (2012) remain valid.

8.2.3. North Richmond Pump Station POC concentrations summary (summary statistics)

The North Richmond pump station is a 1.6 km watershed primarily comprised of industrial, transportation, and residential land uses. The land-use configuration results in a watershed that is approximately 62% covered by impervious surface. Summary statistics (Table 12) were used to provide useful information to compare Richmond pump station water quality to other Bay Area monitoring locations. The comparison of summary statistics to knowledge from other watersheds and conceptual models of pollutant sources and transport processes provided a further check on data quality. The maximum PCB concentration measured in WY 2013 was 31.6 ng/L. In WY2011, the maximum concentration measured was 82 ng/L. PCB concentrations were in the range of other findings for urban locations (range 0.1-1120 ng/L) (Lent and McKee, 2011). Maximum mercury concentrations (98 ng/L) were approximately half the maximum observed concentrations during previous monitoring efforts (200 ng/L) (Hunt et al., 2012). Mercury concentrations were in the range of Zone 4 Line-A findings, another small urban impervious watershed (Gilbreath et al., 2012). Maximum MeHg concentrations in WY 2013 were 0.19 ng/L compared with WY 2011 concentrations of 0.6 ng/L (Hunt et al., 2012). For pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients), concentrations exhibited the typical pattern of median < mean; unlike Marsh Creek and San Leandro Creek, TOC also exhibited this pattern.

Copper, selenium, PAHs, carbaryl, fipronil, and PBDEs were sampled at a lesser frequency using a composite sampling design (see methods section) and were used to characterize pollutant concentrations to help support management questions possible causes of toxicity (in the case of the pesticides). Maximum PBDE concentrations were 50-fold greater than the greatest average observed in the five other locations of this current study and previously reported for Zone 4 Line (Gilbreath et al., 2012). These are the highest PBDE concentrations measured in Bay area stormwater to-date of any study. BDE 209 usually contributes at least 50% of the sum of BDE congeners to stormwater samples in the Bay Area. Richmond appears to be the exception to this rule. The highest concentration samples had approximately 45% BDE 209, and relatively larger amounts of 206-208 than normally observed in Bay Area stormwater samples. Although the relative contributions of 206-208 are a bit unusual, summing to approximately the 209 amount, that it occurred in two samples (albeit in the same event) in similar proportions makes it less likely that it is purely an analytical anomaly. Blanks were fairly low in 206-208 so it is unlikely that the high contribution in the Richmond samples was from blank contamination, as

Table 12. Summary of laboratory measured pollutant concentrations in North Richmond Pump Station during water year 2013.

		Water Year 2012	Water Year 2013						
Analyte Name	**Unit**	**Samples taken (n)**	**Samples taken (n)**	**Proportion detected (%)**	**Min**	**Max**	**Median**	**Mean**	**Standard Deviation**
SSC	mg/L	0	41	95%	ND	213	26.5	45.7	54.3
∑PCB	ng/L	0	12	100%	4.85	31.6	10.1	12.0	7.09
Total Hg	ng/L	0	12	100%	13.0	98.0	18.5	27.7	24.6
Total MeHg	ng/L	0	6	100%	0.030	0.190	0.145	0.118	0.071
TOC	mg/L	0	12	100%	3.50	13.5	6.60	7.46	3.36
NO3	mg/L	0	12	100%	0.210	3.10	0.855	1.13	0.848
Total P	mg/L	0	12	100%	0.180	0.350	0.270	0.276	0.045
PO4	mg/L	0	11	100%	0.110	0.240	0.160	0.168	0.042
Hardness	mg/L	0	-	-	-	-	-	-	-
Total Cu	µg/L	0	3	100%	9.90	20.0	16.0	15.3	5.09
Dissolved Cu	µg/L	0	3	100%	4.40	10.0	4.70	6.37	3.15
Total Se	µg/L	0	3	100%	0.270	0.590	0.330	0.397	0.170
Dissolved Se	µg/L	0	3	100%	0.260	0.560	0.270	0.363	0.170
Carbaryl	ng/L	0	3	100%	12.0	40.0	19.0	23.7	14.6
Fipronil	ng/L	0	3	33%	ND	4.00	0	1.33	2.31
∑PAH	ng/L	0	2	100%	160	1349	754	754	840
∑PBDE	ng/L	0	2	100%	153	3362	1611	1757	2269
Delta/ Tralo-methrin	ng/L	0	3	100%	1.00	3.50	3.05	2.52	1.33
Cypermethrin	ng/L	0	3	100%	2.10	4.35	3.10	3.18	1.13
Cyhalothrin lambda	ng/L	0	3	100%	0.400	1.30	0.600	0.767	0.473
Permethrin	ng/L	0	3	100%	6.40	16.0	13.5	12.0	4.98
Bifenthrin	ng/L	0	3	100%	3.80	8.05	6.10	5.98	2.13

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at the North Richmond Pump Station was two.
All Hardness results in WY 2013 were censored.

those were also the samples with the highest total PBDEs of all those measured. The North Richmond watershed currently contains an auto dismantling yard and a junk/wrecking yard; possible source areas. At this time we are unwilling to sensor the data but anticipate data collected during WY 2014 helping to support or reject the magnitude of concentrations.

Similar to the other sites, carbaryl and fipronil were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L, Moran, 2007) (Carbaryl: DL - 700 ng/L, Ensiminger et al., 2012). Pyrethroid concentrations of Delta/ Tralo-methrin were similar to those observed in Zone 4 Line A, whereas concentrations of Cyhalothrin lambda and Permethrin were about 6-fold and 7-fold lower respectively and concentrations of Bifenthrin were about 3-fold higher (Gilbreath et al., 2012). In summary, the statistics indicate pollutant concentrations typical of a Bay Area urban stream and there is no reason to suspect data quality issues (except PBDE has been flagged for further investigation).

8.2.4. North Richmond Pump Station toxicity

Composite water samples were collected at North Richmond Pump Station during three storms between Nov 28, 2012 and March 6, 2013. Two of these samples showed a significant decrease in *Hyalella Azteca* survival. One sample showed an 88% survival rate compared to a 98% lab survival rate. The other sample showed a 12% survival rate compared to a 100% lab survival rate. No significant effects were observed for the crustacean *Ceriodaphnia dubia*, the algae *Selenastrum capricornutum* or fathead minnows during these storms.

8.2.5. North Richmond Pump Station preliminary loading estimates

The following methods were applied for calculating preliminary loading estimates (Table 13). During active pumpout conditions, regression equations between PCBs, total mercury, methylmercury, SSC and turbidity were used to estimate loads (Table 12). Load estimates for total phosphorous, nitrate, and phosphate utilized flow weighted mean concentration derivations. Preliminary monthly loading estimates correlate very well with monthly discharge (Table 14). Monthly discharge was greatest in December as were the monthly loads for suspended sediment and pollutants. Although there were slight climatic differences that have not been adjusted for, WY 2013 suspended sediment (34.4 t) and PCB (7.90 g) load estimates were comparable to the Water Year 2011 estimates (29 t and 8.0 g, respectively) even thought it was a wetter year (134% MAP) (Hunt., 2012) helping to give us 1st order confidence that the computed loads are reasonable. Due to lessons learned from the previous study, there is much higher confidence in the Water Year 2013 loads estimates due to improvements in both the measurements of turbidity and flow rate using optical sensor equipment.

Given the below average rainfall conditions experienced during WY 2013, loads from the present study may be considered representative of somewhat dry conditions.

Table 13. Regression equations used for loads computations for North Richmond Pump Station during water year 2013. Note that regression equations will be reformulated with each future wet season of storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mainly urban	1.293		0.78	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.21	3.1	0.71	Regression with turbidity
Total Mercury (ng/NTU)	Mainly urban	0.605		0.92	Regression with turbidity
Total Methylmercury (ng/NTU)	Mainly urban	0.0028	0.05	0.88	Regression with turbidity
Total Organic Carbon (mg/L)	Mainly urban	7.48			Flow weighted mean concentration
Total Phosphorous (mg/L)	Mainly urban	0.276			Flow weighted mean concentration
Nitrate (mg/L)	Mainly urban	1.13			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.17			Flow weighted mean concentration

Table 14. Preliminary monthly loads for North Richmond Pump Station.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2013	12-Oct	54	0.0278	1.44	208	0.318	0.674	0.00451	31.4	4.72	7.67
	12-Nov	156	0.152	7.78	1138	1.72	3.64	0.0245	172	25.9	42.0
	12-Dec	232	0.374	20.5	2795	4.46	9.61	0.0632	422	63.5	103
	13-Jan	18	0.0641	1.29	479	0.406	0.605	0.00602	72.4	10.9	17.7
	13-Feb	18	0.0438	1.26	328	0.338	0.590	0.00493	49.5	7.45	12.1
	13-Mar	19	0.0418	0.409	312	0.195	0.191	0.00299	47.2	7.10	11.5
	13-Apr	26	0.0602	1.70	450	0.460	0.796	0.00670	68.0	10.2	16.6
	Wet season total	523	0.763	34.4	5,709	7.90	16.1	0.113	863	130	211

8.3. San Leandro Creek

8.3.1. San Leandro Creek flow

There is no historic flow record on San Leandro Creek. For the previous report that presented WY 2012 results only (McKee et al., 2013), a preliminary rating curve was developed based on discharge sampling during WY 2012 augmented by the Manning's formula. This rating was improved this year by adding known reservoir release rates associated with consistent stage readings. However, the resulting discharge estimates are still challenged by the lack of velocity measurements at flow stages greater than 3.5 feet and therefore are deemed of poor accuracy and precision. Based on this latest version of a still preliminary rating curve, total runoff during WY 2012 for the period 11/7/11 to 4/30/12 was revised from the 4.13 Mm^3 reported previously (McKee et al., 2013) to a new estimate of 5.47 Mm^3. This total discharge was mostly a result of a series of relatively minor storms that occurred during WY 2012 (Figure 5). During WY 2012, flow peaked at 244 cfs on 1/20/12 22:50. During WY 2013, flow peaked at 338 cfs on 12/23/12 14:20 and total wet season flow was 8.81 Mm^3. San Lorenzo Creek to the south has been gauged by the USGS in the town of San Lorenzo (gauge number 11181040) from WY 1968-78 and again from WY 1988-present. Based on these records, annual peak flow has ranged between 300 cfs (1971) and 10300 cfs (1998). During WY 2012, flow peaked on San Lorenzo Creek at San Lorenzo at 1600 cfs on 1/20/2012 at 23:00; a flow that has been exceeded 68% of the years on record. During, WY 2013, flow in San Lorenzo peaked at 2970 cfs on 12/2/2012 at 11:15 am; a flow of this magnitude has been exceeded 38% of the years on record. Annual flow for San Lorenzo Creek at San Lorenzo (gauge number 11181040) for WY 2012 and 2013 respectively was 95 and 99 Mm^3 both well below the long term average for the site of 169 Mm^3. Based on this evidence alone, we suggest flow in San Leandro Creek flow was likely much lower than average for both water years.

In addition to the flow response from rainfall, East Bay Municipal Utility District (EBMUD) made releases from Chabot Reservoir in the first half of the WY 2012 season indicated by the square and sustained nature of the hydrograph at the sampling location. This also occurred in December and January of WY 2013 also indicated by the square nature of the hydrograph. Despite this augmentation, it seems likely that annual flow in San Leandro Creek during both years of observation was below average and would be exceeded in 60-70% of years. Rainfall data corroborates this assertion; rainfall during WY 2012 was 19.02 inches, or 74% of mean annual precipitation (MAP = 25.55 in) based on a long-term record at Upper San Leandro Filter (gauge number 049185) for the period 1971-2010 [Climate Year (CY]). CY 2012 was ranked 17th driest in the available 57-year record (1949-present [Note 7-year data-gap during CY 1952-58]). Data for CY 2013 is not yet available.

8.3.1. San Leandro Creek turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. During the reservoir release period in the early part of WY 2012, turbidity remained relatively low indicating very little sediment was eroded from within San Leandro Creek at this magnitude and consistency of stream power. A similar phenomenon occurred in January of WY 2013 when again little rainfall occurred and relatively clean run-off devoid of sediment and pollutants was associated with the reservoir release. With each of the storms that occurred beginning 1/20/2012 in WY 2012, maximum storm turbidity increased in magnitude. Turbidity peaked at 929 NTU during a late season storm on 4/13/12 at 5:15 am. In contrast, during WY 2013, saturated watershed conditions began to occur in late November and sediment began to be released from the upper watershed much earlier in the season. A peak turbidity of 495 NTU occurred on 11/30/12 at 9:45 am. The post new year period was relatively dry and the latter season storm in April was relatively minor. These observations provide evidence that during larger

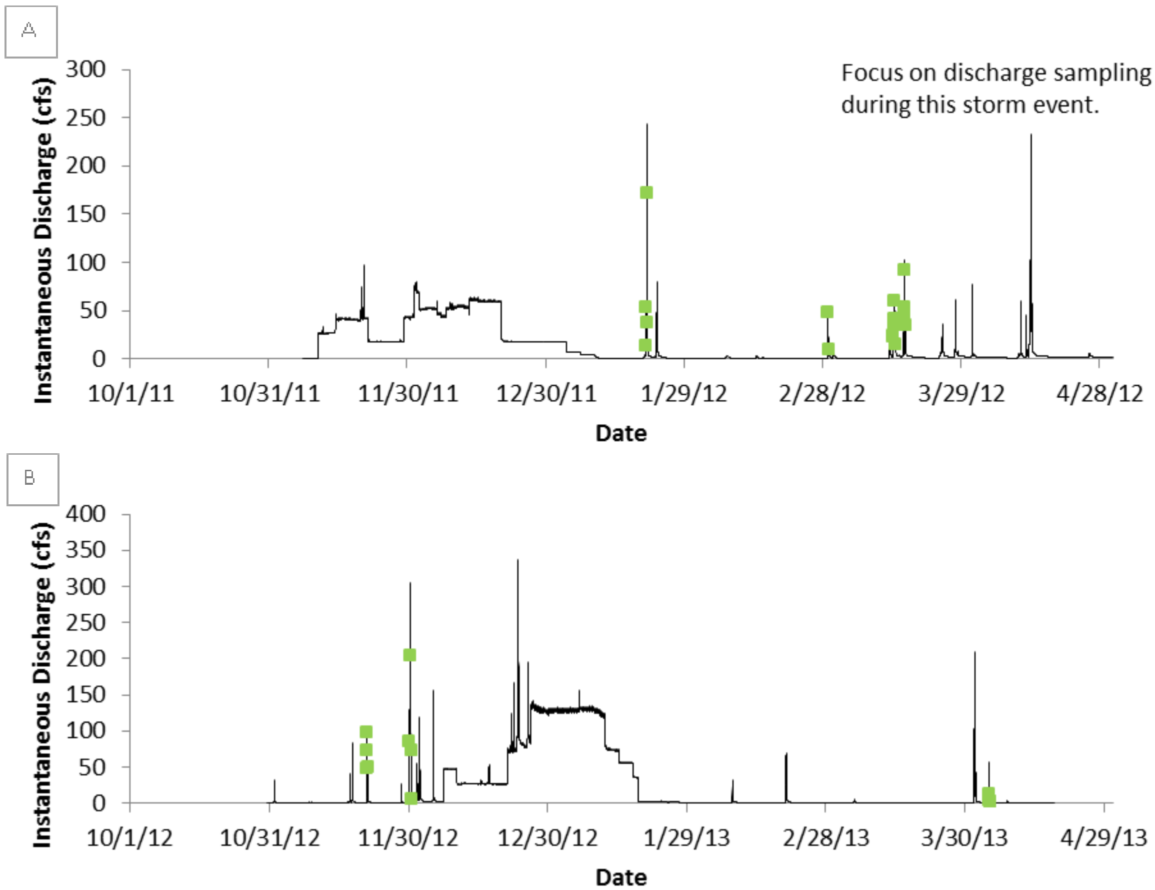


Figure 5. Preliminary flow characteristics (primary y axis) in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A) and WY 2013 (B) with sampling events plotted in green. Note, flow information will be updated in the future when additional data.

storms and wetter years, the San Leandro Creek watershed is likely capable of much greater sediment erosion and transport resulting in greater turbidity and concentrations of suspended sediment. At this time, we have no evidence to suggest that the OBS-500 instrument utilized at this sampling location (with a range of 0-4000 NTU) will not be sufficient to handle most future storms.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. Suspended sediment concentration during WY 2012 peaked at 1141 mg/L during the late season storm on 4/13/12 at 5:15 am; a peak SSC of 608 mg/L occurred on 11/30/12 at 9:45 am for WY 2013; although it should be noted that there was considerable scatter around the upper end of the turbidity-SSC regression relation thus it is possible that this will be reinterpreted with a subsequent year of data collection. The maximum concentration observed during the RMP reconnaissance study (McKee et al., 2012) was 965 mg/L but at this time we have not evaluated the relative storm magnitude between WY 2011 and WY 2012 to determine if the relative concentrations are logical.

