# Integrated Monitoring Report - Part A

## *Water Quality Monitoring*

***Water Years 2012 and 2013 (October 2011 – September 2013)***

Submitted in Compliance with
NPDES Permit No. CAS612008, Provision C.8.g.iii

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program

***A Program of the City/County Association of Governments***

**March 15, 2014**

# CREDITS

**This report is submitted by the participating agencies in the**

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
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**City of Brisbane**
**City of Burlingame**
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# Preface

In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA) joined together to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP)[1]. The RMC includes the following participants:

- Clean Water Program of Alameda County (ACCWP)
- Contra Costa Clean Water Program (CCCWP)
- San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)
- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
- Fairfield-Suisun Urban Runoff Management Program (FSURMP)
- City of Vallejo and Vallejo Sanitation and Flood Control District (Vallejo)

This Integrated Monitoring Report, Part A complies with the MRP Reporting Provision C.8.g.v for comprehensive reporting of all data collected pursuant to Provision C.8 in Water Years 2012 and 2013 (October 1, 2011 through September 30, 2013). Data presented in this report were produced under the direction of the RMC and the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) using probabilistic and targeted monitoring designs as described herein.

In accordance with the BASMAA RMC Multi-Year Work Plan (Work Plan; BASMAA 2011a) and the Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2011b), monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Program Plan (QAPP; BASMAA, 2012a) and BASMAA RMC Standard Operating Procedures (SOPs; BASMAA, 2012b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP[2]. Data presented in this report were also submitted in electronic SWAMP-comparable formats by SMCWPPP to the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) on behalf of SMCWPPP Permittees and pursuant to Provision C.8.g.

[1] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley, which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

[2] The current SWAMP QAPP is available at: http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/swamp_qapp_master090108a.pdf

# List of Acronyms

| | |
|---|---|
| ASBS | Area of Special Biological Significance |
| CEDEN | California Environmental Data Exchange Network |
| DPS | Distinct Population Segment |
| EMAF | Ecological Monitoring and Assessment Framework |
| HDI | Human Disturbance Index |
| ACCWP | Alameda County Clean Water Program |
| BASMAA | Bay Area Stormwater Management Agency Association |
| B-IBI | Benthic Macroinvertebrate Index of Biological Integrity |
| BOD | Biological Oxygen Demand |
| CCCWP | Contra Costa Clean Water Program |
| CRAM | California Rapid Assessment Method |
| FSURMP | Fairfield Suisun Urban Runoff Management Program |
| MBNMS | Monterey Bay National Marine Sanctuary |
| MPC | Monitoring and Pollutants of Concern Committee |
| MRP | Municipal Regional Permit |
| MWAT | Maximum Weekly Average Temperature |
| NPDES | National Pollution Discharge Elimination System |
| PAHs | Polycyclic Aromatic Hydrocarbons |
| PBDEs | Polybrominated Diphenyl Ethers |
| POC | Pollutants of Concern |
| QAPP | Quality Assurance Project Plan |
| RMC | Regional Monitoring Coalition |
| RMP | Regional Monitoring Program |
| SCVURPPP | Santa Clara Valley Urban Runoff Pollution Prevention Program |
| SFEI | San Francisco Estuary Institute |
| SFRWQCB | San Francisco Regional Water Quality Control Board |
| SMCRCD | San Mateo County Resource Conservation District |
| SMCWPPP | San Mateo Countywide Water Pollution Prevention Program |
| SOP | Standard Operating Procedures |
| SPoT | Statewide Stream Pollutant Trend Monitoring |
| SWAMP | Surface Water Ambient Monitoring Program |
| TOC | Total Organic Carbon |
| USEPA | US Environmental Protection Agency |
| WQO | Water Quality Objective |

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Appendix A. SMCWPPP Creek Status Monitoring Report

Appendix B. SMCWPPP Geomorphic Study

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# 1.0 Introduction

This Integrated Monitoring Report, Part A (IMR Part A), was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), on behalf of its 22 member agencies (20 cities/towns, the County of San Mateo, and the San Mateo County Flood Control District) subject to the National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP; Order R2-2009-0074) issued by the San Francisco Regional Water Quality Control Board (SFRWQCB or Regional Water Board) on October 14, 2009. This report fulfills the requirements of MRP Provision C.8.g.v for comprehensively interpreting and reporting all monitoring data collected pursuant to Provision C.8. This report is submitted by SMCWPPP in lieu of the Annual Urban Creeks Monitoring Report and includes data collected during Water Years[3] 2012 and 2013 (October 1, 2011 – September 30, 2013). Monitoring data presented in this report were submitted electronically to the SFRWQCB and may be obtained via the San Francisco Bay Area Regional Data Center (http://water100.waterboards.ca.gov/ceden/sfei.shtml).

This IMR Part A is intended to inform future monitoring efforts conducted by SMCWPPP under the next Report of Waste Discharge for the reissuance of the MRP.

Chapters in this report are organized according to the following topics and MRP provisions. Some topics are summarized briefly in this report but described more fully in appendices.

- San Francisco Estuary Receiving Water Monitoring (MRP Provision C.8.b)
- Creek Status Monitoring (MRP Provision C.8.c), including local targeted monitoring and SMCWPPP's contribution to the regional probabilistic monitoring program (Appendix A)
- Monitoring Projects (MRP Provision C.8.d):
    - Stressor/Source Identification
    - Best Management Practice (BMP) Effectiveness Investigation, and
    - Geomorphic Project (Appendix B)
- Pollutants of Concern Monitoring (MRP Provision C.8.e.i) (Appendix C)
- Long-Term Trends Monitoring (MRP Provision C.8.e.ii)
- Sediment Delivery Estimates (MRP Provision C.8.e.vi)
- Emerging Pollutants (MRP Provision C.8.e.vii)
- Citizen Monitoring and Participation (MRP Provision C.8.f)
- Monitoring Costs Summary
- Recommendations and Next Steps

Figure 1.1 shows locations the monitoring stations associated with Creek Status Monitoring, the Geomorphic Project, Pollutants of Concern (POC) Monitoring, and Long-Term Trends Monitoring conducted at Stream Pollution Trend (SPoT) stations.

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[3] A "water year" begins on October 1 and concludes on September 30 of the named year. For example, water year 2012 (WY2012) began on October 1, 2011, and continued through midnight on September 30, 2012.

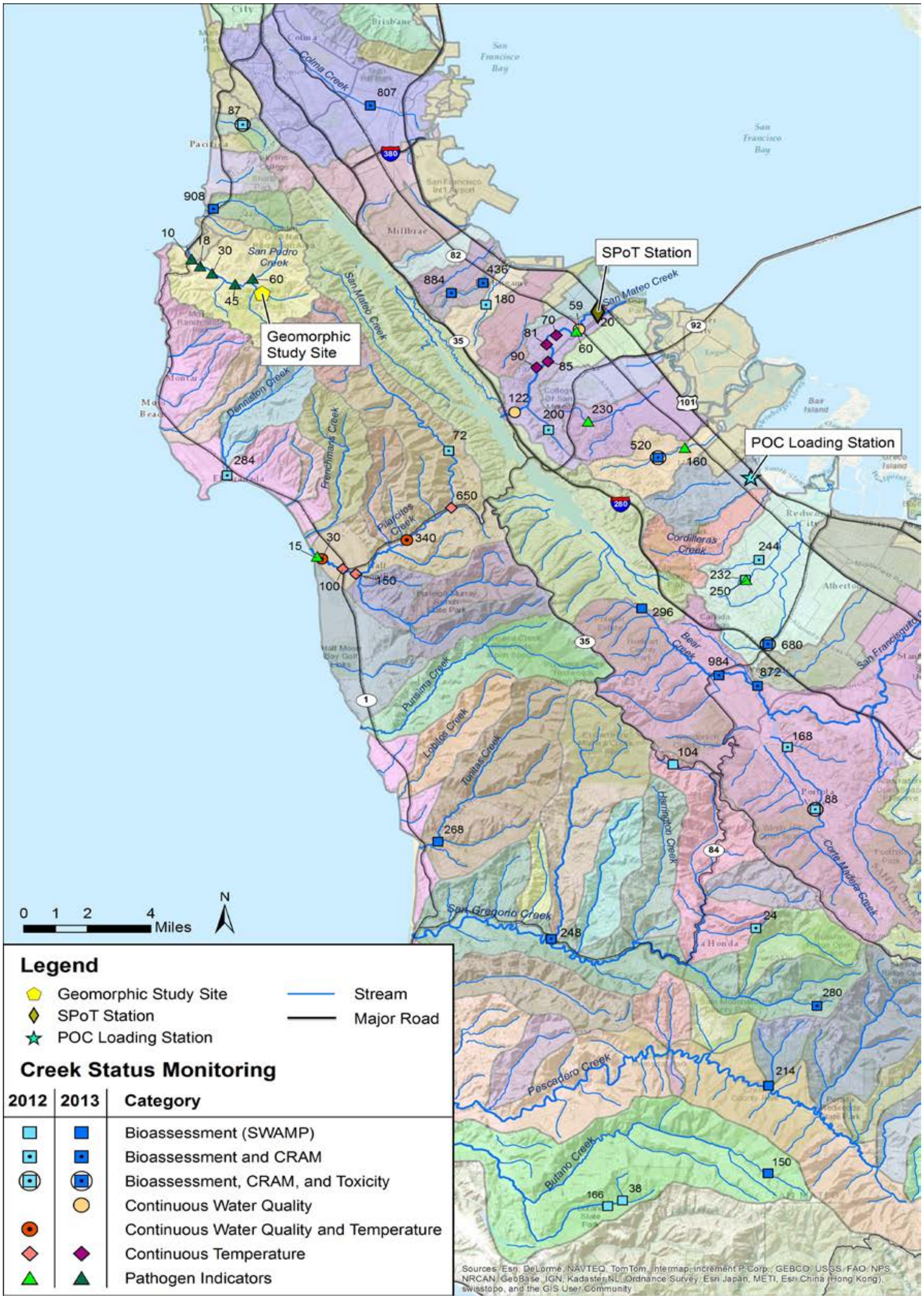


Figure 1.1. San Mateo County MRP Provision C.8 monitoring locations: Geomorphic Study, Long-Term Trends (SPoT), POC Loading, and Creek Status.

## 1.1 RMC Overview

Provision C.8.a (Compliance Options) of the MRP allows Permittees to address monitoring requirements through a "regional collaborative effort," their Stormwater Program, and/or individually. In June 2010, Permittees notified the Water Board in writing of their agreement to participate in a regional monitoring collaborative to address requirements in Provision C.8. The regional monitoring collaborative is referred to as the BASMAA Regional Monitoring Coalition (RMC). With notification of participation in the RMC, Permittees were required to commence water quality data collection by October 2011. In a November 2, 2010 letter to the Permittees, the Water Board's Assistant Executive Officer (Dr. Thomas Mumley) acknowledged that all Permittees have opted to conduct monitoring required by the MRP through a regional monitoring collaborative, the Bay Area Stormwater Management Agencies (BASMAA) Regional Monitoring Coalition (RMC). Participants in the RMC are listed in Table 1.1.

In February 2011, the RMC developed a Multi-Year Work Plan (RMC Work Plan; BASMAA 2011a) to provide a framework for implementing regional monitoring and assessment activities required under MRP provision C.8. The RMC Work Plan summarizes RMC projects planned for implementation between Fiscal Years 2009-10 and 2014-15. Projects were collectively developed by RMC representatives to the BASMAA Monitoring and Pollutants of Concern Committee (MPC), and were conceptually agreed to by the BASMAA BOD. A total of 27 regional projects are identified in the RMC Work Plan, based on the requirements described in provision C.8 of the MRP.

Regionally implemented activities in the RMC Work Plan are conducted under the auspices of the Bay Area Stormwater Management Agencies Association (BASMAA), a 501(c)(3) non-profit organization comprised of the municipal stormwater programs in the San Francisco Bay Area. Scopes, budgets, and contracting or in-kind project implementation mechanisms for BASMAA regional projects follow BASMAA's Operational Policies and Procedures, approved by the BASMAA Board of Directors (BOD). MRP Permittees, through their stormwater program representatives on the BOD and its subcommittees, collaboratively authorize and participate in BASMAA regional projects or tasks. Regional project costs are shared by either all BASMAA members or among those Phase I municipal stormwater programs that are subject to the MRP.

Table 1.1 Regional Monitoring Coalition participants.

| Stormwater Programs | RMC Participants |
|---|---|
| Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) | Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and, Santa Clara County |
| Clean Water Program of Alameda County (ACCWP) | Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and, Zone 7 |
| Contra Costa Clean Water Program (CCCWP) | Cities of Antioch, Brentwood, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, Danville, and Moraga; Contra Costa County; and, Contra Costa County Flood Control and Water Conservation District |
| San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) | Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County |
| Fairfield-Suisun Urban Runoff Management Program (FSURMP) | Cities of Fairfield and Suisun City |
| Vallejo Permittees | City of Vallejo and Vallejo Sanitation and Flood Control District |

# 2.0 San Francisco Estuary Receiving Water Monitoring (C.8.b)

As described in MRP provision C.8.b, Permittees are required to provide financial contributions towards implementing an Estuary receiving water monitoring program on an annual basis that at a minimum is equivalent to the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP). Since the adoption of the MRP, SMCWPPP has complied with this provision by making financial contributions to the RMP directly or through stormwater programs. Additionally, SMCWPPP actively participates in RMP committees and work groups as described in the following sections, which also provide a brief description of the RMP and associated monitoring activities conducted during this two-year reporting period.

The RMP is a long-term monitoring program that is discharger funded and shares direction and participation by regulatory agencies and the regulated community with the goal of assessing water quality in San Francisco Bay. The regulated community includes Permittees, publicly owned treatment works (POTWs), dredgers and industrial dischargers. SMCWPPP contributions to the RMP are discussed in Section 10 (Monitoring Costs Summary) of this report.

The RMP is intended to answer the following core management questions:

1. *Are chemical concentrations in the Estuary potentially at levels of concern and are associated impacts likely?*
2. *What are the concentrations and masses of contaminants in the Estuary and its segments?*
3. *What are the sources, pathways, loadings, and processes leading to contaminant related impacts in the Estuary?*
4. *Have the concentrations, masses, and associated impacts of contaminants in the Estuary increased or decreased?*
5. *What are the projected concentrations, masses, and associated impacts of contaminants in the Estuary?*

The RMP budget is generally broken into two major program elements: Status and Trends, and Pilot/Special Studies. The following sections provide a brief overview of these programs.

## 2.1 RMP Status and Trends Monitoring Program

The Status and Trends Monitoring Program (S&T Program) is the long-term contaminant-monitoring component of the RMP. The S&T Program was initiated as a pilot study in 1989 and redesigned in 2007 based on a more rigorous statistical design that enables the detection of trends. The Technical Review Committee (TRC) continues to assess the efficacy and value of the various elements of the S&T Program. In Water Years 2012 and 2013, the S&T Program was comprised of the following program elements that collect data to address RMP management questions described above:

- Long-term water, sediment, and bivalve monitoring
- Episodic toxicity monitoring
- Sport fish monitoring

- USGS hydrographic and sediment transport studies
    - Factors controlling suspended sediment in San Francisco Bay
    - Hydrography and phytoplankton
- Triennial bird egg monitoring (cormorant and tern)

Additional information on the S&T Program and associated monitoring data are available for downloading via the RMP website using the Status and Trends Monitoring Data Access Tool at www.sfei.org/rmp/data.htm.

## 2.2 RMP Pilot and Special Studies

The RMP also conducts Pilot and Special Studies (P/S Studies) on an annual basis. Studies usually are designed to investigate and develop new monitoring measures related to anthropogenic contamination or contaminant effects on biota in the Estuary. Special Studies address specific scientific issues that RMP committees and standing workgroups identify as priority for further study. These studies are developed through an open selection process at the workgroup level and selected for funding through RMP committees. Results and summaries of the most pertinent P/S Studies can be found on the RMP website (www.sfei.org/rmp/).

In Water Years 2012 and 2013, a considerable amount of RMP and Stormwater Program staff time was spent overseeing and implementing special studies associated with the RMP's Small Tributary Loading Strategy (STLS) and the STLS Multi-Year Monitoring Plan (MYP). Pilot and special studies associated with the STLS are intended to fill data gaps associated with loadings of Pollutants of Concern (POC) from relatively small tributaries to the San Francisco Bay. Additional information is provided on STLS-related studies under Section 5 (POC Loads Monitoring) of this report.

## 2.3 Participation in Committees, Workgroups and Strategy Teams

In Water Years 2012 and 2013, SMCWPPP actively participated in the following RMP Committees and workgroups:

- Steering Committee (SC)
- Technical Review Committee (TRC)
- Sources, Pathways and Loadings Workgroup (SPLWG)
- Contaminant Fate Workgroup (CFWG)
- Exposure and Effects Workgroup (EEWG)
- Emerging Contaminant Workgroup (ECWG)
- Sport Fish Monitoring Workgroup
- Toxicity Workgroup
- Strategy Teams (e.g., PCBs, Mercury, Dioxins, Small Tributaries, Nutrients)

Committee and workgroup representation was provided by Permittee, stormwater program staff and/or individuals designated by RMC participants and the BASMAA BOD. Representation included participating in meetings, reviewing technical reports and work products, co-authoring or reviewing articles included in the RMP's *Pulse of the Estuary*, and providing general program direction to RMP staff. Representatives of the RMC also provided timely summaries and updates to, and received input from stormwater program representatives (on behalf of Permittees) during MPC and/or BOD meetings to ensure Permittees' interests were represented.

# 3.0 Creek Status Monitoring (C.8.c)

Provision C.8.c requires Permittees to conduct creek status monitoring that is intended to answer the following management questions:

1. *Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?*
2. *Are conditions in local receiving waters supportive of or likely supportive of beneficial uses?*

Creek status monitoring parameters, methods, occurrences, durations and minimum number of sampling sites for each stormwater program are described in Table 8.1 of the MRP. Based on the implementation schedule described in MRP Provision C.8.a.ii, creek status monitoring coordinated through the RMC began in October 2011.

The RMC's regional monitoring strategy for complying with MRP provision C.8.c - creek status monitoring - is described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2011b). The strategy includes a regional ambient/probabilistic monitoring component and a component based on local "targeted" monitoring. The combination of these monitoring designs allows each individual RMC participating program to assess the status of beneficial uses in local creeks within its Program (jurisdictional) area, while also contributing data to answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks). Creek status monitoring data from Water Years 2012 and 2013 were submitted to the Regional Water Board by each applicable RMC participating program. The analyses of results from creek status monitoring conducted by SMCWPPP in Water Years 2012 and 2013 are summarized below and presented in detail in Appendix A (SMCWPPP Creek Status Monitoring Report).

The targeted monitoring design focuses on sites selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns. Targeted monitoring parameters consist of water temperature, general water quality, pathogen indicators and riparian assessments. Hourly water temperature measurements were recorded during the dry season using HOBO® temperature data loggers installed at four sites in Pilarcitos Creek in WY2012 and four sites in San Mateo Creek in WY2013. General water quality monitoring (temperature, dissolved oxygen, pH and specific conductivity) was conducted using YSI continuous water quality equipment (sondes) for two 2-week periods (spring and late summer) at two sites in each year in the same creeks. Water samples were collected at five sites each year for analysis of pathogen indicators (*E. coli* and fecal coliform). In WY2012, the pathogen sites were spread throughout San Mateo County. In WY2013, all five pathogen sites were located in San Pedro Creek. Riparian assessments were conducted at probabilistic sites using the California Rapid Assessment Method (CRAM).

The probabilistic monitoring design was developed to remove bias from site selection such that ecosystem conditions can be objectively assessed on local (i.e., SMCWPPP) and regional (i.e., RMC) scales. Probabilistic parameters consist of bioassessment, nutrients and conventional analytes, chlorine, water and sediment toxicity, and sediment chemistry. Twenty-three sites were sampled in Water Years 2012 and 2013. A small number of these sites were sampled by the San Francisco Regional Water Quality Control Board (SFRWQCB) as part of the Surface Water Ambient Monitoring Program (SWAMP), in collaboration with SMCWPPP. Targeted and probabilistic Creek Status monitoring stations are listed in Table 3.1 and mapped in Figure 3.1. (and Figure 1.1, with other types of monitoring stations).

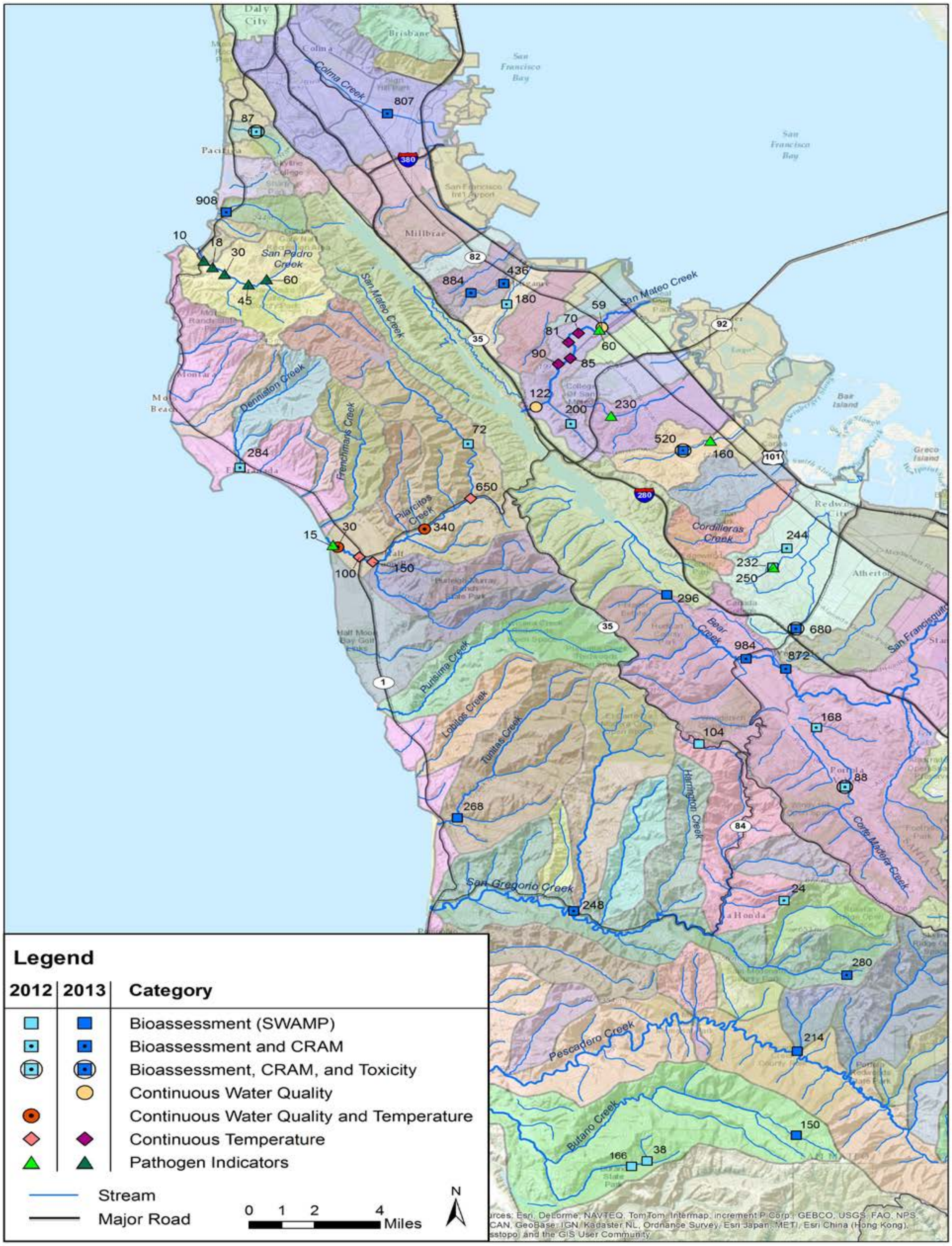


Figure 3.1. Map of SMCWPPP Program Area, major creeks, and stations monitored in Water Years 2012 and 2013 in compliance with MRP Provision C.8.c.