8.3.2. San Leandro Creek POC concentrations summary (summary statistics)

Summary statistics of pollutant concentrations measured in San Leandro Creek during WY 2012 and 2013 provide a basic understanding of general water quality and also allow a first order judgment of quality assurance (Table 15). For pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients), concentrations followed the typical pattern of median < mean with the exception of organic carbon. The range of PCB concentrations were typical of mixed urban land use watersheds (Lent and McKee, 2011). Maximum mercury concentrations (590 ng/L) were greater than observed in Zone 4 Line A in Hayward (Gilbreath et al., 2012) and of a similar magnitude to those observed in the San Pedro stormdrain draining an older urban residential area of San Jose (SFEI, unpublished). Nutrient concentrations were in the same range as measured in in Z4LA (Gilbreath et al., 2012), and as is typical in the Bay Area, phosphorus concentrations appear to be greater than reported elsewhere in the world under similar land use scenarios, an observation perhaps attributable to geological sources (McKee and Krottje, 2005). We find no reason to suspect data quality issues since the concentration ranges appear reasonable in relation to our conceptual models of water quality for these analytes.

A similar style of first order quality assurance is also possible for analytes measured at a lesser frequency using composite sampling design (see methods section) (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) and appropriate for water quality characterization only. During WY 2013, maximum concentrations of PAHs, PBDEs, and the pyrethroid pesticides were all considerably lower (around 5-fold) than observed during WY 2012. This is possibly due to differences in the randomness of the representativeness of sub samples of the composites or due to dilution from cleaner water and sediment loads from upstream, hypotheses to explore further with additional data collection in WY 2014. Concentrations of many of these analytes were generally similar to concentrations observed in Z4LA (Gilbreath et al., 2012). Carbaryl and fipronil have not been measured previously by RMP studies but were on the lower side of the range of peak concentrations reported in studies across the US and California (Fipronil: 70 – 1300 ng/L, Moran, 2007) (Carbaryl: DL - 700 ng/L, Ensiminger et al., 2012). The total selenium concentrations in San Leandro Creek appear to be about double those observed in Z4LA (Gilbreath et al., 2012) but still not remarkable compared to other previous observations made in the Bay Area (e.g. North Richmond Pump station [Hunt et al., 2012] and Walnut and Marsh Creeks [McKee et al., 2012]). Pyrethroid concentrations of Delta/ Tralo-methrin, Cyhalothrin lambda, and Bifenthrin were similar to those observed in Z4LA whereas concentrations of Permethrin were about 10x lower (Gilbreath et al., 2012). In summary, mercury concentrations in San Leandro are on the high end of typical Bay Area urban watersheds, whereas concentrations of other POCs are either within the range of or below those measured in other typical Bay Area urban watersheds. There does not appear to be any data quality issues.

8.3.1. San Leandro Creek toxicity

Composite water samples were collected at the San Leandro Creek station during four storm events in Water Year 2012 and three storm events during Water Year 2013. The survival of the freshwater fish species *Pimephales promelas* was significantly reduced during one of the four Water Year 2012 and one of the three Water Year 2013 events. Similar to the results for other POC monitoring stations, significant

Table 15. Summary of laboratory measured pollutant concentrations in San Leandro Creek during water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	53	98%	ND	590	100	162	100	28	86%	ND	904	48.0	114	202
∑PCB	ng/L	16	100%	2.91	29.4	10.5	12.3	41.5	12	100%	0.730	15.7	4.15	5.59	4.65
Total Hg	ng/L	16	100%	11.9	577	89.4	184	21.7	12	100%	7.50	590	44.0	93	162
Total MeHg	ng/L	9	100%	0.164	1.48	0.220	0.499	0.220	9	100%	0.150	1.40	0.200	0.377	0.397
TOC	mg/L	16	100%	4.50	12.7	7.95	7.79	1.40	12	100%	4.00	14.0	5.65	6.25	2.55
NO3	mg/L	16	100%	0.140	0.830	0.340	0.356	0.119	13	100%	0.130	2.80	0.230	0.520	0.732
Total P	mg/L	16	100%	0.200	0.760	0.355	0.393	0.098	9	100%	0.100	0.610	0.210	0.247	0.144
PO4	mg/L	16	100%	0.057	0.16	0.073	0.087	0.019	13	100%	0.069	0.130	0.093	0.094	0.019
Hardness	mg/L	4	100%	33.8	72.5	45.5	54.8	6.93	-	-	-	-	-	-	-
Total Cu	µg/L	4	100%	12.3	39.5	20.1	23.0	5.79	3	100%	5.90	28.0	11.0	15.0	11.6
Dissolved Cu	µg/L	4	100%	6.04	10.0	8.34	8.18	7.38	3	100%	3.50	4.90	4.10	4.17	0.702
Total Se	µg/L	4	100%	0.104	0.292	0.216	0.207	0.118	3	100%	0.180	0.290	0.190	0.220	0.061
Dissolved Se	µg/L	4	100%	0.068	0.195	0.131	0.131	0.012	3	100%	0.160	0.190	0.170	0.173	0.015
Carbaryl	ng/L	4	50%	ND	14.0	5.00	6.00	7.07	3	0%	ND	-	-	-	-
Fipronil	ng/L	4	100%	6.00	10.0	8.00	8.00	4.24	3	33%	ND	9.00	2.00	3.67	4.73
∑PAH	ng/L	2	100	3230	5352	4291	4291	1501	1	100%	1399	1399	1399	1399	-
∑PBDE	ng/L	2	100	64.9	82.0	73.5	73.5	12.1	2	100%	1.61	29.7	15.7	15.7	19.9
Delta/ Tralo-methrin	ng/L	3	100%	0.163	1.74	1.41	1.10	0.832	3	33%	ND	0.600	0	0.200	0.346
Cypermethrin	ng/L	4	0%	ND	-	-	-	-	3	67%	ND	0.800	0.700	0.500	0.436
Cyhalothrin lambda	ng/L	3	25%	ND	3.86	0	1.29	2.23	3	33%	ND	0.300	0	0.100	0.173
Permethrin	ng/L	4	100%	3.35	13.1	5.77	7.00	10.8	3	33%	ND	6.00	0	2.00	3.46
Bifenthrin	ng/L	4	75%	ND	32.4	12.1	14.1	5.66	3	100%	2.80	7.10	5.50	5.13	2.17

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at San Leandro Creek was two.
All Hardness results in WY 2013 were censored.

reductions in the survival of the amphipod *Hyalella azteca* were observed, in this case in three of the four Water Year 2012 storm events sampled. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of sediments in receiving waters. No significant reductions in the survival, reproduction and growth of the crustacean *Ceriodaphnia dubia* or the algae *Selenastrum capricornutum* were observed during any of these storms.

8.3.2. San Leandro Creek preliminary loading estimates

Site specific methods were developed for computed loads (Table 16). Preliminary loads estimates generated for WY 2012 and reported by McKee et al. (2013) have now been revised based on revisions to the discharge estimates, additional pollutant concentration data collected in WY 2013 and an improving understanding of pollutant transport processes for the site. Preliminary monthly loading estimates correlate well with monthly discharge (Table 17). There are no data available for October of each water year because monitoring equipment was not installed. Discharge and rainfall are not aligned due to reservoir release. Monthly discharge was greatest in January 2013 when large releases were occurring from the upstream reservoir. The greatest monthly loads for each of the pollutants regardless of transport mode (dominantly particulate or dissolved) occurred in December 2012 when rainfall induced run-off caused high turbidity and elevated concentrations of suspended sediments and pollutants. The sediment and pollutant loads were less well correlated with the total discharge than for other sampling sites due to reservoir releases and complex sources. When discharge was dominated by upstream flows induced by rainfall, relatively high loads of mercury occurred; conversely, PCB loads were greater relative to rainfall during smaller rainfall events when less run-off occurred from the upper watershed. At this time, all loads estimate should be considered preliminary. Additional data collected during WY 2014 will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate and finalize loads for WYs 2012 and 2013. Regardless of these improvements however, given the very dry flow conditions of WY 2012 and 2013 (see discussion on flow above), preliminary loads presented here may be considered representative of dry conditions.

8.3. Guadalupe River

8.3.1. Guadalupe River flow

The US Geological Survey has maintained a flow record on lower Guadalupe River (gauge number 11169000; 11169025) since October 1, 1930 (83 WYs; note 1931 is missing). Peak annual flows for the period have ranged between 125 cfs (WY 1960) and 11000 cfs (WY 1995). Annual runoff from Guadalupe River has ranged between 0.422 (WY 1933) and 241 Mm^3 (WY 1983).

During WY 2012, a series of relatively minor storms[2] occurred (Figure 6). A storm that caused flow to escape the low flow channel and inundate the in-channel bars did not occur until 1/21/12, very late in

[2] A storm was defined as rainfall that resulted in flow that exceeds bankfull, which, at this location, is 200 cfs, and is separated by non-storm flow for a minimum of two days.

Table 16. Regression equations used for loads computations for San Leandro Creek during water year 2012 and 2013. Note that regression equations will be reformulated with future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mixed	1.2286		0.81	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.0871	4.097	0.58	Regression with turbidity
Total PCBs (ng/NTU)	Mainly non-urban	0.031	1.567	0.81	Regression with turbidity
Total Mercury urban (ng/NTU)	Mainly urban	0.66	6.17	0.83	Regression with turbidity
Total Mercury non-urban (ng/NTU)	Mainly non-urban	1.34		0.86	Regression with turbidity
Total Methylmercury (ng/NTU)	Mixed	0.0026	0.12	0.92	Regression with turbidity
TOC	Mixed	6.66			Flow weighted mean concentration
Total Phosphorous (mg/NTU)	Mixed	0.0012	0.18	0.64	Regression with turbidity
Nitrate (mg/L)	Mixed	0.38			Flow weighted mean concentration
Phosphate (mg/L)	Mixed	0.092			Flow weighted mean concentration

Table 17. Preliminary monthly loads for San Leandro Creek for water year 2012 and 2013.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	-	-	-	-	-	-	-	-	-	-
	11-Nov	-	-	-	-	-	-	-	-	-	-
	11-Dec	0	3.14	23.9	20,909	5.66	32.1	0.438	1,193	289	587
	12-Jan	73	0.316	17.3	2,106	1.87	15.5	0.0827	120	29.1	76.7
	12-Feb	22	0.0206	0.591	137	0.0931	0.569	0.00329	7.81	1.89	3.32
	12-Mar	151	0.245	22.3	1,634	1.48	27.6	0.0863	93.2	22.6	69.0
	12-Apr	85	0.266	50.2	1,773	2.59	61.4	0.162	101	24.5	107
	Wet season total	332	5.47	120	36,423	14.2	145	0.965	2,078	503	1,113
2013	12-Oct	-	-	-	-	-	-	-	-	-	-
	12-Nov	121	0.238	32.9	1,587	1.93	40.6	0.113	90.5	21.9	80.5
	12-Dec	127	4.07	122	27,128	11.3	155	0.699	1,548	375	715
	13-Jan	7	4.37	54.6	29,111	8.54	73.1	0.665	1,661	402	842
	13-Feb	19	0.0359	1.46	239	0.155	1.61	0.00802	13.6	3.30	8.04
	13-Mar	11	0.0104	0.879	69.0	0.110	0.642	0.00347	3.94	0.954	2.82
	13-Apr[a]	41	0.0811	6.99	540	0.558	8.03	0.0277	30.8	7.46	22.6
	Wet season total	326	8.81	218	58,674	22.6	280	1.52	3,348	811	1,671

[a] April 2013 monthly loads are reported for only the period April 01-18. In the 12 days missing from the record, no rain fell in the San Leandro Creek watershed.