**Table 3.1.** MRP Provision C.8.c Creek Status monitoring stations in San Mateo County, Water Years 2012 and 2013.

| Map ID | Station Number | Bay Ocean | Watershed | Creek Name | Land Use | Latitude | Longitude | Probabilistic | | Targeted | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Bioassessment, Nutrients, General WQ | Toxicity, Sediment Chemistry | CRAM | Temp-erature | Continuous Water Quality | Pathogen Indicators | Water Year |
| 160 | 204BEL160 | Bay | Belmont Creek | Belmont Creek | | 37.51618 | -122.27904 | | | | | | x | 2012 |
| 520 | 204R00520 | Bay | Belmont Creek | Belmont Creek | U | 37.51220 | -122.29121 | x | x | x | | | | 2013 |
| 807 | 204R00807 | Bay | Colma Creek | Colma Creek | U | 37.65227 | -122.42204 | x | | x | | | | 2013 |
| 436 | 204R00436 | Bay | Easton Creek | Easton Creek | U | 37.58173 | -122.37066 | x | | x | | | | 2013 |
| 884 | 204R00884 | Bay | Easton Creek | Easton Creek | U | 37.57775 | -122.38511 | x | | x | | | | 2013 |
| 230 | 204LAU230 | Bay | Laurel Creek | Laurel Creek | | 37.52658 | -122.32298 | | | | | | x | 2012 |
| 232 | 204R00232 | Bay | Redwood Creek | Arroyo Ojo De Aqua | U | 37.46109 | -122.25504 | x | | x | | | | 2012 |
| 250 | 204AOA250 | Bay | Redwood Creek | Arroyo Ojo de Aqua | | 37.46109 | -122.25504 | | | | | | x | 2012 |
| 680 | 204R00680 | Bay | Redwood Creek | Redwood Creek | U | 37.43798 | -122.24128 | x | x | x | | | | 2013 |
| 244 | 204R00244 | Bay | Redwood Creek | Trib to Arroyo Ojo De Aqua | U | 37.47147 | -122.24532 | x | | x | | | | 2012 |
| 984 | 202R00984 | Bay | San Francisquito Creek | Bear Gulch Creek | U | 37.42543 | -122.26349 | x | | x | | | | 2013 |
| 872 | 205R00872 | Bay | San Francisquito Creek | Bear Gulch Creek | U | 37.42125 | -122.24588 | x | | x | | | | 2013 |
| 88 | 205R00088 | Bay | San Francisquito Creek | Corte Madera Creek | U | 37.372 | -122.21964 | x | x | x | | | | 2012/13[1] |
| 168 | 205R00168 | Bay | San Francisquito Creek | Corte Madera Creek | U | 37.3968 | -122.23231 | x | | x | | | | 2012 |
| 296* | 205R00296 | Bay | San Francisquito Creek | West Union Creek | NU | 37.45211 | -122.29852 | x | | | | | | 2013 |
| 200 | 204R00200 | Bay | San Mateo Creek | Polhemus Creek | U | 37.52325 | -122.3409 | x | | x | | | | 2012 |
| 59 | 204SMA059 | Bay | San Mateo Creek | San Mateo Creek | | 37.56331 | -122.32707 | | | | | x | | 2013 |
| 70 | 204SMA070 | Bay | San Mateo Creek | San Mateo Creek | | 37.56096 | -122.33751 | | | | x | | | 2013 |
| 81 | 204SMA081 | Bay | San Mateo Creek | San Mateo Creek | | 37.55722 | -122.34191 | | | | x | | | 2013 |
| 85 | 204SMA085 | Bay | San Mateo Creek | San Mateo Creek | | 37.55053 | -122.34119 | | | | x | | | 2013 |
| 90 | 204SMA090 | Bay | San Mateo Creek | San Mateo Creek | | 37.54816 | -122.34644 | | | | x | | | 2013 |
| 122 | 204SMA122 | Bay | San Mateo Creek | San Mateo Creek | | 37.53033 | -122.356308 | | | | | x | | 2013 |
| 60 | 204SMA060 | Bay | San Mateo Creek | San Mateo Creek | | 37.56244 | -122.32828 | | | | | | x | 2012 |
| 180 | 204R00180 | Bay | Sanchez Creek | Sanchez Creek | U | 37.57313 | -122.36934 | x | | x | | | | 2012 |

| Map ID | Station Number | Bay Ocean | Watershed | Creek Name | Land Use | Latitude | Longitude | Probabilistic | | Targeted | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Bioassessment, Nutrients, General WQ | Toxicity, Sediment Chemistry | CRAM | Temp-erature | Continuous Water Quality | Pathogen Indicators | Water Year |
| 150* | 202R00150 | Ocean | Butano Creek | Butano Creek | NU | 37.22664 | -122.24120 | x | | | | | | 2013 |
| 166* | 202R00166 | Ocean | Butano Creek | Little Butano Creek | NU | 37.21363 | -122.31411 | x | | | | | | 2012 |
| 38* | 202R00038 | Ocean | Butano Creek | Little Butano Creek | NU | 37.21590 | -122.30728 | x | | | | | | 2012 |
| 908 | 202R00908 | Ocean | Calera Creek | Calera Creek | U | 37.61128 | -122.49336 | x | | x | | | | 2013 |
| 284 | 202R00284 | Ocean | Denniston Creek | Denniston Creek | U | 37.50515 | -122.48723 | x | | x | | | | 2012 |
| 87 | 202R00087 | Ocean | Milagra Creek | Milagra Creek | U | 37.64474 | -122.48009 | x | x | x | | | | 2012 |
| 214* | 202R00214 | Ocean | Pescadero Creek | Tarwater Creek | NU | 37.26166 | -122.24082 | x | | | | | | 2013 |
| 30 | 202PIL030 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.47195 | -122.44399 | | | | x | x | | 2012 |
| 100 | 202PIL100 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.46788 | -122.43456 | | | | x | | | 2012 |
| 150 | 202PIL150 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.46584 | -122.42858 | | | | x | | | 2012 |
| 340 | 202PIL340 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.47945 | -122.40549 | | | | x | x | | 2012 |
| 650 | 202PIL650 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.49225 | -122.38523 | | | | x | | | 2012 |
| 72 | 202R00072 | Ocean | Pilarcitos Creek | Pilarcitos Creek | NU | 37.51493 | -122.38637 | x | | x | | | | 2012 |
| 15 | 202PIL015 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.47282 | -122.44616 | | | | | | x | 2012 |
| 104* | 202R00104 | Ocean | San Gregorio Creek | La Honda Creek | NU | 37.38989 | -122.28430 | x | | | | | | 2012 |
| 248 | 202R00248 | Ocean | San Gregorio Creek | San Gregorio Creek | NU | 37.32028 | -122.33978 | x | | x | | | | 2013 |
| 280 | 202R00280 | Ocean | San Gregorio Creek | Tributary to Alpine Creek | NU | 37.29353 | -122.21885 | x | | x | | | | 2013 |
| 24 | 202R00024 | Ocean | San Gregorio Creek | Woodhams Creek | NU | 37.32468 | -122.24666 | x | | x | | | | 2012 |
| 10 | 202SPE010 | Ocean | San Pedro Creek | San Pedro Creek | | 37.59113 | -122.50331 | | | | | | x | 2013 |
| 18 | 202SPE018 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58841 | -122.49944 | | | | | | x | 2013 |
| 30 | 202SPE030 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58556 | -122.49409 | | | | | | x | 2013 |
| 45 | 202SPE045 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58125 | -122.48350 | | | | | | x | 2013 |
| 60 | 202SPE060 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58344 | -122.47548 | | | | | | x | 2013 |
| 268* | 202R00268 | Ocean | Tunitas Creek | Dry Creek | NU | 37.35917 | -122.39124 | x | | | | | | 2013 |

* indicates site sampled by SFRWQCB through the SWAMP program.

The first management question (***Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?***) is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in Table 8.1 of the MRP. A summary of trigger exceedances observed for each site is presented in Table 3.2. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of stressor source identification projects.

The second management question (***Are conditions in local receiving waters supportive of or likely supportive of beneficial uses?***) is addressed primarily through calculation of indices of biological integrity (IBI) using benthic macroinvertebrate data collected at probabilistic sites and sites sampled prior to MRP implementation. Biological condition scores were compared to physical habitat and water quality data collected synoptically with bioassessments to evaluate whether any correlations exist that may explain the variation in IBI scores.

**Biological Condition**

- Under the level of MRP-required monitoring, the RMC probabilistic design requires at least four years of data to develop a statistically-robust characterization of biological conditions of the creeks within SMCWPPP. Therefore, the **overall biological condition assessment** that can be derived based on the Water Years 2012 and 2013 bioassessment data should be considered preliminary.
- Southern California benthic macroinvertebrate index of biological integrity (SoCal B-IBI) scores were calculated to assess biological condition at probabilistic sites. Ten sites (43%) scored as very poor or poor (scores of 0 to 39). All of these sites are located in urban areas, with half the sites characterized as highly modified channels. Ten sites (43%) were scored as very good or good (scores of 60 to 100) with a majority of these sites classified as non-urban.
- California Stream Condition Index (CSCI) scores were calculated for MRP probabilistic sites as well as a large historical dataset (2002 to 2009) to evaluate the utility of this new tool. Overall, the CSCI scores correlated well with SoCal B-IBI scores. The CSCI scores showed greater variability within each condition category, suggesting it may be more responsive to stressors associated with physical habitat condition and water quality. The three CSCI condition categories developed for this report are mapped for the entire 2002 to 2013 dataset in Figure 3.2.
- The mean CSCI scores were higher for perennial sites compared to non-perennial sites (0.82 versus 0.57) and higher for non-urban sites compared to urban sites (1.0 versus 0.55).
- Total Physical Habitat (PHAB) and CRAM scores were moderately correlated with biological condition scores. High CRAM score (79 out of 100) and very poor CSCI score (0.19) at one site (202R00908) may indicate that water quality stressor(s) are impacting biological condition.
- Diatom IBI scores do not correlate well with CSCI or SoCal B-IBI scores. None of the physical habitat or water quality stressor variables correlated well with the Diatom IBI scores.