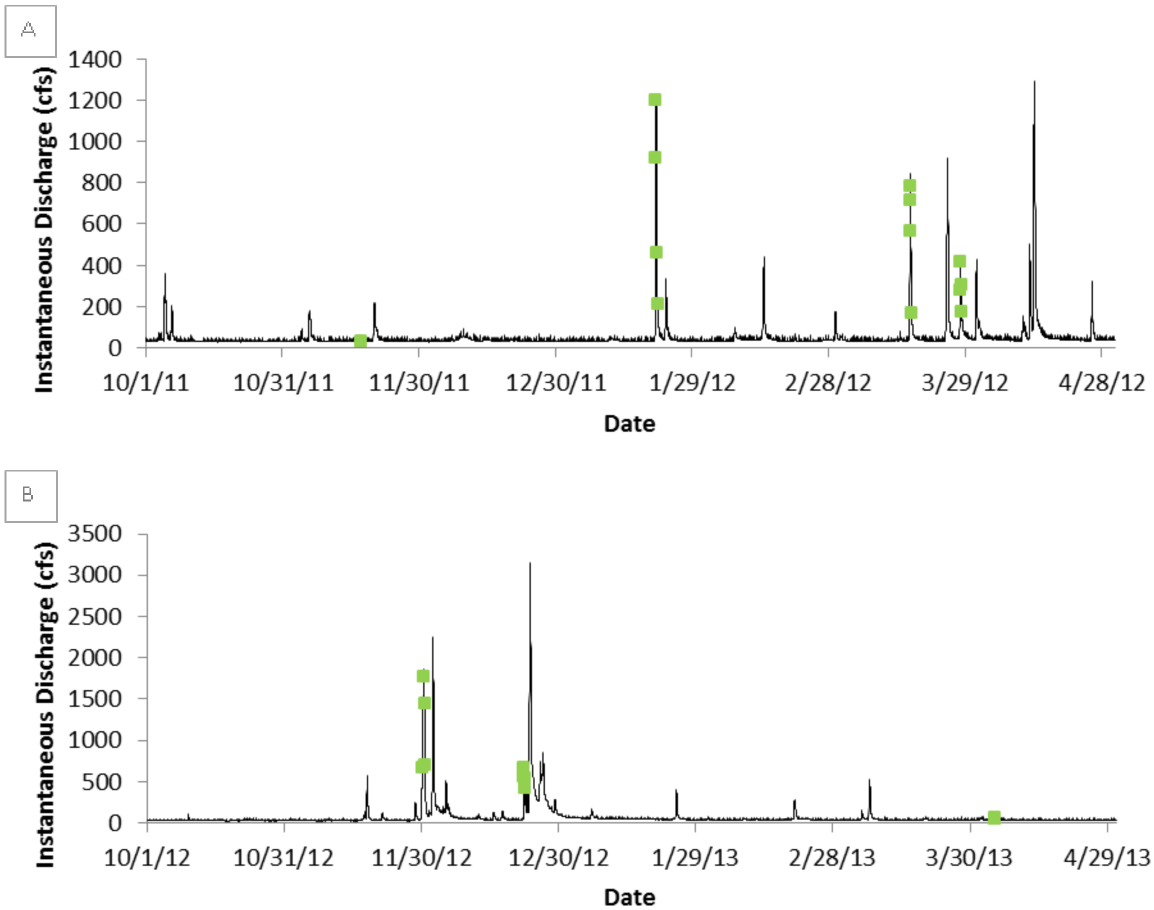


Figure 6. Flow characteristics in Guadalupe River during water year 2012 (A) based on published data and preliminary 15 minute data for water year 2013 (B) provided by the USGS (gauge number 11169025), with sampling events plotted in green. The fuzzy nature of the low flow data are caused by baseflow discharge fluctuations likely caused by pump station discharges near the gauge.

the season compared to what has generally occurred over the past years of sampling and analysis for this system (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011). The flow during this January storm was 1220 cfs; flows of this magnitude are common in most years. Flow peaked in WY 2012 at 1290 cfs on 4/13/2012 at 7:15 am and total runoff during WY 2012 based on USGS data was 38.0 Mm^3; discharge of this magnitude is about 85% mean annual runoff (MAR) based on 83 years of record and 68% MAR if we consider the period WY1971-2010 (perhaps more representative of current climatic conditions given climate change). Rainfall data corroborates this assertion; rainfall during WY 2012 was 7.05 inches, or 47% of mean annual precipitation (MAP = 15.07 in) based on a long-term record at San Jose (NOAA gauge number 047821) for the period 1971-2010 (CY). CY 2012 was the driest year in the past 42 years and the 7^{th} driest for the record beginning CY 1875 (138 years).

Water year 2013 was only slightly wetter, raining 8.78 inches as the San Jose gauge (58% MAP for the period 1971-2010 [CY]). Three moderate sized storms occurred in late November and December which led to three peak flows above 1500 cfs within a span of one month (Figure 6). Flow peaked on the third of these storms at 3160 cfs on 12/23/12 at 18:45, a peak flow which has been exceeded in half of all years monitored (83 years). Total runoff during WY 2013 based on preliminary USGS data was 45.5 Mm^3; discharge of this magnitude is about 82% mean annual runoff (MAR) based on 83 years of record and equivalent to the MAR for the period WY1971-2010. Flow data and resulting loads calculations for WY 2013 will be updated once USGS publishes the official record. The USGS normally publishes finalized data for the permanent record in the spring following the end of each Water Year.

8.3.2. Guadalupe River turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. In WY 2012, Guadalupe River exhibited a pronounced first flush during a very minor early season storm when, relative to flow, turbidity was elevated and reached 260 FNU. In contrast, the storm that produced the greatest flow for the season that occurred on 4/13/2012 had lower peak turbidity (185 FNU). A similar pattern occurred in WY 2013, except that the third large storm event on 12/23/12 raised turbidity to its peak for the season (551 FNU). Peak turbidity for WY 2012 was 388 FNU during a storm on 1/21/12 at 3:15 am. Based on past years of record, turbidity can exceed 1000 FNU at the sampling location (e.g. McKee et al., 2004); the FTS DTS-12 turbidity probe used at this study location is quite capable of sampling most if not all future sediment transport conditions for the site.

A continuous record of SSC was computed by SFEI using the POC monitoring SSC data, the preliminary USGS turbidity record, and a linear regression model between instantaneous turbidity and SSC for each water year. Based on USGS sampling in Guadalupe River in past years, >90% of particles in this system are <62.5 µm in size (e.g. McKee et al., 2004). Because of these consistently fine particle sizes, turbidity correlates well with the concentrations of suspended sediments and hydrophobic pollutants (e.g. McKee et al., 2004). Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. It is estimated that SSC peaked in WY 2012 at 844 mg/L during the 1/21/12 storm event at 3:15, and in WY 2013 at 933 mg/L on 12/23/12 at 19:00. The maximum SSC observed during previous monitoring years was 1180 mg/L in 2002. Rainfall intensity was much greater during WY 2003 than any other year since, leading to the hypothesis that concentrations of this magnitude will likely occur in the future during wetter years with greater and more intense rainfall (McKee et al., 2006).

8.3.3. Guadalupe River POC concentrations summary (summary statistics)

A summary of concentrations is useful for providing comparisons to other systems and also for doing a first order quality assurance check. Concentrations measured in Guadalupe River during WYs 2012 and 2013 are summarized (Table 18). The range of PCB concentrations are typical of mixed urban land use watersheds (Lent and McKee, 2011) and mean concentrations in this watershed were the 3rd highest measured of the six locations (Sunnyvale Channel > Pulgas Creek PS > Guadalupe River >North Richmond PS > San Leandro Creek >Lower Marsh Creek). Maximum mercury concentrations (1000 ng/L measured in WY 2012) are greater than observed in Z4LA (Gilbreath et al., 2012) and the San Pedro stormdrain (SFEI unpublished data), which drains an older urban residential area of San Jose. This maximum concentration was higher than the average mercury concentration (690 ng/L) over the period of record at this location (2002-2010). Nutrient concentrations were in the same range as measured in in Z4LA

Table 18. Summary of laboratory measured pollutant concentrations in Guadalupe River for water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	41	100%	8.6	730	82.0	198	205	41	100%	5.9	342	128	124	104
∑PCB	ng/L	11	100%	2.70	59.1	6.96	17.7	21.5	12	100%	2.04	47.4	6.29	10.6	12.7
Total Hg	ng/L	12	100%	36.6	1000	125	268	324	12	100%	14.5	360	155	153	119
Total MeHg	ng/L	10	100%	0.086	1.15	0.381	0.445	0.352	7	100%	0.040	0.940	0.490	0.428	0.340
TOC	mg/L	12	100%	4.90	18.0	7.45	8.73	4.03	12	100%	5.30	11.0	6.05	6.36	1.55
NO3	mg/L	12	100%	0.560	1.90	0.815	0.918	0.380	12	67%	ND	2.30	0.520	0.921	0.992
Total P	mg/L	12	100%	0.190	0.810	0.315	0.453	0.247	8	100%	0.300	0.610	0.390	0.405	0.092
PO4	mg/L	12	100%	0.060	0.160	0.101	0.101	0.032	12	100%	0.061	0.180	0.120	0.109	0.034
Hardness	mg/L	3	100%	133	157	126	143	12.3	-	-	-	-	-	-	-
Total Cu	µg/L	3	100%	10.7	26.3	24.7	20.6	8.58	3	100%	5.90	28.0	23.0	19.0	11.6
Dissolved Cu	µg/L	3	100%	5.07	7.91	5.51	6.16	1.53	3	100%	2.50	3.60	2.50	2.87	0.635
Total Se	µg/L	3	100%	1.16	1.63	1.21	1.33	0.258	3	100%	0.700	3.30	0.780	1.59	1.48
Dissolved Se	µg/L	3	100%	0.772	1.32	1.04	1.04	0.274	3	100%	0.400	3.20	0.540	1.38	1.58
Carbaryl	ng/L	3	100%	13.0	57.0	57.0	41.4	24.7	3	67%	ND	21.0	17.0	12.7	11.2
Fipronil	ng/L	3	100%	6.50	20.0	11.0	12.5	6.87	3	100%	3.00	11.0	9.00	7.67	4.16
∑PAH	ng/L	1	100%	-	-	-	2186	-	8	100%	40.7	736	174	251	245
∑PBDE	ng/L	1	100%	-	-	-	34.5	-	2	100%	13.1	69.8	41.4	41.4	40.1
Delta/ Tralo-methrin	ng/L	3	100%	0.704	1.90	1.82	1.47	0.667	3	0%	ND	-	-	-	-
Cypermethrin	ng/L	3	0%	ND	-	-	-	-	3	100%	0.500	3.30	1.70	1.83	1.40
Cyhalothrin lambda	ng/L	3	33%	ND	-	-	1.20	-	3	100%	0.300	1.50	0.500	0.767	0.643
Permethrin	ng/L	3	100%	16.8	20.5	19.5	18.9	1.91	3	33%	ND	5.40	0	1.80	3.12
Bifenthrin	ng/L	3	67%	ND	13.3	6.16	6.47	6.63	3	100%	0.900	7.60	5.90	4.80	3.48

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at Guadalupe River was two.
All Hardness results in WY 2013 were censored.

(Gilbreath et al., 2012), and typical for the Bay Area, phosphorus concentrations appear greater than elsewhere in the world under similar land use scenarios, perhaps attributable to geological sources (McKee and Krottje, 2005). Based on previous sampling experience in the system (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011) and these simple comparisons to other studies, there are no reasons to suspect any data quality issues.

In a similar manner, summary statistics and comparisons were developed for the lower sample frequency analytes collected using composite sampling design (see the methods section). Copper, which was sampled at a lesser frequency for characterization only, was similar to concentrations previously observed (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006) and similar to those observed in Z4LA (Gilbreath et al., 2012). Maximum selenium concentrations were generally 2-8 fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Carbaryl and fipronil were on the lower side of the range of peak concentrations reported in studies across the US and California (Fipronil: 70 – 1300 ng/L, Moran, 2007) (Carbaryl: DL - 700 ng/L, Ensiminger et al., 2012). Pyrethroid concentrations of Cyhalothrin lambda were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were on the lower end (Gilbreath et al., 2012). No quality issues appear from the comparisons.

8.3.4. Guadalupe River toxicity

Composite water samples were collected at the Guadalupe River station during three storm events in WY 2012 and three storm events in Water Year 2013. Similar to the results for other POC monitoring stations, no significant reductions in the survival, reproduction and growth of three of four test species were observed during storms. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during two of the three storm Water Year 2012 events sampled. There were no significant effects observed for any samples collected during Water Year 2013. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of receiving water sediments.

8.3.5. Guadalupe River preliminary loading estimates

The following methods were applied to estimate loads for the Guadalupe River in WYs 2012 and 2013. Suspended sediment loads for WY 2012 were downloaded from USGS. Since the WY 2013 suspended sediment record has not yet been published, concentrations were estimated from the turbidity record using a linear relation (Table 19). Once the official USGS flow and SSC record is published for WY 2013, the suspended sediment load will be updated. Concentrations were estimated using regression equations between the contaminant and turbidity, except for nitrate in which a flow weighted mean concentration was used (Table 19). As found during other drier years (McKee et al., 2006), a separation of the data for PCBs and total mercury to form regression relations based on origin of flow was not possible with WY 2012 data, in which the majority of runoff was of urban origin. This separation was, however, possible for PCBs during WY 2013 flows.

Preliminary monthly loading estimates correlate fairly well with monthly discharge (Table 20). Monthly discharge was greatest in December 2012 as were loads of most pollutants. This single wet month transported approximately 50% of the PCB and mercury load of the two wet seasons combined. WY

Table 19. Regression equations used for loads computations for Guadalupe River during water year 2012 and 2013. Note that regression equations will be reformulated upon future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment WY 2013 (mg/NTU)[a]	Mixed	1.69		0.92	Regression with turbidity
Total PCBs urban (ng/NTU)	Mainly urban	0.23898		0.76	Regression with turbidity
Total PCBs non-urban (ng/NTU)	Mainly non-urban	0.079123		0.84	Regression with turbidity
Total Mercury (ng/NTU)	Mixed	2.17		0.81	Regression with turbidity
Total Methylmercury (ng/NTU)	Mixed	0.0031	0.21	0.48	Regression with turbidity
Total Organic Carbon (mg/NTU)	Mixed	0.028	4.7	0.62	Regression with turbidity
Total Phosphorous (mg/NTU)	Mixed	0.0019	0.2	0.71	Regression with turbidity
Nitrate (mg/L)	Mixed	0.633			Flow weighted mean concentration
Phosphate (mg/NTU)	Mixed	0.00028	0.077	0.59	Regression with turbidity

[a]Suspended sediment loads in WY 2012 were downloaded from the USGS for this site.

2013 loads were approximately 3x higher than WY 2012. However, compared to previous sampling years (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011 [Hg only]), loads of total mercury and PCBs were several times lower. At this time, all loads estimates for WY 2013 should be considered preliminary. Once available, USGS official records for flow, turbidity, and SSC can be substituted for the preliminary data presented here. In addition pollutant data collected in future sampling years will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate these loads. Regardless of these improvements, overall, WY 2012 and 2013 loads may be considered representative of loads during dry conditions in this watershed.

8.3. Sunnyvale East Channel

8.3.1. Sunnyvale East Channel flow

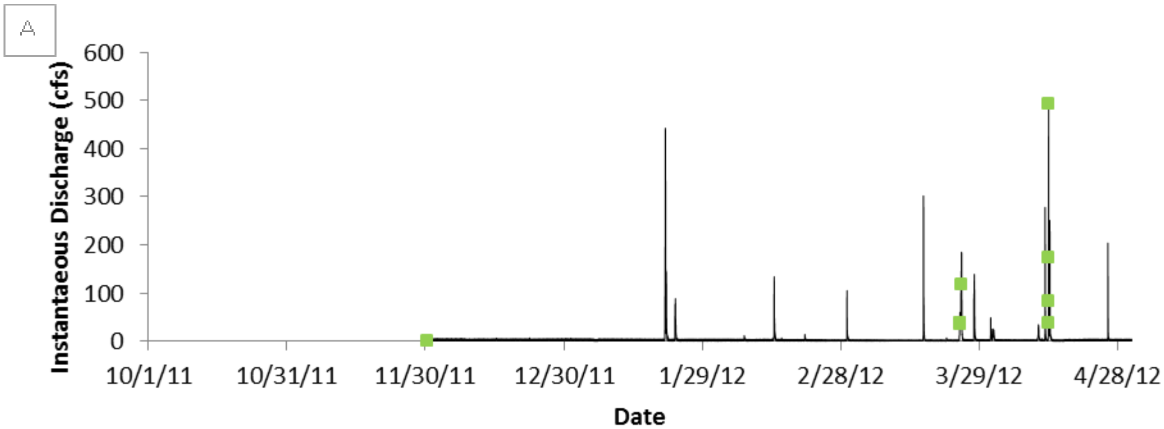
Santa Clara Valley Water District (SCVWD) has maintained a flow gauge on Sunnyvale East Channel from WY 1983 to present. Unfortunately, the record is known to be poor quality (pers. comm., Ken Stumpf, SCVWD), which was apparent when the record was regressed against rainfall (R^2 = 0.58) (Lent et al., 2012). The gauge is presently scheduled for improvement by SCVWD. Due to the knowledge of the poor quality runoff data for this channel, in WY 2012 discharge was estimated based on the continuous stage record and application of the Manning's formula. However, in WY 2013 additional velocity discharge measurements were collected in the field and corroborated the SCVWD rating curve up to stages of 2.9

Table 20. Preliminary monthly loads for Guadalupe River for water year 2012 and 2013.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	19	2.91	167	15966	9.08	188	0.865	1840	247	757
	11-Nov	15	2.88	104	14844	5.68	110	0.750	1823	235	685
	11-Dec	1	2.73	76.4	13244	1.38	38.0	0.619	1730	215	593
	12-Jan	18	3.85	565	25069	29.2	555	1.58	2439	367	1268
	12-Feb	14	3.15	315	17766	10.0	240	0.989	1995	273	852
	12-Mar	50	5.08	404	29516	29.6	456	1.69	3213	448	1433
	12-Apr	44	5.23	485	30078	28.2	446	1.71	3307	458	1454
	Wet season total	161	25.8	2116	146483	113	2033	8.20	16347	2243	7042
2013	12-Oct	8	2.26	52.5	11406	3.44	67.5	0.56	1430	182	521
	12-Nov	48	5.23	913	39385	85.0	1175	2.73	3309	551	2082
	12-Dec	92	14.8	3100	119995	224	3991	8.67	9373	1643	6468
	13-Jan	15	4.14	98.4	20924	7.95	127	1.03	2618	334	957
	13-Feb	11	3.05	58.2	15186	4.45	75.0	0.74	1929	244	689
	13-Mar	21	3.47	93.6	17733	6.93	120	0.89	2196	282	815
	13-Apr	5	2.57	36.6	12598	2.12	47.2	0.60	1626	204	567
	Wet season total	201	35.5	4352	237227	334	5603	15.2	22482	3440	12099

feet (corresponding to flows of 190 cfs). Therefore, WY 2013 discharge was estimated based on continuous stage and application of the SCVWD rating curve, and WY 2012 discharge was recalculated using the same method. Efforts will be made in subsequent sampling years to evaluate the accuracy of the SCVWD rating curve at stages greater than 3 feet.

Both WY 2012 and 2013 were relatively dry years and discharge was likely lower than average. Rainfall during WY 2012 and 2013 was 8.82 and 10.2 inches, respectively, at Palo Alto (NOAA gauge number 046646). Relative to mean annual precipitation (MAP = 15.25 in) based on a long-term record for the period 1971-2010 (CY), WY 2012 was only 58% MAP and WY 2013 67% MAP. A series of relatively minor storms occurred during WY 2012 (Figure 7). Flow peaked at 492 cfs overnight on 4/12/12- 4/13/12 at midnight. Total runoff during WY 2012 for the period 12/1/11 to 4/30/12 was 1.07 Mm^3 based on our stage record and the SCVWD rating curve. Total annual runoff for the period between 10/01/12 and 4/30/13 was 1.79 Mm^3 and likely below average based on below average rainfall. However, unlike WY 2012 in which the rainfall was spread over several smaller events, the majority of WY 2013 rainfall occurred during three large storm events in late November and December, each of which was of 1-2



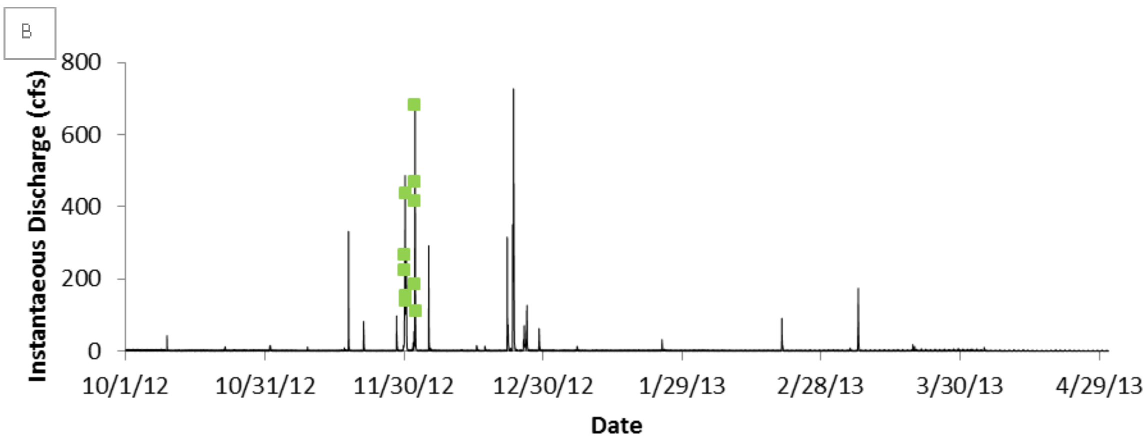


Figure 7. Preliminary flow characteristics in Sunnyvale East Channel at East Ahwanee Avenue during WY 2012 (A) and WY 2013 (B) with sampling events marked in green. The flow record is based on the District rating curve for this station as verified by velocity sampling completed to-date. The rating relationship may be improved in subsequent years as more velocity sampling is completed.

year recurrence based on NOAA Atlas 14 partial duration series data for the area. Flow peaked during the third event of this series at 727 cfs on 12/23/12 at 15:15. Given that SCVWD maintains the channel to support a peak discharge of 800 cfs, the December 2012 storms resulted in significant flows for the system. Field observations during sampling of the early December storms corroborate this assertion; stages neared the top of bank and the banks of the channel for the observable reach at and upstream from the sampling location showed evidence of erosion. This is yet another vivid example of why peak discharge often correlates with total wet season load better than total wet season flow (Lewicki and McKee, 2009).

8.3.2. Sunnyvale East Channel turbidity and suspended sediment concentration

The entire turbidity record for WY 2012 was censored due to problems with the installation design and the OBS-500 instrument reading the bottom of the channel. Suspended sediment concentration in WY 2012 could not be computed from the continuous turbidity data, and was alternatively computed as a function of flow (with much lower confidence due to the loss of hysteresis in the computational scheme). In WY 2013, the OBS-500 instrument was replaced with an FTS DTS-12 turbidity probe (0-1,600 NTU range). This instrument performed well through to the first large storm on 11/30/12 and then the turbidity record experienced numerous spikes through the rest of the season. Our observations during maintenance suggested that the three large storm events in late November and December uprooted and dislodged a lot of vegetation and some trash, which slowly passed through the system throughout the season and caught on the boom structure where turbidity was monitored. After field visits to download data and perform maintenance on site including removing the vegetation from the boom, the turbidity record cleared until the next elevated flow. Consequently, 8.3% of the turbidity record was censored due to fouling. During the period of record in which the turbidity sensor was functioning correctly, SSC was estimated based on regression with turbidity. During the period of record in which turbidity was censored, SSC was computed as a function of flow in a similar manner to estimates made in WY 2012.

Turbidity in Sunnyvale East Channel in WY 2013 remained low (<40 NTU) during base flows and increased to between 500 and 1000 NTU during storms. Turbidity peaked at 1014 NTU early in the season on 10/9/12 in response to a small but intense rainfall in which 0.19 inches fell in 20 minutes. The three large events in November and December resulted in turbidities in the 600-900 NTU range, providing evidence to suggest that the DTS-12 instrument now utilized at this sampling location will be sufficient to handle future storms.

Suspended sediment concentration in WY 2012 peaked at 352 mg/L on 4/13/12 just after midnight and at 3726 mg/L on 10/9/12 in response to the early season small but intense rainfall. Although these concentrations are an order of magnitude different, lab measured samples from storm monitoring events in each WY corroborated these results; the maximum sampled lab measured SSC in WY 2012 was 370 mg/L (collected on 4/13/12) and in WY 2013 was 3120 mg/L (collected on 12/2/12; the 10/9/12 estimated peak SSC occurred during a non-sampled storm event). Note that the estimated SSC (estimated from the continuous turbidity record) for the 10/9/12 peak had a ratio to turbidity of 3.7:1. This ratio is higher than typical for urban creeks and resulted because the WY 2013 sampling occurred during two of the three largest storm events, at which time bank erosional processes led to mixed grain fractions in the samples and higher SSC per unit of turbidity. This observation suggests that as the Sunnyvale East Channel dataset grows in future sampling years, the data should be stratified between storms that do and do not exhibit bank erosional processes. The maximum concentration measured during the WY 2011 RMP reconnaissance study (McKee et al., 2012) was 1050 mg/L and was collected during a relatively small but intense rain event, but at this time we have not evaluated the relative storm magnitude between WY 2011, 2012 and 2013 to determine if the relative concentrations are logical.

8.3.3. Sunnyvale East Channel POC concentrations summary (summary statistics)

A wide range of pollutants were measured in Sunnyvale East Channel during WY 2012 and 2013 (Table 21). Concentrations for pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients) exhibited the typical pattern of median < mean except for organic carbon, nitrate and phosphate in WY 2013 in which the mean and median were similar. The range of PCB concentrations were typical of mixed urban land use watersheds

Table 21. Summary of laboratory measured pollutant concentrations in Sunnyvale East Channel during water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	28	97%	ND	370	49.0	81.6	100	34	97%	ND	3120	312	485	645
∑PCB	ng/L	8	100%	3.27	119	33.6	41.3	41.5	10	100%	9.16	176	31.3	59.3	64.3
Total Hg	ng/L	8	100%	6.30	64.1	21.7	27.7	21.7	10	100%	13	220	55.5	72.9	65.2
Total MeHg	ng/L	6	86%	ND	0.558	0.184	0.250	0.220	6	100%	0.020	0.540	0.290	0.252	0.220
TOC	mg/L	8	100%	4.91	8.60	5.94	6.41	1.40	10	100%	4.10	10.0	5.85	5.85	1.71
NO3	mg/L	8	100%	0.200	0.560	0.280	0.309	0.119	10	100%	0.150	0.370	0.280	0.269	0.069
Total P	mg/L	8	100%	0.190	0.500	0.250	0.278	0.098	11	100%	0.230	1.70	0.390	0.527	0.412
PO4	mg/L	8	100%	0.067	0.110	0.079	0.085	0.019	10	100%	0.094	0.130	0.120	0.115	0.010
Hardness	mg/L	2	100%	51.4	61.2	56.3	56.3	6.93	-	-	-	-	-	-	-
Total Cu	µg/L	2	100%	10.8	19.0	14.9	14.9	5.79	2	100%	19.0	31.0	25.0	25.0	8.49
Dissolved Cu	µg/L	2	100%	4.36	14.8	9.58	9.58	7.38	2	100%	3.10	4.90	4.00	4.00	1.27
Total Se	µg/L	2	100%	0.327	0.494	0.411	0.411	0.118	2	100%	0.490	0.490	0.490	0.490	0
Dissolved Se	µg/L	2	100%	0.308	0.325	0.317	0.317	0.012	2	100%	0.35	0.39	0.370	0.370	0.028
Carbaryl	ng/L	2	100%	11.0	21.0	16.0	16.0	7.07	2	50%	ND	19.0	9.50	9.5	13.4
Fipronil	ng/L	2	100%	6.00	12.0	9.00	9.00	4.24	2	50%	ND	6.00	3.00	3.00	4.24
∑PAH	ng/L	1	100%	-	-	-	1289	-	1	100%	-	-	-	1355	-
∑PBDE	ng/L	1	100%	-	-	-	4.77	-	1	100%	-	-	-	34.9	-
Delta/ Tralo-methrin	ng/L	1	0%	ND	-	-	-	-	2	100%	3.60	3.80	3.70	3.70	0.141
Cypermethrin	ng/L	2	0%	ND	-	-	-	-	2	100%	3.20	5.20	4.20	4.20	1.41
Cyhalothrin lambda	ng/L	1	0%	ND	-	-	-	-	2	100%	1.20	2.50	1.85	1.85	0.919
Permethrin	ng/L	2	100%	5.70	20.9	13.3	13.3	10.8	2	100%	22.0	48.0	35.0	35.0	18.4
Bifenthrin	ng/L	2	50%	ND	8	4	4.0	5.7	2	100%	8.70	18.0	13.4	13.4	6.58

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at Sunnyvale East Channel was two.
All Hardness results in WY 2013 were censored.

(Lent and McKee, 2011) and maximum PCB concentrations (176 ng/L) exceeded the maximum observed in Z4LA (110 ng/L) (Gilbreath et al., 2012). Similarly, the range of mercury concentrations were comparable to those observed in Z4LA while the maximum total mercury concentration in Sunnyvale East Channel (220 ng/L) was greater than sampled in Z4LA (150 ng/L). Nutrient concentrations were also in the same range as measured in in Z4LA (Gilbreath et al., 2012) and like the other watersheds reported from the current study, phosphorus concentrations appear to be greater than elsewhere in the world under similar land use scenarios.

Of the pollutants sampled at a lesser frequency using a composite sampling design (see methods section) appropriate for characterization only, copper and selenium were similar to concentrations observed in Z4LA (Gilbreath et al., 2012) while PAHs and PBDEs were on the lower end of the range observed in Z4LA. Carbaryl and Fipronil (not measured previously by RMP studies) were lower or on the low end relative to peak concentrations reported in studies across the US and California (Fipronil: 70 – 1300 ng/L, Moran, 2007) (Carbaryl: DL - 700 ng/L, Ensiminger et al., 2012). Concentrations of Bifenthrin, Cyhalothrin lambda, and Permethrin were within but on the low end of the range observed in Z4LA. Based on these first order comparisons, we see no quality issues with the data.

8.3.1. Sunnyvale East Channel toxicity

Composite water samples were collected in the Sunnyvale East Channel during two storm events in WY 2012 and two storm events in WY 2013. No significant reductions in the survival, reproduction and growth of three of four test species were observed during storms. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during both WY 2012 and WY 2013 storm events[3]. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used for assessments of receiving water sediment toxicity. No significant effects were observed for the crustacean *Ceriodaphnia dubia*, the algae *Selenastrum capricornutum* or the fathead minnow during these storms.