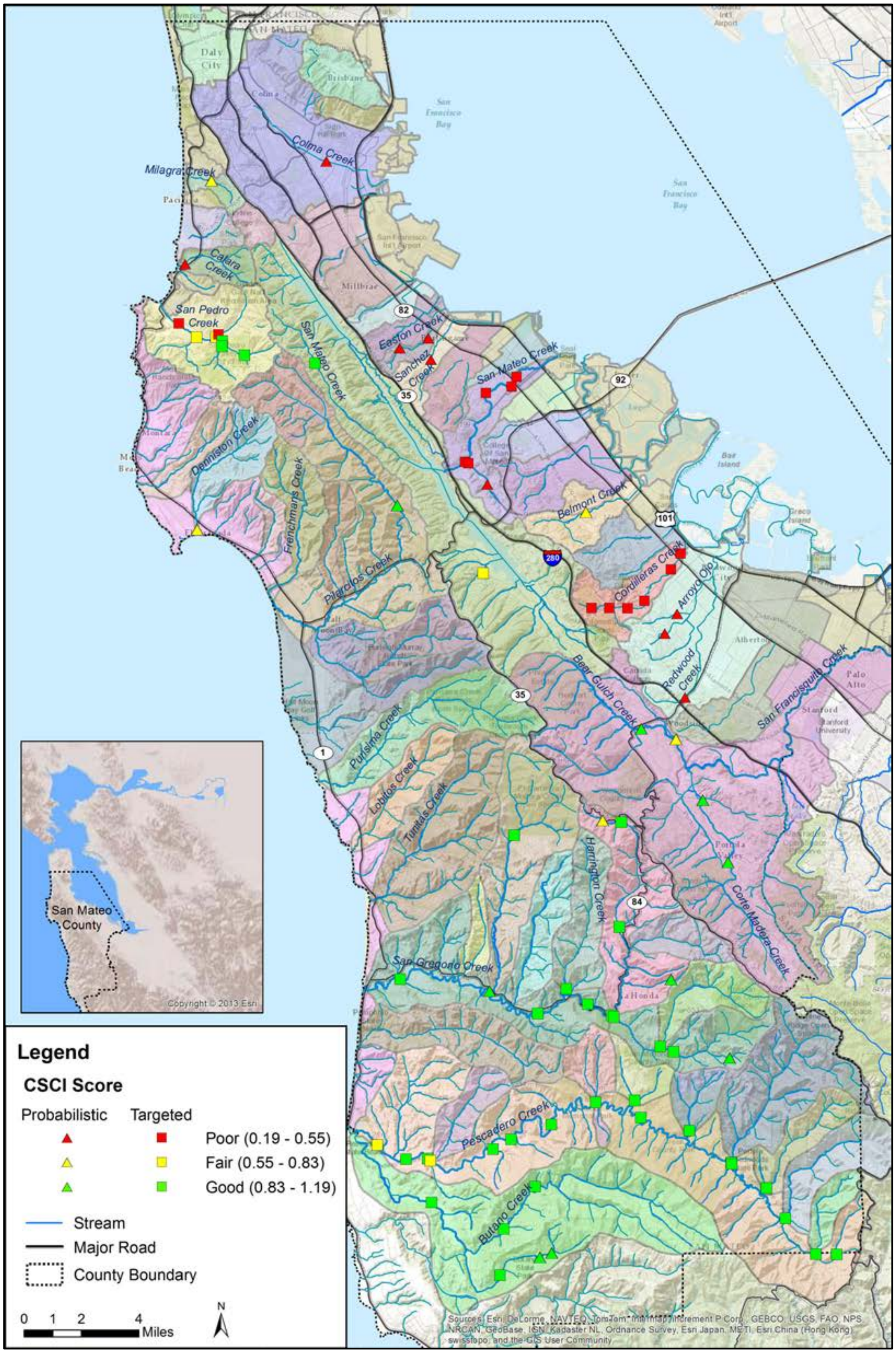


Figure 3.2. CSCI condition category for sites sampled between 2002 and 2013, San Mateo County.

### Nutrients and Conventional Analytes

- Nutrients (nitrogen and phosphorus), algal biomass indicators, and other conventional analytes were measured in samples collected concurrently with bioassessments which are conducted in the spring season. MRP Trigger thresholds for chloride, unionized ammonia, and nitrate were not exceeded.

- The parameters in this group of constituents that correlates well with SoCal B-IBI and CSCI scores include chloride, nitrate, and total Kjeldahl nitrogen.

### Water Toxicity

- Water toxicity samples were collected from three sites during each year of the program at a frequency of twice per year. No water toxicity samples exceeded the MRP trigger thresholds.

### Sediment Toxicity and Chemistry/Sediment Triad Analysis

- Sediment toxicity and chemistry samples were collected concurrently with the summer water toxicity samples. No MRP trigger thresholds were exceeded.

- Sediment toxicity was evaluated with bioassessment scores and sediment chemistry data (TEC and PEC quotients, and pyrethroid TU equivalents) as part of the Sediment Triad Analysis. One or more aspects of the Sediment Triad Analysis were exceeded at each site.

### Spatial and Temporal Variability of Water Quality Conditions

- There was minimal spatial variability in water temperature across the five sites in Pilarcitos Creek and across the four sites in San Mateo Creek.

- Dissolved oxygen concentrations at the De Anza Park site (204SMA059) in San Mateo Creek were consistently lower compared to levels measured at the site below the dam. At the De Anza site, DO levels had diurnal fluctuations that appear to be driven by stratification and mixing caused by changes in air temperature.

### Potential Water Quality Impacts to Aquatic Life

- There were no exceedances of the Mean Weekly Average Temperature (MWAT) threshold at the two sites in Pilarcitos Creek or two sites in San Mateo Creek. These results suggest that water temperature is not a limiting factor for the resident steelhead population.

- Dissolved oxygen concentrations at both sites monitored in Pilarcitos Creek did not exceed WARM or COLD Water Quality Objectives. The WQO for COLD was exceeded at the De Anza Park site (204SMA059) for 24% - 36% of the measurements made during the summer and spring sampling event, respectively. In WY 2014, SMCWPPP will conduct further investigation on the spatial and temporal extent of reduced dissolved oxygen concentrations at the De Anza Park site.

- Values for pH were within Water Quality Objectives at both sites in Pilarcitos Creek and San Mateo Creek.

**Potential Impacts to Water Contact Recreation**

- Pathogen indicator densities were measured at five sites spread throughout San Mateo County in WY2012. In WY2013, pathogen indicator sites were focused in San Pedro Creek where a bacteria TMDL was recently adopted. Threshold triggers for fecal coliform and/or *E. coli* were exceeded at all sites in WY2012 and at four sites in WY2013.

- It is important to recognize that pathogen indicator thresholds are based on human recreation at beaches receiving bacteriological contamination from human wastewater (not animal sources), and may not be applicable to conditions found in urban creeks. As a result, the comparison of pathogen indicator results to Water Quality Objectives and criteria for full body contact recreation, may not be appropriate and should be interpreted cautiously.

**Table 3.2.** Summary of SMCWPPP trigger threshold exceedance analysis, Water Years 2012 and 2013. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger

| Station Number | Creek Name | Bioassessment | Nutrients | Chlorine | Water Toxicity | Sediment Toxicity | Sediment Chemistry | Temperature | Continuous WQ | Pathogen Indicators | Water Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 204BEL160 | Belmont Creek | | | | | | | | | Yes | 2012 |
| 204R00520 | Belmont Creek | Yes | No | Yes | No | No | Yes | | | | 2013 |
| 204R00807 | Colma Creek | Yes | No | No | | | | | | | 2013 |
| 204R00436 | Easton Creek | Yes | No | No | | | | | | | 2013 |
| 204R00884 | Easton Creek | Yes | No | No | | | | | | | 2013 |
| 204LAU230 | Laurel Creek | | | | | | | | | Yes | 2012 |
| 204R00232 | Arroyo Ojo De Aqua | Yes | No | No | | | | | | | 2012 |
| 204AOA250 | Arroyo Ojo de Aqua | | | | | | | | | Yes | 2012 |
| 204R00680 | Redwood Creek | Yes | No | No | No | No | Yes | | | | 2013 |
| 204R00244 | Tributary to Arroyo Ojo De Aqua | Yes | No | Yes | | | | | | | 2012 |
| 202R00984 | Bear Gulch Creek | No | No | No | | | | | | | 2013 |
| 205R00872 | Bear Gulch Creek | No | No | No | | | | | | | 2013 |
| 205R00088 | Corte Madera Creek | No | No | No | No | No | Yes | | | | 2012 |
| 205R00168 | Corte Madera Creek | No | No | No | | | | | | | 2012 |
| 204R00200 | Polhemus Creek | Yes | No | No | | | | | | | 2012 |
| 204SMA059 | San Mateo Creek | | | | | | | | Yes | | 2013 |
| 204SMA070 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA081 | San Mateo Creek | | | | | | | No | | | 2013 |

| Station Number | Creek Name | Bioassessment | Nutrients | Chlorine | Water Toxicity | Sediment Toxicity | Sediment Chemistry | Temperature | Continuous WQ | Pathogen Indicators | Water Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 204SMA085 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA090 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA122 | San Mateo Creek | | | | | | | | No | | 2013 |
| 204SMA060 | San Mateo Creek | | | | | | | | | Yes | 2012 |
| 204R00180 | Sanchez Creek | Yes | No | No | | | | | | | 2012 |
| 202R00166 | Little Butano Creek | No | No | No | | | | | | | 2012 |
| 202R00038 | Little Butano Creek | No | No | No | | | | | | | 2012 |
| 202R00908 | Calera Creek | Yes | No | Yes | | | | | | | 2013 |
| 202R00284 | Denniston Creek | No | No | No | | | | | | | 2012 |
| 202R00087 | Milagra Creek | No | No | No | No | No | Yes | | | | 2012 |
| 202PIL030 | Pilarcitos Creek | | | | | | | No | No | | 2012 |
| 202PIL100 | Pilarcitos Creek | | | | | | | No | | | 2012 |
| 202PIL150 | Pilarcitos Creek | | | | | | | No | | | 2012 |
| 202PIL340 | Pilarcitos Creek | | | | | | | No | No | | 2012 |
| 202PIL650 | Pilarcitos Creek | | | | | | | No | | | 2012 |
| 202R00072 | Pilarcitos Creek | No | No | No | | | | | | | 2012 |
| 202PIL015 | Pilarcitos Creek | | | | | | | | | Yes | 2012 |
| 202R00104 | La Honda Creek | No | No | | | | | | | | 2012 |
| 202R00248 | San Gregorio Creek | No | No | No | | | | | | | 2013 |
| 202R00280 | Tributary to Alpine Creek | No | No | No | | | | | | | 2013 |
| 202R00024 | Woodhams Creek | No | No | No | | | | | | | 2012 |
| 202SPE010 | San Pedro Creek | | | | | | | | | Yes | 2013 |
| 202SPE018 | San Pedro Creek | | | | | | | | | Yes | 2013 |
| 202SPE030 | San Pedro Creek | | | | | | | | | No | 2013 |
| 202SPE045 | San Pedro Creek | | | | | | | | | Yes | 2013 |
| 202SPE060 | San Pedro Creek | | | | | | | | | Yes | 2013 |

# 4.0 Monitoring Projects (C.8.d)

Three types of monitoring projects are required by provision C.8.d of the MRP:

1. Stressor/Source Identification Projects (C.8.d.i);
2. BMP Effectiveness Investigations (C.8.d.ii); and,
3. Geomorphic Projects (C.8.d.iii).

The overall scopes of these projects are generally described in the MRP and the RMC Work Plan. The status of projects that SMCWPPP is conducting are described in the sections below.