8.3.2. Sunnyvale East Channel preliminary loading estimates

Given that the turbidity record in WY 2012 was unreliable due to optical interference from bottom substrate (problem now rectified), and gaps existed in the WY 2013 record due to vegetation interference throughout the season, continuous suspended sediment concentration was estimated from the discharge record using a linear relation for the period of record in which turbidity was censored, and otherwise using the power relation with turbidity during the period in which the turbidity record was acceptable (Table 22). Concentrations of other POCs were estimated using regression equations between the contaminant and either flow or estimated SSC, whichever relation was stronger. Total organic carbon and the dissolved nutrients did not have a strong relation with either suspended sediment or flow and therefore a flow weighted mean concentration was applied.

Preliminary monthly loading estimates for Sunnyvale East Channel are presented in Table 23. This table highlights how monthly loads can be dominated by a few large storm events. Relative to discharge,

[3] In one of the two samples where significant toxicity was observed, a holding time violation occurred and therefore the results should be considered in the context of this exceedance of measurement quality objectives.

Table 22. Regression equations used for loads computations for Sunnyvale East Channel during water year 2012 and 2013. Note that regression equations will be reformulated upon future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (WY2012) (mg/CFS)	Mainly urban	0.7145		0.97	Regression with flow
Suspended Sediment (WY2013) (mg/CFS)	Mainly urban	1.4421		0.67	Regression with flow
Suspended Sediment (WY2013) (mg/NTU)	Mainly urban	0.4913x1.2907		0.75	Regression with turbidity
Total PCBs (ng/CFS)	Mainly urban	0.23	2.7	0.62	Regression with flow
Total Mercury (ng/mg)	Mainly urban	0.13	13	0.93	Regression with estimated SSC
Total Methylmercury (ng/CFS)	Mainly urban	0.0011	0.12	0.77	Regression with flow
Total Organic Carbon (mg/L)	Mainly urban	5.77			Flow weighted mean concentration
Total Phosphorous (mg/mg)	Mainly urban	0.00076	0.2	0.86	Regression with estimated SSC
Nitrate (mg/L)	Mainly urban	0.245			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.106			Flow weighted mean concentration

suspended sediment load exerted quite high variability relative to some of the other sampling locations in the study. Although December 2012 only discharged 27% of the total volume for WYs 2012 and 2013 combined, 73% of the suspended sediment load was transported during this month as well as approximately 60% of the PCB and mercury loads. Normalized to total annual discharge, WY 2013 transported 11-fold more sediment than WY 2012, 3-fold the amount of PCBs and almost 4-fold the amount of Hg. Provided the context that both WY 2012 and 2013 were relatively dry years, we may be likely to see an even broader range of rainfall-runoff-pollutant transport processes in Sunnyvale East Channel if wetter seasons are sampled.

8.6. Pulgas Creek Pump Station

8.6.1. Pulgas Creek Pump Station flow

Flow into the Pulgas Creek Pump Station from the southern catchment has not historically been monitored. An ISCO area velocity flow meter situated directly in the incoming pipe was used to measure stage and flow in WY 2013. Total runoff during WY 2013 for the period of record 12/17/12 to 3/15/13 was 0.09 Mm^3. A monthly (or partial monthly for December 2012 and March 2013) rainfall to runoff regression was applied to the missing period of the wet season. Based on this regression estimator method, a coarse estimate total runoff during WY 2013 for the period 10/01/12 to 4/30/13 was 0.21

Table 23. Preliminary monthly loads for Sunnyvale East Channel during water years 2012 and 2013.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	-	-	-	-	-	-	-	-	-	-
	11-Nov	-	-	-	-	-	-	-	-	-	-
	11-Dec	2	0.148	0.282	852	0.492	1.92	0.0175	36.2	15.7	29.6
	12-Jan	37	0.254	13.4	1468	4.98	4.96	0.0502	62.3	27.0	60.7
	12-Feb	22	0.151	1.36	872	0.846	2.10	0.0196	37.0	16.0	31.1
	12-Mar	69	0.260	8.29	1501	3.36	4.38	0.0429	63.7	27.6	58.0
	12-Apr	39	0.260	13.3	1498	4.95	5.01	0.0506	63.6	27.5	61.7
	Wet season total	169	1.07	36.7	6192	14.6	18.4	0.181	263	114	241
2013	12-Oct	13	0.125	7.33	722	0.445	2.53	0.0150	30.7	13.3	30.4
	12-Nov	61	0.456	130	2634	19.1	22.5	0.139	112	48.4	189
	12-Dec	101	0.786	516	4535	50.9	76.1	0.327	193	83.3	546
	13-Jan	8	0.115	2.78	664	0.407	1.82	0.0138	28.2	12.2	25.0
	13-Feb	10	0.102	7.15	591	0.536	2.22	0.0131	25.1	10.9	25.8
	13-Mar	20	0.150	8.80	867	1.51	3.04	0.0227	36.8	15.9	36.5
	13-Apr	6	0.059	0.238	339	0.187	0.780	0.007	14.4	6.24	11.9
	Wet season total	219	1.79	673	10352	73.1	109	0.538	440	190	865

Mm^3. This estimate will be improved as the monthly rainfall to runoff regression improves in future years with a larger dataset. Since runoff from this watershed is likely to highly correlate with rainfall due to its small drainage area and high imperviousness, but since MAP for the nearby Redwood City NCDC meteorologic gauge (gauge number 047339-4) was 78% of normal, total runoff for WY 2013 at Pulgas Creek was likely below average.

During the very short and incomplete period of record at Pulgas Creek pump station, a large storm series occurred towards the end of December 2012, followed by few and relatively minor storms for the remainder of the record. Flow peaked at 50 cfs on 12/23/12 at 17:04 (Figure 8). San Francisquito Creek to the south has been gauged by the USGS at the campus of Stanford University (gauge number 11164500) from WY 1930-41 and again from 1950-present. Annual peak flows in San Francisquito over the long term record have ranged between 12 cfs (WY 1961) and 7200 cfs (WY1998). During WY 2013, flow at San Francisquito Creek peaked at 5400 cfs on 12/23/12 at 18:45, a flow that has been exceeded in only two previous years on record. However large the peak flows were for nearby creek systems such as San Francisquito Creek, flows in Pulgas Creek Pump Station south may respond differently again due to its very small size and high imperviousness. Pulgas Creek Pump Station south would be less affected by antecedent saturation conditions than San Francisquito Creek and more by hourly and sub-hourly

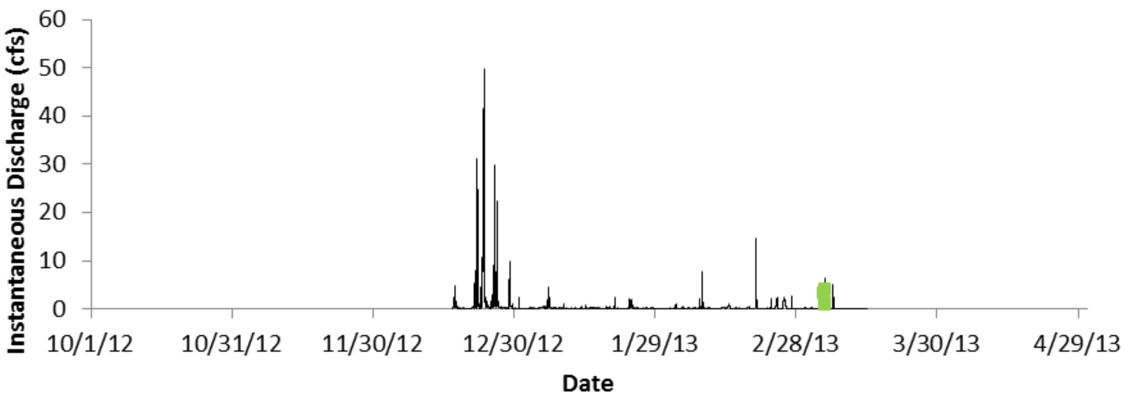


Figure 8. Preliminary flow characteristics at Pulgas Creek Pump Station South during Water Year 2013 with sampling events plotted in green. Pulgas Creek Pump Station turbidity and suspended sediment concentration

rainfall intensities. The maximum 1-hour rainfall intensity at Pulgas Creek was 0.43 inches per hour and occurred on 12/23/12 at 17:10, concurrent with the peak flow. Relative to the Redwood City NCDC meteorologic gauge and based on the partial duration series, the maximum 1-hour rainfall intensity at Pulgas has approximately a 1-year recurrence interval. Based on this rainfall intensity recurrence, we suggest peak flows in Pulgas Creek Pump Station South watershed were approximately average.

8.6.2. Pulgas Creek Pump Station turbidity and suspended sediment concentration

Turbidity in Pulgas Creek Pump Station south watershed generally responded to rainfall events in a similar manner to runoff. During non-storm periods, turbidity fluctuated between 2 and 20 NTU, whereas during storms, maximum turbidity for each event reached between 100 and 600 NTU. Near midnight on 12/30/12, during flow conditions slightly elevated above base flows but not associated with rainfall, turbidity spiked above the sensor maximum[4] and did not return to readings below 20 NTU for 18 hours. Storm-associated turbidity peaked at 588 NTU on 1/6/13 during the first storm following the 12/30/12 spike. During all storm events after the 12/30/12 spike, storm maximum turbidities were all greater than maximum turbidities in the large storm series around 12/23/12. Two hypotheses are suggested to explain these observations: a) during larger storm events such as the 12/23/12 storm, turbidity becomes diluted, or b) that the signal of particles released into the watershed and measured on 12/30/12 continued to present at lower magnitudes through the remainder of the season. Future monitoring at Pulgas Creek will help elucidate which of these current hypotheses are more likely and what the typical range of turbidity is for this watershed sampling location as water passes through to the Bay. Despite the turbidity measurements being out of the sensor range during the 12/30/12 spike, at this time we have no evidence to suggest that the DTS-12 instrument utilized at this sampling location (with a range of 0-1600 NTU) will not be sufficient to handle most future storms.

[4] Note the reported DTS-12 turbidity sensor maximum is 1600 NTU. Maximum sensor reading during this spike was 2440 NTU. Given this is beyond the accurate range of the sensor, we do not suggest this reading is accurate but rather reflects that a significant spike in turbidity occurred in the system at this time.

Suspended sediment concentration was computed from the continuous turbidity data and therefore follows the same patterns as turbidity in relation to discharge and the non-storm associated spike on 12/20/12. Suspended sediment concentration peaked at 2693 mg/L during the spike on 12/30/12 at 23:00. Storm-associated suspended sediment concentration peaked at 647 mg/L and occurred in the first subsequent storm event on 1/6/13 at 6:15. These concentration estimates based on the continuous turbidity record are much greater than observed during collection events. The maximum SSC concentration was 110 mg/L measured on 3/6/13 L while the maximum concentration measured during the RMP reconnaissance study (McKee et al., in review) was 60 mg/L. At this time we have chosen to censor the data minimally, however future sampling may indicate that further censorship or reinterpretation is necessary.

8.6.3. Pulgas Creek Pump Station POC concentrations summary (summary statistics)

Summary statistics of pollutant concentrations measured in Pulgas Creek Pump Station South in WY 2013 are presented in Table 24. Except for total methylmercury, in which two dry flow samples were additionally collected, these samples were collected during a single small storm event. Due to the small size of this dataset and relatively low SSC during sample collection, it is likely that samples collected in future years will yield higher concentrations for many pollutants of concern. Therefore, the following statements provide a first order judgment of quality assurance, but are heavily caveated by the currently unrepresentative sample dataset.

For all pollutants sampled with the exception of total methylmercury and total phosphorous, concentrations followed the typical pattern of median < mean. The range of PCB concentrations were typical of mixed urban land use watersheds previously monitored in the San Francisco Bay Area (i.e. Guadalupe River, Zone 4 Line A, Coyote Creek, reported in Lent and McKee, 2011). Mean total mercury concentrations (10.5 ng/L) were lower than observed in any of the other watersheds in this study and on the very low end of concentrations sampled in Z4LA (Gilbreath et al., 2012). Nutrient concentrations were in the same range as measured in in Z4LA, but generally lower than the other watersheds in this study. Although the dataset is possibly unrepresentative of the broader range of concentrations we might see in subsequent years as the dataset grows, we find no reason to suspect data quality issues since the concentration ranges appear reasonable in relation to our conceptual models of water quality for these analytes.

Pollutants sampled at a lesser frequency using a composite sampling design (see methods section) and appropriate for water quality characterization only (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) were similar to concentrations observed in Z4LA (Gilbreath et al., 2012). Carbaryl and fipronil were on the lower side of the range of peak concentrations reported in studies across the US and California (Fipronil: 70 – 1300 ng/L, Moran, 2007) (Carbaryl: DL - 700 ng/L, Ensiminger et al., 2012). Concentrations of Cypermethrin were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were about 20x and 10x lower, respectively (Gilbreath et al., 2012). In summary, concentrations measured at Pulgas Creek Pump Station South during WY 2013 are in a the typical range of Bay Area urban watersheds, however the dataset is currently very small and is probably unrepresentative of the full range of concentrations for this site.

Table 24. Summary of laboratory measured pollutant concentrations in Pulgas Creek Pump Station during water year 2013.

		Water Year 2012	Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	0	15	100%	4.3	110	24.0	33.3	33.1
∑PCB	ng/L	0	4	100%	15.1	62.7	30.5	34.7	20.1
Total Hg	ng/L	0	6	100%	4.20	23.0	7.45	10.53	6.90
Total MeHg	ng/L	0	6	100%	0.040	0.280	0.215	0.178	0.100
TOC	mg/L	0	4	100%	7.30	17.0	8.35	10.3	4.53
NO3	mg/L	0	4	100%	0.240	0.490	0.350	0.358	0.102
Total P	mg/L	0	4	100%	0.100	0.250	0.125	0.150	0.071
PO4	mg/L	0	4	100%	0.051	0.094	0.059	0.066	0.020
Hardness	mg/L	0	-	-	-	-	-	-	-
Total Cu	µg/L	0	1	100%	-	-	-	30.0	-
Dissolved Cu	µg/L	0	1	100%	-	-	-	20.0	-
Total Se	µg/L	0	1	100%	-	-	-	0.180	-
Dissolved Se	µg/L	0	1	100%	-	-	-	0.170	-
Carbaryl	ng/L	0	1	100%	-	-	-	204	-
Fipronil	ng/L	0	1	0%	ND	-	-	-	-
∑PAH	ng/L	0	4	100%	211	1138	552	614	389
∑PBDE	ng/L	0	4	100%	5.18	89.8	32.5	40.0	39.7
Delta/ Tralo-methrin	ng/L	0	1	0%	ND	-	-	-	-
Cypermethrin	ng/L	0	1	100%	-	-	-	0.9	-
Cyhalothrin lambda	ng/L	0	1	0%	ND	-	-	-	-
Permethrin	ng/L	0	1	100%	-	-	-	2.9	-
Bifenthrin	ng/L	0	1	100%	-	-	-	1.3	-

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation Pulgas Creek Pump Station was four.
All Hardness results in WY 2013 were censored.

8.6.4. Pulgas Creek Pump Station toxicity

A composite water sample was collected at Pulgas Creek on March 6, 2013. No significant effects were observed on any of the four test organisms.

8.6.5. Pulgas Creek Pump Station preliminary loading estimates

Continuous concentrations of suspended sediment, PCBs, total mercury and methylmercury, and total phosphorous were computed using regression equations of each contaminant with turbidity (Table 25). Similarly, continuous concentrations of TOC and phosphate were computed using regression equations with instantaneous flow. A flow weighted mean concentration (FWMC) was computed for nitrate and the static concentration was applied to the entire record. These equations and FWMC were applied during both storm and baseflow conditions as there was no data to support using a different method for base flow conditions. The monthly (or partial monthly for December 2012 and March 2013) load for each POC was regressed with monthly (or partial monthly) rainfall. The resulting equation was used to estimate the monthly POC load for the non-monitored period of record. This is considered a coarse method of estimation and the resulting loads are shown for uses of preliminary comparison between the six monitored watersheds and should not be considered accurate at this time. As the dataset for this site grows in future monitoring years, these estimates will be recalculated.

Preliminary monthly loading estimates are dominated by the two wet months of WY 2013 (November and December) (Table 26), during which time 65% of the total discharge volume occurred and 67 – 83% of the total load for each POC passed through the system. At this time, all loads estimates should be considered preliminary and data collected in subsequent water years will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate and finalize loads for WY 2013.

Table 25. Regression equations used for loads computations for Pulgas Creek Pump Station during water year 2013. Note that regression equations will be reformulated upon future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mainly urban	1.102		0.84	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.73	8.6	0.77	Regression with turbidity
Total Mercury (ng/NTU)	Mainly urban	0.24	3.4	0.94	Regression with turbidity
Total Methylmercury (ng/NTU)	Mainly urban	0.00094	0.2	0.53	Regression with turbidity
Total Organic Carbon (mg/CFS)	Mainly urban	1.8	5.8	0.4	Regression with flow
Total Phosphorous (mg/NTU)	Mainly urban	0.0016	0.081	0.47	Regression with turbidity
Nitrate (mg/L)	Mainly urban	0.34			Flow weighted mean concentration
Phosphate (mg/CFS)	Mainly urban	0.0086	0.045	0.41	Regression with flow

Table 26. Preliminary monthly loads for Pulgas Creek Pump Station during water year 2013.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2013	12-Oct[a]	25	*0.0165*	*0.779*	*339*	*0.667*	*0.233*	*0.00394*	*6.00*	*1.93*	*2.56*
	12-Nov[a]	121	*0.0548*	*3.28*	*1947*	*2.69*	*0.932*	*0.0135*	*20.5*	*10.4*	*9.67*
	12-Dec[a]	183	*0.0797*	*4.90*	*2992*	*4.00*	*1.39*	*0.0197*	*29.9*	*15.9*	*14.3*
	13-Jan	8	0.0103	0.253	68.8	0.256	0.0908	0.00230	3.49	0.503	1.20
	13-Feb	10	0.0168	0.735	159	0.631	0.220	0.00403	5.70	1.05	2.43
	13-Mar[a]	20	*0.0143*	*0.640*	*249*	*0.555*	*0.194*	*0.00341*	*5.19*	*1.46*	*2.17*
	13-Apr[a]	18	*0.0134*	*0.580*	*211*	*0.506*	*0.177*	*0.00318*	*4.84*	*1.25*	*2.00*
	Wet season total	386	*0.206*	*11.2*	*5967*	*9.30*	*3.23*	*0.0501*	*75.6*	*32.4*	*34.3*

[a] As described in the text, discharge and loads for these months (data italicized) were computed based on monthly or partial monthly regressions between rainfall and discharge/load. These loads are considered coarse estimates and will be updated in future sampling years.

Attachment 1. Quality Assurance information

Table A1: Summary of QA data at all sites. This table includes the top eight PAHs found commonly at all sites , the PBDE congeners that account for 75% of the sum of all PBDE congeners, the top nine PCB congeners found at all sites, and the pyrethroids that were detected at any site.

Analyte	Unit	Average Lab Blank	Detection Limit (MDL) (range; mean)	Average Reporting Limit (RL)	RSD of Lab Duplicates (% range; % mean)	RSD of Field Duplicates (% range; % mean)	Percent Recovery of CRM (% range; % mean)	Percent Recovery of Matrix Spike (% range; % mean)
Carbaryl	ug/L	0	0.01-0.01; 0.01	0.02	75.71-75.71; 75.71	1.39-83.55; 42.47	NA	90-116; 102.3
Fipronil	ug/L	0	0-0.01; 0	0.0064	NA	0-141.42; 37.68	NA	45-112.5; 74.4
NH4	mg/L	0.0018	0.01-0.02; 0.01	0	0-9.87; 1.89	0-9.87; 2.43	NA	NA
NO3	mg/L	0	0-0.02; 0.01	0.046	NA	0-4.47; 0.35	NA	105-105; 105
NO2	mg/L	0	0-0; 0	0.013	0-0.73; 0.29	0-4.04; 0.56	NA	89-103.5; 96.5
TKN	mg/L	0	0.07-0.4; 0.23	0.1	0-47.88; 13.65	0-36.35; 14.94	NA	NA
PO4	mg/L	0	0-0.06; 0.01	0.011	0-1.61; 0.9	0-5.29; 1.16	NA	83.5-107; 97.8
Total P	mg/L	0	0.01-0.1; 0.03	0.01	0-2.4; 0.79	0-14.24; 3.86	NA	86-86; 86
SSC	mg/L	470	0.23-6.8; 2.55	3	NA	0-50.63; 13.23	99.8-99.8; 99.8	NA
Benz(a)anthracenes /Chrysenes, C1-	pg/L	102	99-75500; 3661.22	NA	1.01-6.77; 3.96	1.01-27.92; 8.64	NA	NA
Benz(a)anthracenes /Chrysenes, C2-	pg/L	164	118-43100; 2374.97	NA	2.59-16.42; 9.24	0.64-25.76; 9.46	NA	NA
Fluoranthene	pg/L	106	57.9-2580; 481.01	NA	1.26-15.98; 6.48	2.21-33.15; 17.99	NA	NA
Fluoranthene/Pyrenes, C1-	pg/L	430	138-25400; 2277.5	NA	2.63-4.4; 3.3	2.63-24.68; 13.55	NA	NA
Fluorenes, C3-	pg/L	1588	45.1-29400; 1888.57	NA	0.13-5.43; 2.09	0.69-15.99; 8.69	NA	NA
Naphthalenes, C4-	pg/L	2864	95.5-3540; 918.73	NA	2.44-10.96; 6.45	2.44-78.83; 18.97	NA	NA
Phenanthrene/Anthracene, C4-	pg/L	1565	208-27100; 3350.34	NA	0-6.39; 2.27	0.43-23.46; 8.75	NA	NA
Pyrene	pg/L	77.4	57.4-5960; 662.16	NA	0.99-14.38; 5.71	1.59-31.82; 16.25	NA	NA
PBDE 047	pg/L	40.9	0.37-0.87; 0.41	NA	0.39-18.19; 6.09	1.2-13.82; 6.86	NA	NA
PBDE 099	pg/L	43.4	0.47-12.4; 3.19	NA	1.99-9.88; 5.14	1.81-15.1; 7.31	NA	NA
PBDE 209	pg/L	76	12.7-146; 49.83	NA	2.21-42.31; 17.67	1.39-45.22; 19.57	NA	NA
PCB 087	pg/L	0.834	0.18-5.42; 0.87	NA	0-31.19; 13.75	0-31.19; 12.29	NA	NA
PCB 095	pg/L	1.31	0.18-6.23; 1	NA	3.89-37.99; 16.43	0.59-37.99; 14.24	NA	NA
PCB 110	pg/L	1.27	0.18-4.58; 0.74	NA	0.27-25.61; 12.31	0.27-27.4; 12.04	NA	NA
PCB 138	pg/L	2.36	0.25-19.8; 2.26	NA	3.01-25.44; 11.74	0.34-25.44; 9.04	NA	NA
PCB 149	pg/L	1.3	0.26-21.3; 2.45	NA	1.97-31.09; 11.26	1.97-28.66; 10.39	NA	NA
PCB 151	pg/L	0.56	0.18-8.38; 0.75	NA	0.26-29.2; 8.97	0.26-39.81; 10.25	NA	NA
PCB 153	pg/L	2.44	0.22-17.4; 2	NA	1.21-24.37; 10.36	0.59-23.88; 9.57	NA	NA
PCB 174	pg/L	0.039	0.2-4; 0.78	NA	0.25-36.32; 6.22	0.25-37.01; 7.79	NA	NA
PCB 180	pg/L	0.91	0.18-4.52; 0.68	NA	0.43-29.54; 6.15	0.43-23.7; 8.7	NA	NA
Bifenthrin	pg/L	274	1500-5520; 2830	NA	NA	4.8-34.98; 16.11	NA	NA
Cypermethrin	pg/L	0	968-5290; 2694.53	NA	NA	27.58-27.58; 27.58	NA	NA
Delta/Tralomethrin	pg/L	243	185-862; 353.6	NA	NA	22.99-32.44; 27.71	NA	NA
Total Cu	ug/L	0	0.04-0.42; 0.16	0.55	0.2-2.68; 0.88	0.2-10.56; 3.31	104.2-104.2; 104.2	100-100.6; 100.3
Dissolved Cu	ug/L	0	0.04-0.42; 0.12	0.5	NA	3.01-27.52;	104.2-104.2;	100-100.6; 100.3

Analyte	Unit	Average Lab Blank	Detection Limit (MDL) (range; mean)	Average Reporting Limit (RL)	RSD of Lab Duplicates (% range; % mean)	RSD of Field Duplicates (% range; % mean)	Percent Recovery of CRM (% range; % mean)	Percent Recovery of Matrix Spike (% range; % mean)
						10.41	104.2	
Total Hg	ug/L	0	0-0; 0	0.0005	2.12-2.12; 2.12	1.07-31.06; 8.59	98.5-98.5; 98.5	100-100.8; 100.4
Total MeHg	ng/L	0.006	0.01-0.02; 0.02	0.033	0.97-5.87; 3.35	0-37.52; 6.34	NA	74.2-90.4; 85.4
Total Se	ug/L	0.006	0.02-0.06; 0.04	0.086	0-2.4; 0.79	0-14.24; 3.86	103.4-103.4; 103.4	86.5-90.3; 88.4
Dissolved Se	ug/L	0	0.02-0.06; 0.04	0.15	6.18-6.18; 6.18	0-8.59; 4.72	103.4-103.4; 103.4	86.5-90.3; 88.4
TOC	ug/L	0	0.3-0.35; 0.32	462	NA	NA	NA	NA

Table A2: Field blank data from all sites.

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Carbaryl	ug/L	0.01	0.02	ND	ND	ND
Fipronil	ug/L	0.000875	0.004	ND	ND	ND
Fipronil Desulfinyl	ug/L	0.000625	0.0028	ND	ND	ND
Fipronil Sulfide	ug/L	0.000625	0.0028	ND	ND	ND
Fipronil Sulfone	ug/L	0.000875	0.004	ND	ND	ND
NH4	mg/L	0.01	-	0.01	0.01	0.01
NO3	mg/L	0.0164	0.041	ND	0.039	0.0078
NO2	mg/L	0.001142	0.01	ND	0.025	0.005
TKN	mg/L	0.18	0.1	ND	ND	ND
PO4	mg/L	0.006	0.01	ND	ND	ND
Total P	mg/L	0.0076	0.01	ND	0.018	0.0052
SSC	pg/L	653	-	ND	ND	ND
Acenaphthene	pg/L	147	-	ND	ND	ND
Acenaphthylene	pg/L	119.5	-	ND	ND	ND
Anthracene	pg/L	230	-	ND	ND	ND
Benz(a)anthracene	pg/L	68.5	-	ND	ND	ND
Benz(a)anthracenes/Chrysenes, C1-	pg/L	31	-	69.5	109	89.25
Benz(a)anthracenes/Chrysenes, C2-	pg/L	63.05	-	171	393	282
Benz(a)anthracenes/Chrysenes, C3-	pg/L	64.9	-	149	389	269
Benz(a)anthracenes/Chrysenes, C4-	pg/L	66.35	-	449	1030	739.5
Benzo(a)pyrene	pg/L	199	-	ND	ND	ND
Benzo(b)fluoranthene	pg/L	82.05	-	ND	ND	ND
Benzo(e)pyrene	pg/L	182.5	-	ND	ND	ND
Benzo(g,h,i)perylene	pg/L	123.9	-	ND	ND	ND
Benzo(k)fluoranthene	pg/L	110	-	ND	ND	ND
Chrysene	pg/L	72.3	-	ND	86.5	43.25
Dibenz(a,h)anthracene	pg/L	119	-	ND	ND	ND
Dibenzothiophene	pg/L	78.6	-	ND	ND	ND
Dibenzothiophenes, C1-	pg/L	63.85	-	ND	ND	ND

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Dibenzothiophenes, C2-	pg/L	62.9	-	278	582	430
Dibenzothiophenes, C3-	pg/L	48.95	-	576	771	673.5
Dimethylnaphthalene, 2,6-	pg/L	422	-	ND	ND	ND
Fluoranthene	pg/L	45.15	-	238	343	290.5
Fluoranthene/Pyrenes, C1-	pg/L	90.05	-	82.8	716	399.4
Fluorene	pg/L	207.5	-	ND	ND	ND
Fluorenes, C2-	pg/L	139.15	-	2080	2730	2405
Fluorenes, C3-	pg/L	133.5	-	2950	4130	3540
Indeno(1,2,3-c,d)pyrene	pg/L	43.1	-	ND	ND	ND
Methylnaphthalene, 2-	pg/L	479.5	-	ND	677	338.5
Methylphenanthrene, 1-	pg/L	210.7	-	ND	89.5	44.75
Naphthalene	pg/L	207	-	2330	21200	11765
Naphthalenes, C1-	pg/L	129	-	ND	1120	560
Naphthalenes, C3-	pg/L	298.5	-	941	3940	2440.5
Perylene	pg/L	213.5	-	ND	ND	ND
Phenanthrene	pg/L	101.6	-	469	608	538.5
Phenanthrene/Anthracene, C1-	pg/L	210.7	-	ND	335	167.5
Phenanthrene/Anthracene, C2-	pg/L	82.95	-	423	843	633
Pyrene	pg/L	43.25	-	179	229	204
Trimethylnaphthalene, 2,3,5-	pg/L	154.5	-	ND	189	94.5
PBDE 007	pg/L	0.3775	-	ND	1.64	0.82
PBDE 008	pg/L	0.3775	-	ND	1.3	0.65
PBDE 010	pg/L	0.527	-	ND	ND	ND
PBDE 011	pg/L	-	-	-	-	-
PBDE 012	pg/L	0.3775	-	ND	0.793	0.3965
PBDE 013	pg/L	-	-	-	-	-
PBDE 015	pg/L	0.3775	-	ND	4.16	2.08
PBDE 017	pg/L	0.3905	-	ND	23.6	11.8
PBDE 025	pg/L	-	-	-	-	-
PBDE 028	pg/L	0.3775	-	0.811	29	14.9055
PBDE 030	pg/L	0.4105	-	ND	ND	ND
PBDE 032	pg/L	0.3775	-	ND	ND	ND
PBDE 033	pg/L	-	-	-	-	-
PBDE 035	pg/L	1.7285	-	ND	ND	ND
PBDE 047	pg/L	0.3775	-	26.4	1040	533.2
PBDE 049	pg/L	0.3775	-	0.845	86.3	43.5725
PBDE 051	pg/L	0.3775	-	ND	8.65	4.325
PBDE 066	pg/L	0.3775	-	ND	49.4	24.7
PBDE 071	pg/L	0.3775	-	ND	14.3	7.15
PBDE 075	pg/L	1.6885	-	ND	ND	ND
PBDE 077	pg/L	0.529	-	ND	ND	ND