## 4.1 Stressor/Source Identification Projects

Stressor/Source Identification (SSID) projects are required by Provision C.8.d.i of the MRP. This provision requires that SMCWPPP conduct monitoring projects to identify and isolate potential sources and/or stressors associated with observed water quality impacts. Creeks considered for SSID projects are those with creek status monitoring results that trigger follow-up actions per Table 8.1 of the MRP.

Based on creek status monitoring data collected by SMCWPPP, two SSID projects have been initiated.

### 4.1.1 San Mateo Creek Low Dissolved Oxygen SSID Project

San Mateo Creek drains approximately 33 square miles including parts of unincorporated San Mateo County, the City of San Mateo, and the Town of Hillsborough. Below the Crystal Springs reservoir dam, the watershed encompasses approximately five square miles and is mostly urbanized. In 2003, the SFRWQCB monitored several stations within the San Mateo Creek watershed to assess water quality impacts and establish regional reference sites as part of the Surface Water Ambient Monitoring Program (SWAMP). Sondes programmed to continuously monitor pH, dissolved oxygen (DO), temperature, and specific conductivity were deployed for one to two week “episodes” during three parts of the annual hydrograph: wet season, decreasing hydrograph/spring, and dry season (SFRWQCB 2007). DO concentrations measured at two of the stations below Crystal Springs reservoir were below the cold water minimum Water Quality Objective of 7 mg/L during the spring (April 27 to May 12, 2003), summer (August 7 to 25 , 2003) and fall (October 20 to 31, 2003) deployments. Citing maximum DO percent saturation levels above 120, SFRWQCB (2007) reported that the DO concentrations were consistent with excessive photosynthesis.

In WY2013, in an effort to confirm SFRWQCB findings, SMCWPPP conducted MRP Provision C.8.c continuous monitoring at one of the SFRWQCB stations (Arroyo Court/De Anza Historical Park). A second station on San Mateo Creek, just below Crystal Springs reservoir, was also sampled by SMCWPPP to further assess the extent of potential low DO conditions. Results of the two-week deployment in June 2013 at Arroyo Court showed low DO concentrations that trigger follow-up actions per Table 8.1 of the MRP. A daily pattern of fluctuating DO concentrations was observed. However, the pattern was not consistent with excessive photosynthesis. Excessive photosynthesis typically results in maximum DO concentrations in late afternoon when photosynthesis (e.g., oxygen production) is at a maximum followed by minimum DO concentrations at night when photosynthesis has stopped and micro-organisms are consuming oxygen. The DO pattern was instead more consistent with late-afternoon thermal stratification of the pool (possibly as a result of low stream flow, high air temperatures, and cold groundwater seepage) followed by mixing at night as air temperatures cool. Similar patterns have been observed in Coyote Creek by SCVURPPP.

SMCWPPP is in the process of developing a work plan to further investigate the extent, duration, and cause of low DO concentrations in San Mateo Creek. Increased summer discharges from Crystal Springs reservoir are anticipated in the future as a result of the dam improvements that are currently being constructed by the San Francisco Public Utilities Commission (SFPUC). The date when the new reservoir release schedule begins is still unknown due to construction delays (Jason Bielski, SFPUC Supervising Biologist, personal communication). If feasible, the San Mateo Creek SSID project will include monitoring before and after the new release schedule to assess whether DO concentrations respond to increased summer flows. SMCWPPP anticipates completing a conceptual work plan for this SSID project and implementing it beginning in spring 2014.

### 4.1.2 San Mateo Creek Indicator Bacteria SSID Project

SMCWPPP recently selected San Mateo Creek (in the City and County of San Mateo and Town of Hillsborough) to be the focus of a second SSID project. Samples collected in WY2012 where the creek passes through De Anza Park exceeded MRP trigger thresholds for pathogen indicator bacteria (fecal coliform and *E. coli*). San Mateo creek drains a watershed with a high percentage of residential land uses. Based on this land use and anecdotal evidence, pet waste has been identified as one likely source of pathogen indicator bacteria, but human sources (e.g., leaking sanitary sewer collection system infrastructure) are also possible. SMCWPPP is developing a work plan to conduct a microbial source tracking (MST) study to characterize source(s) of pathogen indicator bacteria in the watershed and potentially inform future management practices to reduce sources of pathogen indicator bacteria. SMCWPPP anticipates completing a conceptual work plan for this SSID project and implementing it beginning in spring 2014.

## 4.2 BMP Effectiveness Investigation

The purpose of the BMP Effectiveness Investigation is to complete monitoring tasks to address requirements listed under Provision C.8.d.ii of the MRP. This MRP provision requires that SMCWPPP investigate the effectiveness of one BMP for stormwater treatment or hydrograph modification control. The MRP encourages investigation of BMP(s) used to fulfill requirements of Provisions C.3.b.iii, C.11.e, and C.12.e, provided the BMP Effectiveness Investigation includes the range of pollutants generally found in urban runoff.

The Clean Watershed for a Clean Bay (CW4CB) project was initiated to evaluate pilot BMPs installed for the control of polychlorinated biphenyls (PCBs) and mercury in stormwater runoff from urban areas pursuant to MRP Provisions C.11 and C.12. A monitoring plan is currently being developed to quantify PCB and mercury load reduction from several pilot BMPs in the Bay Areas. In San Mateo County, the CW4CB monitoring will focus on a series of curb extensions and bioretention/biotreatment facilities located along Bransten Road in the City of San Carlos. The CW4CB monitoring design at Bransten Road will likely include paired influent and effluent sampling and volume/flow measurements to calculate PCB and mercury load reductions. CW4CB analytical constituents will likely include suspended sediments, total organic carbon, lead, mercury, and PCBs. Samples will be collected and flow volumes will be measured during two to four storm events in WY2014.

In compliance with MRP Provision C.8.d.ii, SMCWPPP will add additional analytical constituents to the CW4CB study plan for one of the paired BMP influent/effluent stations at Bransten Road. The additional constituents will include typical urban runoff pollutants such as total and dissolved metals and nutrients.

## 4.3 Geomorphic Project

MRP Provision C.8.d.iii requires Permittees to conduct a geomorphic monitoring project intended to answer the management question:

- *How and where can our creeks be restored or protected to cost-effectively reduce the impacts of pollutants, increased flow rates, and increased flow durations of urban runoff?*

The provision requires that Permittees select a waterbody/reach, preferably one that contains significant fish and wildlife resources, and conduct one of three types of projects. SMCWPPP elected to conduct a geomorphic study to help in the development of regional curves which help estimate equilibrium channel conditions for different sized drainages. As part of this Geomorphic Study, SMCWPPP surveyed bankfull geometries at two consecutive riffles in the Middle Fork of San Pedro Creek. The survey location is mapped in Figure 1.1.

The reach of San Pedro Creek where the survey was conducted is located within a County park with a 1.2-square mile watershed consisting of coastal brush and chaparral. The reach was determined to be a geomorphically stable, self-formed alluvial channel. This conclusion was based on the absence of erosion and/or aggradation in the channel and field observations of even-aged alder trees on the terrace corresponding to cohorts which sprouted in association with major storms of the past several decades.

On November 22, 2013, a longitudinal profile and two crest-of-riffle cross-sections were surveyed using TopCon Total Station equipment provided by the San Francisco State University Geography Department. Channel cross-sections were marked with permanent, protruding monuments (rebar posts). Average bankfull cross-sectional area was plotted with other Bay Area regional curves developed by: Collins and Leventhal (2013) for Marin and Sonoma Counties, Hecht et al. (2013) for Inland Santa Clara County, Riley (2003) for the East Bay, and Dunne and Leopold (1978) for the Bay Area. San Pedro Creek plots close to the Dunne and Leopold (1978) curve which is considered appropriate for areas with 30 inches or more of annual precipitation. Mean annual precipitation for the Middle Fork of San Pedro Creek watershed was estimated to be 36 inches using the spatially gridded long-term average annual precipitation dataset (1981-2010) downloaded from the PRISM Climate Group at Oregon State University.

More details on the SMCWPPP Geomorphic Study are included as Appendix B.

# 5.0 POC Loads Monitoring (C.8.e)

Pollutants of Concern (POC) loads monitoring is required by Provision C.8.e.i of the MRP. Loads monitoring is intended to assess inputs of POCs to the Bay from local tributaries and urban runoff, assess progress toward achieving wasteload allocations (WLAs) for TMDLs, and help resolve uncertainties associated with loading estimates for these pollutants. In particular, there are four priority management questions that need to be addressed though POC loads monitoring:

1. *Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs?*
2. *What are the annual loads or concentrations of POCs from tributaries to the Bay?*
3. *What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay?*
4. *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?*

An RMP Small Tributaries Loading Strategy (STLS) was developed in 2009 by the STLS Team, which included representatives from BASMAA, Regional Water Board staff, RMP staff, and technical advisors. The objective of the STLS is to develop a comprehensive planning framework to coordinate POC loads monitoring/modeling between the RMP and RMC participants. With concurrence of participating Regional Water Board staff, the framework presents an alternative approach to the POC loads monitoring requirements described in MRP Provision C.8.e.i, as allowed by Provision C.8.e. The framework is updated annually with summaries of activities and products to date. The current version (Version 2013a) of the STLS Multi-Year Plan (MYP) was submitted with the Regional Urban Creeks Monitoring Report in March 2013. The MYP includes four main elements that collectively address the four priority management questions for POC monitoring:

1. Watershed Modeling (Regional Watershed Spreadsheet Model),
2. Bay Margins Modeling,
3. Source Area Runoff Monitoring, and
4. Small Tributaries Watershed Monitoring.

Results of each of the STLS MYP elements are described in Part C of the IMR. This Part A of the IMR focuses on a comparison of water quality data measured at the SMCWPPP Small Tributaries Watershed Monitoring station (element No. 4) to Water Quality Objectives. Results of the analysis do not trigger SSID projects.

## 5.1 Small Tributaries Watershed Monitoring

The STLS MYP includes intensive monitoring at a total of six “bottom-of-the watershed” stations over several years to accumulate data needed to calibrate the Regional Watershed Spreadsheet Model and assist in developing loading estimates from small tributaries for priority POCs. Monitoring is also intended to provide a limited characterization of additional lower priority analytes.

Water Year 2013 was the second year of monitoring activities at four stations that were set up and mobilized beginning in October 2011. Two additional stations were established in October 2012 to complete the monitoring network.

1. Lower Marsh Creek (Contra Costa County), established Water Year 2012
2. Guadalupe River (Santa Clara County), established Water Year 2012
3. Lower San Leandro Creek (Alameda County), established Water Year 2012
4. Sunnyvale East Channel (Santa Clara County), established Water Year 2012
5. North Richmond Pump Station (Contra Costa County), established Water Year 2013
6. Pulgas Creek Pump Station (San Mateo County), established Water Year 2013

The stations in Lower Marsh Creek, Guadalupe River and Pulgas Creek Pump Station are operated by CCCWP, SCVURPPP, and SMCWPPP, respectively, on behalf of RMC participants. The stations in the Sunnyvale East Channel and North Richmond Pump Station are operated by SFEI on behalf of the RMP, as was the Lower San Leandro Creek Station in its first year before operation was transferred to ACCWP in summer 2012. The San Mateo County station at the Pulgas Creek Pump Station is mapped in Figure 1.1.

Monitoring methods implemented by SFEI are documented in the POC Monitoring Field Instruction manual. This is a living document that is frequently updated on an as-needed-basis. SMCWPPP follows the same instructions but may allow for minor modifications depending on site-specific conditions. Laboratory analyses are implemented according to the BASMAA RMC Quality Assurance Project Plan (QAPP) (BASMAA 2012a).

For Water Years 2012 and 2013, BASMAA (on behalf of all RMC participants) contracted with SFEI to coordinate laboratory analyses, data management and data quality assurance. The goal was to ensure data consistency among all watershed monitoring stations.