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PBDE 079	pg/L	0.3775	-	ND	ND	ND
PBDE 085	pg/L	0.8735	-	1.49	57.8	29.645
PBDE 099	pg/L	0.6535	-	29.9	1200	614.95
PBDE 100	pg/L	0.505	-	6.47	281	143.735
PBDE 105	pg/L	1.0985	-	ND	ND	ND
PBDE 116	pg/L	1.557	-	ND	11.3	5.65
PBDE 119	pg/L	0.9635	-	ND	6.86	3.43
PBDE 120	pg/L	-	-	-	-	-
PBDE 126	pg/L	0.619	-	ND	1.21	0.605
PBDE 128	pg/L	9.519	-	ND	ND	ND
PBDE 140	pg/L	0.5205	-	ND	6.77	3.385
PBDE 153	pg/L	0.4765	-	3.34	135	69.17
PBDE 155	pg/L	0.382	-	ND	9.43	4.715
PBDE 166	pg/L	-	-	-	-	-
PBDE 181	pg/L	2.3685	-	ND	ND	ND
PBDE 183	pg/L	1.715	-	ND	43.7	21.85
PBDE 190	pg/L	6.1835	-	ND	ND	ND
PBDE 197	pg/L	4.52	-	2.36	97.3	49.83
PBDE 203	pg/L	4.9135	-	5.08	123	64.04
PBDE 204	pg/L	-	-	-	-	-
PBDE 205	pg/L	8.683	-	ND	ND	ND
PBDE 206	pg/L	24.92	-	ND	1400	700
PBDE 207	pg/L	2.2935	-	75.6	2330	1202.8
PBDE 208	pg/L	25.115	-	ND	1690	845
PBDE 209	pg/L	9.99	-	1240	22900	12070
PCB 008	pg/L	1.4536	-	ND	1.33	0.4176
PCB 018	pg/L	0.5882	-	ND	1.37	0.748
PCB 020	pg/L	-	-	-	-	-
PCB 021	pg/L	-	-	-	-	-
PCB 028	pg/L	0.2558	-	1.58	2.43	2.05
PCB 030	pg/L	-	-	-	-	-
PCB 031	pg/L	0.4338	-	ND	1.61	1.082
PCB 033	pg/L	0.2446	-	0.617	0.915	0.7782
PCB 044	pg/L	0.7	-	ND	2.94	1.85
PCB 047	pg/L	-	-	-	-	-
PCB 049	pg/L	0.2668	-	0.782	2.07	1.1386
PCB 052	pg/L	0.734	-	ND	2.65	2.06
PCB 056	pg/L	0.3356	-	0.408	0.909	0.6332
PCB 060	pg/L	0.3888	-	ND	1.3	0.3304
PCB 061	pg/L	-	-	-	-	-
PCB 065	pg/L	-	-	-	-	-

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 066	pg/L	0.4328	-	ND	4.87	1.5982
PCB 069	pg/L	-	-	-	-	-
PCB 070	pg/L	0.317	-	2.33	5.91	3.478
PCB 074	pg/L	-	-	-	-	-
PCB 076	pg/L	-	-	-	-	-
PCB 083	pg/L	-	-	-	-	-
PCB 086	pg/L	-	-	-	-	-
PCB 087	pg/L	0.3138	-	2.53	3.74	2.962
PCB 090	pg/L	-	-	-	-	-
PCB 093	pg/L	-	-	-	-	-
PCB 095	pg/L	0.354	-	2.76	4.39	3.568
PCB 097	pg/L	-	-	-	-	-
PCB 098	pg/L	-	-	-	-	-
PCB 099	pg/L	0.3666	-	1.39	2.4	1.952
PCB 100	pg/L	-	-	-	-	-
PCB 101	pg/L	0.3208	-	3.14	3.92	3.422
PCB 102	pg/L	-	-	-	-	-
PCB 105	pg/L	0.7304	-	ND	2.16	1.048
PCB 108	pg/L	-	-	-	-	-
PCB 110	pg/L	0.2704	-	3.43	6.53	4.968
PCB 113	pg/L	-	-	-	-	-
PCB 115	pg/L	-	-	-	-	-
PCB 118	pg/L	0.355	-	1.72	3.74	2.778
PCB 119	pg/L	-	-	-	-	-
PCB 125	pg/L	-	-	-	-	-
PCB 128	pg/L	0.401	-	0.28	1.27	0.7448
PCB 129	pg/L	-	-	-	-	-
PCB 132	pg/L	0.4912	-	0.846	2.72	1.6392
PCB 135	pg/L	-	-	-	-	-
PCB 138	pg/L	0.3996	-	1.76	5.37	3.33
PCB 141	pg/L	0.4506	-	ND	0.78	0.2378
PCB 147	pg/L	-	-	-	-	-
PCB 149	pg/L	0.4212	-	1.63	3.64	2.39
PCB 151	pg/L	0.3766	-	ND	1.65	0.978
PCB 153	pg/L	0.355	-	1.19	3.08	1.826
PCB 154	pg/L	-	-	-	-	-
PCB 156	pg/L	0.409	-	ND	0.581	0.2076
PCB 157	pg/L	-	-	-	-	-
PCB 158	pg/L	0.3134	-	ND	0.602	0.1204
PCB 160	pg/L	-	-	-	-	-
PCB 163	pg/L	-	-	-	-	-

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 166	pg/L	-	-	-	-	-
PCB 168	pg/L	-	-	-	-	-
PCB 170	pg/L	0.3922	-	ND	1.09	0.5358
PCB 174	pg/L	0.4822	-	ND	0.58	0.2824
PCB 177	pg/L	0.3628	-	ND	0.645	0.1854
PCB 180	pg/L	0.6086	-	ND	1.66	0.4408
PCB 183	pg/L	0.4356	-	ND	0.24	0.048
PCB 185	pg/L	-	-	-	-	-
PCB 187	pg/L	0.3644	-	ND	1.31	0.3662
PCB 193	pg/L	-	-	-	-	-
PCB 194	pg/L	0.3704	-	ND	ND	ND
PCB 195	pg/L	0.3968	-	ND	ND	ND
PCB 201	pg/L	0.295	-	ND	ND	ND
PCB 203	pg/L	0.3798	-	ND	ND	ND
Allethrin	pg/L	2790	-	ND	ND	ND
Bifenthrin	pg/L	949	-	ND	ND	ND
Cyfluthrin, total	pg/L	7020	-	ND	ND	ND
Cyhalothrin,lambda, total	pg/L	748	-	ND	ND	ND
Cypermethrin, total	pg/L	997	-	ND	ND	ND
Delta/Tralomethrin	pg/L	539	-	ND	ND	ND
Esfenvalerate/Fenvalerate, total	pg/L	845	-	ND	ND	ND
Fenpropathrin	pg/L	1770	-	ND	ND	ND
Permethrin, total	pg/L	287	-	ND	ND	ND
Phenothrin	pg/L	525	-	ND	ND	ND
Prallethrin	pg/L	7020	-	ND	ND	ND
Resmethrin	pg/L	653	-	ND	ND	ND
Calcium	ug/L	6.32	31.6	ND	ND	ND
Total Cu	ug/L	0.063	0.4013	ND	1.13	0.365
Dissolved Cu	ug/L	0.063	0.4013	ND	0.681	0.17025
Magnesium	pg/L	43.1	-	ND	ND	ND
Total Hg	ug/L	0.000198	0.0004	ND	0.0044	0.00092
Total MeHg	ng/L	0.018571429	0.0314	ND	0.021	0.003
Dissolved Se	ug/L	0.051	0.093	ND	ND	ND
Total Se	ug/L	0.051	0.093	ND	ND	ND
Total Hardness (calc)	mg/L	0.02	0.09	ND	ND	ND
TOC	mg/L	-	-	-	-	-

Table A3: Average RSD of field and lab duplicates at each site.

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Carbaryl	-	-	-	-	-	-	83.5%	75.7%	-	-	1.4%	-
Fipronil	79.5%	-	-	-	9.2%	-	10.9%	-	-	-	-	-
Fipronil Desulfinyl	10.9%	-	0.0%	-	15.5%	-	-	-	-	-	-	-
Fipronil Sulfide	0.0%	-	-	-	-	-	-	-	-	-	-	-
Fipronil Sulfone	0.0%	-	-	-	4.9%	-	-	-	-	-	-	-
NH4	3.1%	0.0%	1.8%	1.5%	4.0%	4.9%	0.0%	0.0%	3.3%	-	-	-
NO3	0.0%	0.0%	0.0%	0.0%	1.1%	-	0.0%	0.0%	0.0%	-	0.0%	-
NO2	1.0%	0.7%	0.0%	0.0%	1.0%	-	0.0%	0.0%	0.0%	-	0.0%	-
TKN	10.2%	3.4%	-	-	14.5%	23.9%	12.0%	-	31.4%	-	-	-
PO4	0.3%	0.8%	0.9%	0.9%	0.3%	-	1.5%	1.1%	0.0%	-	4.7%	-
Total P	7.1%	0.0%	0.0%	0.0%	3.0%	2.4%	0.0%	0.0%	2.9%	-	-	-
SSC	12.3%	-	11.9%	-	11.5%	-	8.6%	-	19.6%	-	19.9%	-
Acenaphthene	20.1%	-	-	-	-	-	10.0%	0.4%	1.5%	1.5%	-	-
Acenaphthylene	10.7%	-	-	-	-	-	31.8%	18.1%	5.5%	5.5%	-	-
Anthracene	14.2%	-	24.6%	9.4%	43.4%	-	39.1%	23.4%	5.7%	5.7%	-	-
Benz(a)anthracene	15.3%	-	-	-	-	-	-	-	-	-	-	-
Benz(a)anthracenes/Chrysenes, C1-	5.7%	-	6.9%	4.1%	2.9%	-	17.3%	6.8%	1.0%	1.0%	-	-
Benz(a)anthracenes/Chrysenes, C2-	4.3%	-	7.5%	8.7%	6.0%	-	19.0%	16.4%	2.6%	2.6%	-	-
Benz(a)anthracenes/Chrysenes, C3-	23.6%	-	6.3%	6.9%	11.1%	-	40.2%	8.9%	0.7%	0.7%	-	-
Benz(a)anthracenes/Chrysenes, C4-	5.9%	-	25.2%	20.6%	10.6%	-	16.7%	7.0%	0.3%	0.3%	-	-
Benzo(a)pyrene	16.7%	-	19.5%	7.0%	20.8%	-	23.6%	6.5%	1.1%	1.1%	-	-
Benzo(b)fluoranthene	9.3%	-	10.2%	2.7%	26.6%	-	17.5%	5.2%	4.7%	4.7%	-	-
Benzo(e)pyrene	13.5%	-	7.0%	4.4%	9.9%	-	28.4%	5.9%	0.9%	0.9%	-	-
Benzo(g,h,i)perylene	16.6%	-	8.8%	0.0%	4.6%	-	14.2%	5.3%	4.5%	4.5%	-	-
Benzo(k)fluoranthene	36.4%	-	20.6%	1.8%	-	-	33.0%	2.8%	2.0%	2.0%	-	-
Chrysene	8.4%	-	11.6%	1.3%	9.5%	-	19.0%	7.5%	2.2%	2.2%	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Dibenz(a,h)anthracene	39.9%	-	31.9%	9.9%	-	-	-	-	2.1%	2.1%	-	-
Dibenzothiophene	-	-	8.5%	2.1%	-	-	15.9%	13.0%	-	-	-	-
Dibenzothiophenes, C1-	8.9%	-	6.3%	1.7%	5.1%	-	24.6%	2.9%	2.5%	2.5%	-	-
Dibenzothiophenes, C2-	4.5%	-	3.8%	0.7%	10.2%	-	12.2%	2.9%	6.1%	6.1%	-	-
Dibenzothiophenes, C3-	4.8%	-	7.3%	2.1%	8.0%	-	14.7%	0.8%	0.5%	0.5%	-	-
Dimethylnaphthalene, 2,6-	22.2%	-	4.7%	1.6%	0.4%	-	12.2%	13.8%	7.1%	7.1%	-	-
Fluoranthene	16.0%	-	16.3%	1.3%	33.2%	-	17.2%	16.0%	2.2%	2.2%	-	-
Fluoranthene/Pyrenes, C1-	16.3%	-	10.5%	4.4%	8.7%	-	17.4%	2.9%	2.6%	2.6%	-	-
Fluorene	15.3%	-	-	-	-	-	15.8%	9.1%	3.7%	3.7%	-	-
Fluorenes, C2-	14.0%	-	7.3%	8.9%	0.8%	-	9.4%	1.2%	1.8%	1.8%	-	-
Fluorenes, C3-	7.0%	-	8.6%	5.4%	9.0%	-	12.3%	0.1%	0.7%	0.7%	-	-
Indeno(1,2,3-c,d)pyrene	21.9%	-	14.5%	0.4%	14.9%	-	18.1%	5.3%	8.9%	8.9%	-	-
Methylnaphthalene, 2-	9.3%	-	3.3%	1.1%	2.1%	-	10.6%	6.3%	3.4%	3.4%	-	-
Methylphenanthrene, 1-	16.7%	-	12.7%	13.6%	11.6%	-	14.6%	10.7%	0.0%	0.0%	-	-
Naphthalene	10.3%	-	7.6%	1.5%	3.2%	-	2.1%	3.8%	0.5%	0.5%	-	-
Naphthalenes, C1-	14.5%	-	-	-	0.5%	-	7.5%	5.7%	3.4%	3.4%	-	-
Naphthalenes, C3-	17.2%	-	1.3%	1.9%	0.6%	-	8.9%	11.2%	8.5%	8.5%	-	-
Perylene	17.6%	-	20.8%	4.2%	5.0%	-	25.6%	8.6%	-	-	-	-
Phenanthrene	5.8%	-	33.9%	6.1%	29.0%	-	21.3%	26.5%	1.6%	1.6%	-	-
Phenanthrene/Anthracene, C1-	28.7%	-	12.0%	2.1%	13.7%	-	13.0%	0.2%	2.5%	2.5%	-	-
Phenanthrene/Anthracene, C2-	15.6%	-	6.0%	8.4%	7.1%	-	12.9%	8.1%	3.9%	3.9%	-	-
Pyrene	16.7%	-	13.4%	1.0%	19.5%	-	19.2%	14.4%	1.7%	1.7%	-	-
Trimethylnaphthalene, 2,3,5-	22.1%	-	3.6%	0.3%	2.3%	-	17.6%	9.0%	-	-	-	-
PBDE 007	-	-	-	-	-	-	-	11.2%	15.4%	15.6%	2.0%	2.0%
PBDE 008	8.3%	4.7%	-	-	-	-	-	-	56.9%	65.0%	6.5%	6.5%
PBDE 010	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 011	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PBDE 012	-	-	-	-	-	-	-	11.7%	68.7%	73.4%	9.5%	9.5%
PBDE 013	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 015	11.7%	9.5%	-	-	-	-	3.2%	4.3%	13.8%	15.4%	7.5%	7.5%
PBDE 017	5.9%	12.7%	7.6%	-	-	-	-	-	9.1%	5.0%	12.9%	12.9%
PBDE 025	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 028	4.5%	7.0%	0.9%	-	-	-	15.6%	20.7%	5.8%	2.0%	14.9%	14.9%
PBDE 030	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 032	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 033	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 035	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 047	2.9%	1.2%	5.9%	-	-	-	13.8%	18.2%	12.0%	0.4%	4.6%	4.6%
PBDE 049	5.0%	0.7%	1.7%	-	-	-	10.2%	8.6%	5.7%	0.7%	12.4%	12.4%
PBDE 051	5.7%	5.7%	-	-	-	-	-	-	16.2%	7.8%	15.3%	15.3%
PBDE 066	2.3%	0.5%	1.0%	-	-	-	13.8%	14.1%	6.2%	1.7%	8.4%	8.4%
PBDE 071	1.9%	1.9%	-	-	-	-	-	-	-	-	32.7%	32.7%
PBDE 075	0.7%	0.7%	9.8%	-	-	-	-	-	-	-	22.0%	22.0%
PBDE 077	15.8%	15.8%	-	-	-	-	-	-	-	-	-	-
PBDE 079	16.4%	16.4%	-	-	-	-	-	-	11.3%	13.2%	-	-
PBDE 085	6.3%	5.2%	5.7%	-	-	-	4.6%	5.7%	19.6%	2.4%	2.9%	2.9%
PBDE 099	4.8%	3.9%	6.2%	-	-	-	8.1%	9.9%	15.1%	2.0%	4.8%	4.8%
PBDE 100	2.8%	0.3%	6.5%	-	-	-	9.2%	11.7%	14.6%	0.0%	6.0%	6.0%
PBDE 105	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 116	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 119	6.8%	6.3%	-	-	-	-	-	21.0%	34.7%	13.6%	-	-
PBDE 120	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 126	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 128	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PBDE 140	-	-	-	-	-	-	12.1%	12.5%	10.0%	1.6%	9.8%	9.8%
PBDE 153	6.9%	6.6%	5.5%	-	-	-	6.2%	7.1%	12.5%	1.4%	3.5%	3.5%
PBDE 155	8.1%	12.5%	-	-	-	-	6.4%	7.8%	15.2%	1.0%	6.0%	6.0%
PBDE 166	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 181	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 183	21.3%	1.5%	-	-	-	-	27.4%	32.6%	17.6%	11.2%	11.0%	11.0%
PBDE 190	-	-	-	-	-	-	-	-	-	-	1.7%	1.7%
PBDE 197	42.2%	12.3%	15.8%	-	-	-	-	-	-	-	1.7%	1.7%
PBDE 203	26.6%	17.6%	-	-	-	-	-	3.3%	33.4%	21.4%	4.6%	4.6%
PBDE 204	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 205	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 206	9.0%	23.9%	8.8%	-	-	-	6.1%	7.6%	34.1%	17.3%	37.3%	37.3%
PBDE 207	12.8%	25.5%	5.8%	-	-	-	2.0%	2.1%	34.9%	24.4%	28.2%	28.2%
PBDE 208	17.6%	23.7%	13.0%	-	-	-	3.5%	4.1%	36.6%	25.3%	30.5%	30.5%
PBDE 209	22.5%	19.4%	2.2%	-	-	-	2.1%	2.2%	35.6%	6.7%	42.3%	42.3%
PCB 008	15.5%	10.4%	13.6%	13.6%	20.0%	-	5.0%	0.3%	6.8%	3.1%	10.4%	11.9%
PCB 018	13.9%	4.1%	10.0%	10.0%	15.9%	-	4.2%	0.7%	12.3%	5.2%	6.5%	6.5%
PCB 020	-	-	-	-	-	-	-	-	-	-	-	-
PCB 021	-	-	-	-	-	-	-	-	-	-	-	-
PCB 028	10.8%	12.5%	5.9%	7.5%	4.7%	-	3.8%	1.2%	10.9%	3.6%	8.8%	5.4%
PCB 030	-	-	-	-	-	-	-	-	-	-	-	-
PCB 031	11.1%	9.1%	5.1%	7.5%	8.5%	-	4.7%	0.7%	11.3%	2.7%	7.1%	0.8%
PCB 033	13.8%	7.2%	6.4%	8.2%	13.2%	-	3.1%	0.4%	11.3%	7.0%	10.4%	0.4%
PCB 044	4.9%	9.9%	6.6%	10.0%	2.9%	-	6.5%	13.3%	13.0%	8.6%	9.0%	0.2%
PCB 047	-	-	-	-	-	-	-	-	-	-	-	-
PCB 049	6.6%	9.6%	5.6%	8.5%	5.5%	-	5.1%	13.6%	14.3%	12.8%	10.0%	2.0%
PCB 052	8.0%	13.8%	7.6%	10.4%	9.9%	-	7.0%	14.4%	19.2%	22.6%	11.9%	6.6%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PCB 056	6.4%	5.1%	13.7%	7.3%	2.2%	-	5.5%	12.0%	7.2%	1.6%	11.9%	3.8%
PCB 060	6.1%	4.3%	16.9%	7.8%	2.0%	-	6.1%	13.6%	3.1%	3.1%	11.8%	3.2%
PCB 061	-	-	-	-	-	-	-	-	-	-	-	-
PCB 065	-	-	-	-	-	-	-	-	-	-	-	-
PCB 066	7.0%	8.0%	7.5%	8.9%	1.5%	-	8.2%	15.0%	2.3%	1.9%	11.5%	1.6%
PCB 069	-	-	-	-	-	-	-	-	-	-	-	-
PCB 070	8.9%	11.1%	7.8%	10.7%	2.2%	-	6.4%	15.5%	5.2%	9.9%	12.8%	5.5%
PCB 074	-	-	-	-	-	-	-	-	-	-	-	-
PCB 076	-	-	-	-	-	-	-	-	-	-	-	-
PCB 083	-	-	-	-	-	-	-	-	-	-	-	-
PCB 086	-	-	-	-	-	-	-	-	-	-	-	-
PCB 087	11.3%	10.2%	8.7%	9.9%	16.3%	-	6.3%	17.6%	17.3%	22.4%	16.7%	23.2%
PCB 090	-	-	-	-	-	-	-	-	-	-	-	-
PCB 093	-	-	-	-	-	-	-	-	-	-	-	-
PCB 095	13.9%	14.3%	6.2%	7.5%	18.2%	-	11.5%	18.8%	19.8%	29.8%	16.8%	27.1%
PCB 097	-	-	-	-	-	-	-	-	-	-	-	-
PCB 098	-	-	-	-	-	-	-	-	-	-	-	-
PCB 099	11.9%	10.9%	7.6%	7.4%	15.0%	-	8.1%	18.7%	19.6%	24.7%	18.5%	28.6%
PCB 100	-	-	-	-	-	-	-	-	-	-	-	-
PCB 101	10.8%	9.0%	7.6%	8.4%	19.9%	-	13.0%	18.6%	18.0%	23.9%	16.8%	33.0%
PCB 102	-	-	-	-	-	-	-	-	-	-	-	-
PCB 105	7.7%	7.9%	8.5%	11.0%	13.4%	-	7.7%	19.2%	8.1%	17.8%	18.6%	22.5%
PCB 108	-	-	-	-	-	-	-	-	-	-	-	-
PCB 110	10.7%	9.1%	6.9%	6.1%	16.3%	-	8.4%	18.2%	15.9%	20.9%	17.2%	23.3%
PCB 113	-	-	-	-	-	-	-	-	-	-	-	-
PCB 115	-	-	-	-	-	-	-	-	-	-	-	-
PCB 118	8.5%	8.6%	8.6%	8.7%	15.0%	-	8.1%	20.8%	9.2%	21.2%	17.2%	27.9%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PCB 119	-	-	-	-	-	-	-	-	-	-	-	-
PCB 125	-	-	-	-	-	-	-	-	-	-	-	-
PCB 128	7.6%	8.3%	5.5%	4.2%	29.2%	-	10.0%	26.9%	9.6%	15.0%	7.9%	7.7%
PCB 129	-	-	-	-	-	-	-	-	-	-	-	-
PCB 132	10.5%	9.2%	8.2%	4.7%	18.5%	-	11.8%	25.8%	6.5%	14.2%	7.4%	11.4%
PCB 135	-	-	-	-	-	-	-	-	-	-	-	-
PCB 138	8.5%	11.0%	7.6%	4.5%	12.4%	-	12.1%	25.2%	4.2%	10.8%	10.7%	16.8%
PCB 141	10.3%	10.3%	8.4%	3.5%	14.8%	-	14.0%	22.9%	4.6%	6.7%	12.8%	15.9%
PCB 147	-	-	-	-	-	-	-	-	-	-	-	-
PCB 149	10.2%	7.6%	8.7%	5.0%	13.5%	-	15.7%	31.1%	4.8%	10.4%	9.6%	19.3%
PCB 151	9.1%	4.9%	8.4%	5.2%	9.0%	-	25.9%	29.2%	2.8%	5.9%	7.3%	15.6%
PCB 153	8.3%	8.3%	9.7%	4.2%	12.6%	-	14.4%	24.4%	5.1%	7.6%	9.2%	19.8%
PCB 154	-	-	-	-	-	-	-	-	-	-	-	-
PCB 156	9.1%	9.9%	6.3%	3.1%	16.1%	-	10.0%	25.1%	11.2%	18.6%	8.0%	13.2%
PCB 157	-	-	-	-	-	-	-	-	-	-	-	-
PCB 158	9.9%	11.0%	6.5%	3.8%	16.7%	-	11.1%	24.8%	6.9%	13.8%	11.5%	16.7%
PCB 160	-	-	-	-	-	-	-	-	-	-	-	-
PCB 163	-	-	-	-	-	-	-	-	-	-	-	-
PCB 166	-	-	-	-	-	-	-	-	-	-	-	-
PCB 168	-	-	-	-	-	-	-	-	-	-	-	-
PCB 170	6.9%	4.7%	5.4%	1.4%	11.3%	-	13.2%	24.7%	8.5%	1.0%	6.8%	7.7%
PCB 174	4.9%	1.7%	5.6%	2.2%	11.5%	-	21.8%	36.3%	1.4%	1.3%	5.1%	7.2%
PCB 177	4.2%	3.7%	6.1%	3.4%	18.9%	-	22.1%	-	4.6%	4.6%	4.8%	6.0%
PCB 180	9.2%	1.7%	6.2%	3.0%	5.0%	-	15.4%	29.5%	8.1%	4.4%	7.0%	8.9%
PCB 183	3.6%	3.3%	6.6%	4.6%	16.7%	-	20.0%	31.6%	2.5%	5.5%	6.2%	11.3%
PCB 185	-	-	-	-	-	-	-	-	-	-	-	-
PCB 187	3.0%	3.8%	6.2%	3.9%	6.4%	-	23.8%	34.9%	3.1%	2.7%	6.0%	10.5%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PCB 193	-	-	-	-	-	-	-	-	-	-	-	-
PCB 194	7.9%	3.3%	6.1%	5.6%	14.4%	-	16.1%	38.7%	12.4%	13.5%	5.9%	8.2%
PCB 195	4.7%	2.0%	7.1%	3.4%	29.7%	-	15.3%	26.9%	14.8%	14.1%	4.4%	3.8%
PCB 201	11.0%	2.4%	4.0%	1.1%	10.1%	-	24.4%	-	10.3%	5.6%	4.9%	8.2%
PCB 203	9.2%	6.7%	6.7%	5.4%	14.3%	-	18.2%	44.1%	10.7%	14.4%	6.0%	12.9%
Allethrin	-	-	-	-	-	-	-	-	-	-	-	-
Bifenthrin	35.0%	-	-	-	8.5%	-	4.8%	-	9.7%	-	-	-
Cyfluthrin, total	-	-	-	-	-	-	-	-	4.3%	-	-	-
Cyhalothrin,lambda, total	-	-	-	-	-	-	-	-	-	-	-	-
Cypermethrin, total	-	-	-	-	27.6%	-	-	-	1.6%	-	-	-
Delta/Tralomethrin	-	-	-	-	32.4%	-	23.0%	-	1.6%	-	-	-
Esfenvalerate/Fenvalerate, total	-	-	-	-	-	-	-	-	24.4%	-	-	-
Fenpropathrin	-	-	-	-	-	-	-	-	-	-	-	-
Permethrin, total	12.9%	-	2.4%	-	10.6%	-	2.1%	-	5.2%	-	-	-
Phenothrin	-	-	-	-	-	-	-	-	0.4%	0.4%	-	-
Prallethrin	-	-	-	-	-	-	-	-	0.0%	-	-	-
Resmethrin	-	-	-	-	-	-	-	-	1.7%	1.7%	-	-
Calcium	0.5%	0.4%	-	-	0.5%	0.5%	1.0%	1.0%	1.3%	1.3%	-	-
Total Cu	1.5%	1.1%	0.2%	0.2%	7.3%	0.8%	-	-	-	-	-	-
Dissolved Cu	9.8%	-	-	-	27.5%	-	-	-	3.0%	-	-	-
Magnesium	0.8%	0.6%	0.3%	0.3%	0.5%	0.5%	1.3%	1.3%	8.9%	8.9%	-	-
Total Hg	13.8%	2.1%	11.5%	-	5.7%	-	5.8%	-	-	-	10.1%	-
Total MeHg	14.4%	4.1%	3.1%	-	3.3%	-	6.1%	2.6%	-	-	0.0%	-
Dissolved Se	3.7%	6.2%	-	-	8.6%	-	-	-	5.2%	-	-	-
Total Se	14.0%	10.1%	-	-	6.4%	1.5%	1.4%	1.4%	-	-	-	-
Total Hardness (calc)	0.4%	-	-	-	-	-	-	-	-	-	-	-
TOC	1.3%	-	-	-	3.8%	-	-	-	15.7%	-	-	-