During Water Year 2013 storms, discrete and composite samples were collected at the Pulgas Creek Pump Station POC loads monitoring station over the rising, peak and falling stages of the hydrographs. Samples collected were analyzed for multiple analytes (Table 5.1) consistent with MRP provision C.8.e and turbidity was recorded continuously during the entire wet weather season.

Complete results of Water Years 2012 and 2013 POC monitoring conducted by the STLS team are presented in Appendix C. This section focuses on comparisons of water quality data to applicable numeric WQOs and toxicity thresholds.

Table 5.1. Laboratory analysis methods used by the STLS Team for POC (loads) monitoring in WYs 2012 and 2013.

| Analyte | Analytical Method | | Analytical Laboratory | |
|---|---|---|---|---|
| | 2012 | 2013 | 2012 | 2013 |
| Carbaryl | EPA 632M | | DFG WPCL[a] | |
| Fipronil | EPA 619M | | DFG WPCL | |
| Suspended Sediment Concentration | ASTM D3977 | | EBMUD[b] | Caltest |
| Total Phosphorus | EBMUD 488 Phosphorus | SM4500-P E | EBMUD | |
| Nitrate | EPA 300.1 | SM4500-NO3 F | EBMUD | Caltest |
| OrthoPhosphate | EPA 300.1 | SM 4500-P E | EBMUD | Caltest |
| PAHs | AXYS MLA-021 Rev 10 | | AXYS[c] | |
| PBDEs | AXYS MLA-033 Rev 06 | | AXYS | |
| PCBs | AXYS MLA-010 Rev 11 | | AXYS | |
| Pyrethroids | AXYS MLA-046 Rev 04 | EPA 8270M_NCI | AXYX | Caltest |
| Total Methylmercury | EPA 1630M | EPA 1630 | MLML[d] | Caltest |
| Total Mercury | EPA 1631E | | MLML | Caltest |
| Copper | EPA 1638M | EPA 1638 | Brooks[e] | Caltest |
| Selenium | EPA 1638M | EPA 1638 | Brooks | Caltest |
| Total Hardness | EPA 1638M | SM 2340 C | Brooks | Caltest |
| Total Organic Carbon | SM 5310 C | SM 5310 B | DEL[f] | Caltest |

[a] California Department of Fish and Game Water Pollution Control Laboratory
[b] East Bay Municipal Utilities District
[c] AXYS Analytical Services Ltd.
[d] Moss Landing Marine Laboratories
[e] Brooks Rand Labs LLC
[f] Delta Environmental Lab LLC

### 5.1.1 Comparisons to Numeric Water Quality Objectives/Criteria for Specific Analytes

MRP Provision C.8.g.iii requires RMC participants to assess all data collected pursuant to provision C.8 for compliance with applicable WQOs. In compliance with this requirement, an assessment of data collected at the SMCWPPP POC monitoring stations in Water Years 2012 and 2013 is provided below.

When conducting a comparison to applicable water quality objectives/criteria, certain considerations should be taken into account to avoid the mischaracterization of water quality data:

**Freshwater vs. Saltwater** - POC monitoring data were collected in freshwater receiving water bodies above tidal influence and therefore comparisons were made to freshwater Water Quality Objectives/criteria.

**Aquatic Life vs. Human Health** - Comparisons were primarily made to objectives/criteria for the protection of aquatic life, not objectives/criteria for the protection of human health to support the consumption of water or organisms. This decision was based on the assumption that water and organisms are not likely being consumed from the creeks monitored.

**Acute vs. Chronic Objectives/Criteria** - For POC monitoring required by provision C.8.e, data were collected in an attempt to develop more robust loading estimates from small tributaries. Therefore, detecting the concentration of a constituent in any single sample was not the primary driver of POC monitoring. Monitoring was conducted during episodic storm events and results do not likely represent long-term (chronic) concentrations of monitored constituents. POC monitoring data were therefore compared to "acute" water quality objectives/criteria for aquatic life that represent the highest concentrations of an analyte to which an aquatic community can be exposed briefly (e.g., 1-hour) without resulting in an unacceptable effect. For analytes for which no Water Quality Objectives/criteria have been adopted, comparisons were not made.

It is important to note that acute Water Quality Objectives or criteria have only been promulgated for a small set of analytes collected at POC monitoring stations. These include objectives for trace metals (i.e., copper, selenium and total mercury). Table 5.2 provides a comparison of data collected at the Pulgas Creek Pump Station POC monitoring station to applicable numeric Water Quality Objectives/criteria adopted by the SFRWQCB or the State of California for these analytes.

All samples collected in Water Year 2013 were below applicable numeric Water Quality Objectives (i.e., freshwater acute objective for aquatic life) for mercury and selenium. However, the dissolved copper concentration exceeded the Water Quality Objective. Stormwater management activities are currently underway for mercury (via MRP provision C.11), selenium (via MRP provision C.14), and copper (via MRP provision C.13).

For all other analytes measured via POC monitoring (e.g., pyrethroid pesticides and polycyclic aromatic hydrocarbons), the State of California has yet to adopt numeric Water Quality Objectives applicable to beneficial uses of interest. For these analytes, an assessment of compliance of applicable water quality standards cannot be conducted at this time. Descriptive statistics of these results are included in Appendix C.

Table 5.2. Comparison of Pulgas Creek Pump Station POC monitoring data to applicable numeric WQOs.

| Analyte | Fraction | Freshwater Acute Water Quality Objective for Aquatic Life[a] | Unit | Number of Samples > Objective (WY 2013) |
|---|---|---|---|---|
| Copper | Dissolved | 13[b] | µg/L | 1/1 |
| Selenium | Total | 20 | µg/L | 0/1 |
| Mercury | Total | 2.1 | µg/L | 0/6 |

[a] San Francisco Bay Water Quality Control Plan (SFRWQCB 2013)

[b] The copper water quality objective is dependent on hardness; therefore, comparisons were made based on hardness values of samples collected synoptically with samples analyzed for copper. The objective presented in the table is based on a hardness of 100 mg/L.

### 5.1.2 Summary of Toxicity Testing Results

In addition to comparisons of data for specific analytes, the results of toxicity testing conducted on water samples collected during storm events were also evaluated in the context of adopted Water Quality Objectives. Toxicity testing was conducted using four different types of test organisms:

- *Pimephales promelas* (freshwater fish)
- *Hyalella azteca* (amphipod)
- *Ceriodaphnia dubia* (crustacean)
- *Selenastrum capricornutum* (algae)

Both acute and chronic endpoints were recorded. A summary of toxicity results is presented in Table 5.3.

Table 5.3. Summary of toxicity testing results for Pulgas Creek Pump Station POC monitoring station.

| | *Pimephales promelas* | | *Hyalella azteca* | *Ceriodaphnia dubia* | | *Selenastrum capricornutum* |
|---|---|---|---|---|---|---|
| | Significant Reduction in Survival | Significant Reduction in Growth | Significant Reduction in Survival | Significant Reduction in Survival | Significant Reduction in Reproduction | Significant Reduction in Growth |
| Number of Samples with Significant Toxicity | 0/1 | 0/1 | 1/1 | 0/1 | 0/1 | 0/1 |

Of the organisms exposed to water collected from the Pulgas Creek Pump Station POC monitoring station in Water Year 2013, toxicity was only observed for the amphipod *Hyalella azteca*. Observations of toxicity to *H. azteca* are similar to those from recent wet weather monitoring conducted in Southern California (Riverside County 2007, Weston Solutions 2006), the Imperial Valley (Phillips et al. 2007), the Central Valley (Weston and Lydy 2010), and the Sacramento-San Joaquin Delta (Werner et al., 2010), where follow up toxicity identification evaluations indicated that pyrethroid pesticides were almost certainly the cause of the toxicity observed. Based on recent studies conducted in California receiving waters, pyrethroid pesticides have also been identified as the likely current causes of sediment toxicity in urban creeks (Ruby 2013, Amweg et al. 2005, Weston and Holmes 2005, Anderson et al. 2010). These results are not unexpected given that *H. azteca* is considerably more sensitive to pyrethroids than other species tested as part of the POC monitoring studies (Palmquist 2008).

To further explore the potential causes of toxicity to *H. azteca* in the one sample, pyrethroid concentrations in a sediment sample collected at the same time as those exhibiting toxicity were compiled and compared to thresholds (i.e., LC50s) known to be lethal to *H. azteca*. LC50s were identified through a review of the scientific literature and are only available for a limited number of types of pyrethroids.[4] The results of these comparisons are provided in Table 5.4. All results were below LC50 values. Thus, unlike other POC monitoring stations, results from the Pulgas Creek Pump Station POC station do not suggest that pyrethroids caused toxicity to *H. Azteca.* However, this is based on a very limited amount of data; only one sample was tested for toxicity and pyrethroids. Management actions designed to reduce the impacts of pesticide-related toxicity are outlined in the TMDL and Water Quality Attainment Strategy for Diazinon and Pesticide-related Toxicity in Urban Creeks TMDL, and are currently underway via provision C.9 of the MRP.

Table 5.4. Water quality samples with observed toxicity to *Hyalella Azteca* and concentrations of pesticides detected.

| Sample Date | Mean % Survival *H. azteca* | Bifenthrin (ng/L) | Cyfluthrin (ng/L) | Cypermethrin (ng/L) | Delta/ Tralomethrin (ng/L) | Permethrin (ng/L) | Carbaryl (ng/L) |
|---|---|---|---|---|---|---|---|
| | LC50 (ng/L) | 7.7[a] | 2.3[a] | 2.3[a] | 10[b] | 48.9[c] | 2100[d] |
| 3/6/13 | 12% | 1.3 | 1.9 | 0.9 | - | 2.9 | 202 |

[a] As reported by D. Weston, University of California, Berkeley.
[b] LC50 values for *Hyalella Azteca* unavailable. LC50 values listed are for Daphnia magna as reported by Xiu et al. (1989)
[c] Brander et al. (2009)
[d] USEPA (2012)
Dashed represent concentrations less than method detection limits.

[4] Adverse effects concentrations for pyrethroids presented in Table 5.4 are not adopted Water Quality Objectives and should not be used to draw conclusions about compliance with water quality standards. The comparison contained in this table is only intended to facilitate an evaluation of the potential need for further evaluation of the stressors causing the toxicity.

# 6.0 Long-Term Trends Monitoring (C.8.e)

In addition to POC loads monitoring, Provision C.8.e requires Permittees to conduct long-term trends monitoring to evaluate if stormwater discharges are causing or contributing to toxic impacts on aquatic life. Required long-term monitoring parameters, methods, intervals and occurrences are included as Category 3 parameters in Table 8.4 of the MRP, and prescribed long-term monitoring locations are included in MRP Table 8.3. Similar to creek status and POC loads monitoring, long-term trends monitoring was scheduled to begin in October 2011 for RMC participants.

As described in the RMC Creek Status and Trends Monitoring Plan (BASMAA 2011b), the State of California's Surface Water Ambient Monitoring Program (SWAMP) through its Statewide Stream Pollutant Trend Monitoring (SPoT) Program currently monitors the seven long-term monitoring sites required by Provision C.8.e.ii. Sampling via the SPoT program is currently conducted at the sampling interval described in Provision C.8.e.iii in the MRP. The SPoT program is generally conducted to answer the following management question:

- *What are the long-term trends in water quality in creeks?*

Based on discussions with Regional Water Board staff, RMC participants are complying with long-term trends monitoring requirements described in MRP provision C.8.e via monitoring conducted by the SPoT program. This manner of compliance is consistent with the MRP language in provisions C.8.e.ii and C.8.a.iv. RMC representatives coordinate with the SPoT program on long-term monitoring to ensure MRP monitoring and reporting requirements are addressed. Additional information on the SPoT program can be found at http://www.waterboards.ca.gov/water_issues/programs/swamp.

A technical report emphasizing data collected in 2009 and 2010 (but summarizing results from 2008 through 2011) was published in March 2013 (Anderson et al. 2012). The statewide network of SPoT sites includes one station in San Mateo County at the base of San Mateo Creek (Figure 1.1). Stream sediments were collected 2008, 2009, and 2010 during summer base flow conditions. Sediments were analyzed for a suite of water quality indicators including toxicity with *Hyalella azteca*, organic contaminants (organophosphate, organochlorine, pyrethroid pesticides, and PCBs), trace metals, total organic carbon (TOC), and polycyclic aromatic hydrocarbons (PAHs) and polybrominated diphenyl ethers (PBDEs).

The SPoT report (Anderson et al. 2013) summarizes the data on statewide and regional scales. In addition, pollutant concentrations are correlated to land use characteristics and bioassessment data. The SPoT report made the following *statewide* conclusions:

- Sediment toxicity remained relatively stable between 2008 and 2011.
- Pyrethroids demonstrated an increasing trend in detections and concentrations between 2008 and 2010 with bifenthrin being the most commonly detected pyrethroid in 2008 and 2010 SPoT sediment samples.
- There was a general decrease in DDT, PCB, and organophosphate pesticides detections over the three year period (2008 to 2010).
- Detections and concentrations of PAHs, PBDEs, and metals remained constant over the three year period (2008 to 2010).
- There is a significant relationship between land use and stream pollution.

SMCWPPP queried the SWAMP database for the San Mateo Creek site (204SMA020) and evaluated the data using the same methods used to evaluate MRP Provision C.8.c sediment data. Threshold Effect Concentration (TEC) (Table 6.1) and Probable Effect Concentration (PEC) quotients (Table 6.2) as defined in MacDonald et al. (2000) were calculated for all non-pyrethroid constituents. In addition, pyrethroid Toxic Unit (TU) equivalents (Table 6.3) were calculated using TOC-normalized data and LC50 values from Maund et al. (2002) and Amweg et al. (2005). Some of the calculated numbers for TEC quotients, PEC quotients, and pyrethroid TU equivalents may be artificially elevated due to the method used to account for filling in non-detect data (e.g., concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data).

Table 6.1. Threshold Effect Concentration (TEC) quotients for sediment chemistry constituents measured by SPoT in San Mateo Creek. Bolded values exceed 1.0.

| Site ID – Creek<br>Sample Date | TEC | 204SMA020 – San Mateo Creek | | |
|---|---|---|---|---|
| | | 6/18/2008 | 6/16/2009 | 6/30/2010 |
| Fine Sediment Metals (µg/kg DW) | | | | |
| Arsenic | *9.79* | 0.87 | 1.3 | 0.58 |
| Cadmium | *0.99* | 0.62 | 0.96 | 0.29 |
| Chromium | *43.4* | 4.7 | 7.9 | 3.5 |
| Copper | *31.6* | 3.2 | 4.6 | 1.6 |
| Lead | *35.8* | 2.0 | 3.0 | 1.1 |
| Mercury | *0.18* | 1.4 | 2.2 | 2.0 |
| Nickel | *22.7* | 8.5 | 14 | 6.0 |
| Zinc | *121* | 2.6 | 4.0 | 1.3 |
| PAHs (µg/kg DW) | | | | |
| Anthracene | *57.2* | 0.4 | 0.2 | -- |
| Fluorene | *77.4* | 2.2 | 1.2 | -- |
| Naphthalene | *176* | 0.6 | 0.8 | -- |
| Phenanthrene | *204* | 2.0 | 1.2 | -- |
| Benz(a)anthracene | *108* | 0.9 | 0.5 | -- |
| Benzo(a)pyrene | *150* | 0.8 | 0.5 | -- |
| Chrysene | *166* | 1.9 | 1.1 | -- |
| Dibenz[a,h]anthracene | *33.0* | 0.9 | 0.5 | -- |
| Fluoranthene | *423* | 1.2 | 0.6 | -- |
| Pyrene | *195* | 1.5 | 0.8 | -- |
| Total PAHs | *1,610* | 1.6 | 1.0 | -- |
| Pesticides (µg/kg DW) | | | | |
| Chlordane | *3.24* | 9.29 | 7.87 | -- |
| Dieldrin | *1.90* | 4.76 | 3.29 | -- |
| Endrin | *2.22* | 0.10 [a] | 0.24 [a] | -- |
| Heptachlor Epoxide | *2.47* | 0.70 [b] | 0.62 | -- |
| Lindane (gamma-BHC) | *2.37* | 0.07 [a] | 0.11 [a] | -- |
| Sum DDD | *4.88* | 6.08 | 4.61 | -- |
| Sum DDE | *3.16* | 13.7[b] | 11.9 [a] | -- |
| Sum DDT | *4.16* | 3.84 [b] | 4.86 | -- |
| Total DDTs | *5.28* | 17.2 [b] | 15.5 [a] | -- |

[a] Concentration was below the method detection limit (MDL). TEC quotient calculated using ½ MDL.

[b] TEC quotient calculated from concentration below the reporting limit (DNQ-flagged).

Table 6.2. Probable Effect Concentration (PEC) quotients for sediment chemistry constituents measured by SPoT in San Mateo Creek. Bolded values exceed 1.0.

| Site ID – Creek<br>Sample Date | PEC | 204SMA020 – San Mateo Creek | | |
|---|---|---|---|---|
| | | 6/18/2008 | 6/16/2009 | 6/30/2010 |
| Fine Sediment Metals (µg/kg DW) | | | | |
| Arsenic | *33.0* | 0.26 | 0.39 | 0.17 |
| Cadmium | *4.98* | 0.12 | 0.19 | 0.058 |
| Chromium | *111* | **1.9** | **3.1** | **1.4** |
| Copper | *149* | 0.68 | 0.98 | 0.35 |
| Lead | *128* | 0.55 | 0.83 | 0.30 |
| Mercury | *1.06* | 0.23 | 0.37 | 0.35 |
| Nickel | *48.6* | **4.0** | **6.6** | **2.8** |
| Zinc | *459* | 0.69 | **1.1** | 0.35 |
| PAHs (µg/kg DW) | | | | |
| Anthracene | *845* | 0.10 | 0.050 | -- |
| Fluorene | *536* | 0.32 | 0.17 | -- |
| Naphthalene | *561* | 0.18 | 0.24 | -- |
| Phenanthrene | *1170* | 0.34 | 0.22 | -- |
| Benz(a)anthracene | *1050* | 0.10 | 0.050 | -- |
| Benzo(a)pyrene | *1450* | 0.083 | 0.052 | -- |
| Chrysene | *1290* | 0.25 | 0.14 | -- |
| Fluoranthene | *2230* | 0.23 | 0.12 | -- |
| Pyrene | *1520* | 0.19 | 0.10 | -- |
| Total PAHs | *22,800* | 0.11 | 0.071 | -- |
| Pesticides (µg/kg DW) | | | | |
| Chlordane | *17.6* | **1.7** | **1.4** | -- |
| Dieldrin | *61.8* | 0.15 | 0.10 | -- |
| Endrin | *207.0* | 0.001[a] | 0.003[a] | -- |
| Heptachlor Epoxide | *16* | 0.11[b] | 0.10 | -- |
| Lindane (gamma-BHC) | *4.99* | 0.034[a] | 0.053[a] | -- |
| Sum DDD | *28* | **1.1** | 0.80 | -- |
| Sum DDE | *31.3* | **1.4**[b] | **1.2**[a] | -- |
| Sum DDT | *62.9* | 0.25[b] | 0.32 | -- |
| Total DDTs | *572* | 0.16[b] | 0.14[a] | -- |

[a] Concentration was below the method detection limit (MDL). TEC quotient calculated using ½ MDL.

[b] TEC quotient calculated from concentration below the reporting limit (DNQ-flagged).

**Table 6.3.** Pyrethroid Toxic Unit (TU) equivalents for sediment chemistry constituents measured in San Mateo Creek.

| Site ID – Creek<br><br>Sample Date | LC50 (µg/g dw) | 204SMA020 – San Mateo Creek | | |
|---|---|---|---|---|
| | | 6/18/2008 | 6/16/2009 | 6/30/2010 |
| Bifenthrin | 0.52 | 0.44 | 0.012 [a] | 0.22 |
| Cyfluthrin | 1.08 | 0.015[a] | 0.024 [a] | 0.16 |
| Cypermethrin | 0.38 | 0.042 [a] | 0.067 [a] | 0.094 |
| Deltamethrin | 0.79 | 0.020 [a] | 0.032 [a] | 0.019[b] |
| Esfenvalerate | 1.54 | 0.005 [a] | 0.0083 [a] | 0.0036 [b] |
| Lambda-Cyhalothrin | 0.45 | 0.018 [a] | 0.028 [a] | 0.013 [b] |
| Permethrin | 10.83 | 0.010 [a] | 0.0030 [a] | 0.011 |
| Sum of Toxic Unit Equivalents per Site | -- | 0.55 | 0.18 | 0.52 |

[a] Concentration was below the method detection limit (MDL). TEC quotient calculated using ½ MDL.

[b] TEC quotient calculated from concentration below the reporting limit (DNQ-flagged).

# 7.0 Sediment Delivery Estimate/Budget (C.8.e.vi)

Provision C.8.e.vi of the MRP requires Permittees to develop a design for a robust sediment delivery estimate/sediment budget in local tributaries and urban drainages, and implement the study by July 1, 2012. The purpose of the sediment delivery estimate is to improve the Permittees' ability to estimate urban runoff contributions to loads of POCs, most of which are closely associated with sediment. To determine a strategy for a robust sediment estimate/budget, BASMAA representatives reviewed recent sediment delivery estimates developed by the RMP, and determined that these objectives would be met effectively through sediment-specific submodeling with the Regional Watershed Spreadsheet Model (RWSM), under the ongoing oversight of the RMP Sources Pathways Loadings Work Group and the Small Tributaries Loading Strategy (STLS) Work Group.

The implementation of the sediment delivery/budget study was designed to occur in coordination with the STLS Multi-Year Plan, with funding from both the RMP and BASMAA regional projects. Sediment-specific model developments included:

- Literature-based refinement of land-use based Event Mean Concentrations;
- Development of a sub-model incorporating bedrock type, hillslope and convergence processes, and level /age of urbanization;
- Incorporation and calibration of specific watershed sediment loads calculated from available USGS gauge data or previous monitoring stations;
- Coordination of sediment submodeling with RWSM model development for PCBs and mercury; and
- Mapping of areas upstream of reservoirs and application of estimated delivery ratios to adjust modeled loads for storage of sediment within watersheds.

BASMAA-funded activities included:

- Sensitivity analyses and evaluation of weaknesses in the initial set of sediment runoff coefficients for the RWSM;
- Implementation of high-priority improvements and convening a panel of local experts to provide input on the geological bases for model coefficients;
- Analysis of results of calibration on modeled sediment estimates and model loads; and
- Development of a RWSM geoprocessing tool to incorporate the sediment model structure and its parameterization from locally derived land use/geological sediment erosion coefficients and equations.

SFEI produced annual progress reports on overall RWSM development and provided a June 2013 internal update to BASMAA on the sediment model. In December 2013, SFEI distributed for STLS review a draft report section with preliminary results of the RWSM models for PCBs and mercury, which apply coefficients based on particle concentrations to the estimates of suspended sediment loadings from the modeled watersheds. SFEI noted that the sediment model remains unverified and the parameterization calibration runs would potentially be improved by the addition of a climatic parameter as recommended by the expert panel.

The initial results of the sediment-associated portion of the RWSM are planned for further development in 2014. An update will be submitted with the WY 2014 Urban Creek Monitoring Report, which will be submitted by March 15, 2015.

# 8.0 Emerging Pollutants (C.8.e.vii)

Provision C.8.e.vii of the MRP requires Permittees to develop a work plan and schedule for initial loading estimates and source analyses for contaminants of emerging concern (CECs). Contaminants that are mentioned in the MRP include: endocrine-disrupting compounds, PFOS/PFAS (Perfluorooctane Sulfonates (PFOS), Perfluoroalkyl Sulfonates (PFAS), and NP/NPEs (Nonylphenols/Nonylphenol Esters - estrogen-like compounds). The work plan developed by Permittees is to be implemented in the next Permit term.

Consistent with these requirements, SMCWPPP and other Bay Area stormwater programs have and will continue to coordinate the investigation and significance of CECs with the RMP. As such, Permittees have participated in the development and funding of a CEC strategy entitled "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations" (Sutton et.al. 2013). Consistent with the CEC strategy, Permittees have also participated in the development and implementation of the following work plans, which are consistent with provision C.8.e.vii:

- *Monitoring Alternative Flame Retardants in SF Bay Water, Sediment and Biota* (Sutton and Sedlak 2013);
- *Monitoring Alternative Flame Retardants in SF Bay Water, Sediment, and Biota: Pathway Characterization – Wastewater and Stormwater* (Sutton and Sedlak 2013); and
- Special two-year study of Bioanalytical tools entitled *Linkage of in Vitro Assay Results with in Vivo End Points* (Denslow et.al, 2012).

In addition, Permittees have and continue to participate in the broader Statewide CEC investigation and monitoring efforts through RMP coordination with the State Water Board's contractor, the Southern California Coastal Water Research Project (SCCWRP).

Summary tables that illustrate the relationship between CECs of high priority to the broader statewide effort and the RMP strategy are included as Tables 8.1 through 8.3. During the next Permit term, Permittees intend to continue to work with RMP staff and update the current CEC strategy as needed based on the significance of the results of the various ongoing investigations. In addition, the need for the development of preliminary loading estimates as well as source analyses will be considered as part of the CEC strategy updates and investigatory results.

**Table 8.1.** San Francisco Bay Regional Monitoring Program's CEC Pilot Monitoring Work Plan Approach **-** Receiving Waters, Sediment, and Tissue (Relative to SWRCB Panel Guidance).

| Compound[1] | San Francisco Bay Risk level[2] | SWRCB Panel Guidance Embayment Water / Sediment/Tissue[3] | RMP Approach |
|---|---|---|---|
| Bis(2-ethylhexyl) phthalate (PPCP) | I | NA/NA/NA | Widely detected at low level in surface water, tissue, and sediment. Below available effects thresholds for sediment. Uncertainty regarding the applicability of thresholds to Bay data. |
| Bisphenol A (PPCP) | I | M/NA/NA | ND samples; DL high. Consider re-sampling using lower DLs. BPA is included in RMP Bioanalytical study[4]. |
| Bifenthrin (pesticide) | II | M/M/NA | Hydrophobic; based on Bay sediment concentrations, expect ND in water |
| Butylbenzyl phthalate (PPCP) | I | NA/NA/NA | Exceed low apparent effects threshold values in sediment but high uncertainty regarding the application of these thresholds to the Bay. ND in mussel tissue. |
| Permethrin (pesticide) | II | M/M/NA | Hydrophobic; based on Bay sediment concentrations, expect ND in water |
| Estrone (hormone) | | NA/NA/NA | No Bay data. Included in RMP Bioanalytical study[4] |
| Ibuprofen (PPCP) | II | NA/NA/NA | Mostly ND in pilot study. Low priority. |
| 17-beta estradiol (hormone) | | M/NA/NA | No Bay data. Include in bioanalytical tools. |
| Galaxolide –HHCB (PPCP) | II | M/NA/NA | Detected in Bay samples from 1999-2000 and in later Bay POCIS passive sampling study. Included in RMP Bioanalytical study[4]. Special study of PPCPs under consideration. |
| Diclofenac (PPCP) | | NA/NA/NA | No data. RMP reviewing as part of PPCP paper. |
| p-Nonylphenol (PPCP) | III | NA/NA/NA | Detected in water, sediment and tissue. Included in RMP Bioanalytical study[4]. |
| PBDE-47 and 99 (flame retardants) | III | NA/M/M | Analyzed extensively in water, sediment and tissue. Concentrations declining in multiple species. Prepared summary report on 10 years of RMP data[5]. |
| Fipronil | III | M/M/NA | Monitored in sediment and water (pilot study). |
| PFOS (PFAS) | III | NA/M/M | Detected in elevated concentrations in seals and bird eggs. Continue monitoring in tissue (bird/seal). Consider evaluating effluent and sediments |
| Triclosan (PPCP) | II | NA/NA/NA | Low to ND in sediment. ND in water and mussels. |
| Non-PBDE Flame Retardants[6] | I | RMP | RMP special study; see note 6 below (RMP special study plan and addendum dated June 2013 ) |

1. Chlorpyrifos not included in monitoring – see SWRCB Panel September 2013 meeting notes and rationale
2. Risk Levels (for San Francisco Bay Receiving Waters): Tier IV (High Concern), Tier III (Moderate Concern), Tier II (Low Concern), and Tier I (Possible Concern); see RMP report "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations," Contribution 700, 2013.
3. NA = Not Applicable, M = Monitoring suggested
4. See RMP Detailed Workplan 2014, December 2013
5. PBDE Synthesis Report. Draft 2013.
6. Additional SF Bay CEC special study; see discussion and rationale in "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations," Contribution 700, 2013; RMP Study Plan "Monitoring Alternative Flame Retardants in SF bay Water, Sediment and Biota" Sutton and Sedlak, June 2013; and RMP addendum "Monitoring Alternative Flame Retardants in SF Bay Water, Sediment, and Biota: Pathway Characterization – Wastewater and Stormwater," Sutton and Sedlak, June 2013.

**Table 8.2.** San Francisco Bay Regional Monitoring Program's CEC Pilot Monitoring Work Plan Approach – Wastewater Treatment Plant Effluent (Relative to SWRCB Panel Guidance).

| Compound[1] | San Francisco Bay Risk level[2] | SWRCB Panel Guidance Embayment Water / Sediment/Tissue[3] | RMP Approach |
|---|---|---|---|
| Bis(2-ethylhexyl) phthalate (PPCP) | I | NA | Consider monitoring in concert with butylbenxyl phthalate? |
| Bisphenol A (PPCP) | I | M | Included in RMP Bioanalytical study[4] |
| Bifenthrin (pesticide) | II | M | Effluent from 32 facilities have been monitored for pyrethroids. Report pending (Jan 2014). |
| Butylbenzyl phthalate (PPCP) | I | NA | Under consideration to analyze? |
| Permethrin (pesticide) | II | M | Effluent from 32 facilities have been monitored for pyrethroids. Report pending (Jan 2014). |
| Estrone (hormone) | I | M | Included in RMP Bioanalytical study[4] |
| Ibuprofen (PPCP) | II | NA | Mostly ND in pilot study in Bay. |
| 17-beta estradiol (hormone) | | NA | No data. Address using bioanalytical tools |
| Galaxolide –HHCB (PPCP) | II | M | Included in RMP Bioanalytical study[4] |
| Diclofenac (PPCP) | | NA | No data. Conducting review of PPCPs. |
| p-Nonylphenol (PPCP) | III | NA | Included in RMP Bioanalytical study[4] |
| PBDE -47 and 99 (flame retardants) | III | M | Declining concentrations; Not a high priority to monitor in effluent due to use restrictions[5] |
| Fipronil | III | NA | Depending on water results, consider effluent? |
| PFOS (PFAS) | III | M | Consider monitoring PFOS and precursors in effluent? |
| Triclosan (PPCP) | II | NA | Not a high priority because low levels observed in Bay sediments. |
| Non-PBDE Flame Retardants[6] | I | RMP | RMP special study; see note 6 below (RMP special study plan and addendum dated June 2013 ) |

1. Chlorpyrifos not included in monitoring – see SWRCB Panel September 2013 meeting notes and rationale
2. Risk Levels (for San Francisco Bay Receiving Waters): Tier IV (High Concern), Tier III (Moderate Concern), Tier II (Low Concern), and Tier I (Possible Concern); see RMP report "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations," Contribution 700, 2013.
3. NA = Not Applicable, M = Monitoring suggested
4. See RMP Detailed Workplan 2014, December 2013
5. PBDE Synthesis Report. Draft 2013.
6. Additional SF Bay CEC special study; see discussion and rationale in "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations," Contribution 700, 2013; RMP Study Plan "Monitoring Alternative Flame Retardants in SF bay Water, Sediment and Biota" Sutton and Sedlak, June 2013; and RMP addendum "Monitoring Alternative Flame Retardants in SF Bay Water, Sediment, and Biota: Pathway Characterization – Wastewater and Stormwater," Sutton and Sedlak, June 2013.

Table 8.3. San Francisco Bay Regional Monitoring Program's CEC Pilot Monitoring Work Plan Approach – Urban Creeks (Stormwater) (Relative to SWRCB Panel Guidance).

| Compound[1] | San Francisco Bay Risk level[2] | SWRCB Panel Guidance Embayment Water / Sediment/Tissue[3] | RMP Approach |
|---|---|---|---|
| Bis(2-ethylhexyl) phthalate (PPCP) | II | NA | NA |
| Bisphenol A (PPCP) | II | M | NA |
| Bifenthrin (pesticide) | IV (UC) | M | Monitoring in urban creeks (UC) |
| Butylbenzyl phthalate (PPCP) | I | NA | NA |
| Permethrin (pesticide) | IV (UC) | M | Monitoring in urban creeks (UC) |
| Estrone (hormone) | I | M | NA |
| Ibuprofen (PPCP) | II | M | NA |
| 17-beta estradiol (hormone) | I | M | NA |
| Galaxolide –HHCB (PPCP) | II | M | NA |
| Diclofenac (PPCP) | | M | NA |
| p-Nonylphenol (PPCP) | III | NA | NA |
| PBDE -47 and 99 (flame retardants) | III | M | Monitoring in urban creeks (UC) |
| Fipronil | III | M | Monitoring in urban creeks (UC) |
| PFOS (PFAS) | III | M | Have monitored in the past (see Houtz and Sedlak 2012) |
| Triclosan (PPCP) | II | M | NA |
| Non-PBDE Flame Retardants[4] | I | RMP | RMP special study; see note 4 below (RMP special study plan and addendum dated June 2013 ) |

1. Chlorpyrifos not included in monitoring – see SWRCB Panel September 2013 meeting notes and rationale
2. Risk Levels (for San Francisco Bay Receiving Waters): Tier IV (High Concern), Tier III (Moderate Concern), Tier II (Low Concern), and Tier I (Possible Concern); see RMP report "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations," Contribution 700, 2013.
3. NA = Not Applicable, M = Monitoring suggested
4. See RMP Detailed Workplan 2014, December 2013
5. PBDE Synthesis Report. Draft 2013.
6. Additional SF Bay CEC special study; see discussion and rationale in "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations," Contribution 700, 2013; RMP Study Plan "Monitoring Alternative Flame Retardants in SF bay Water, Sediment and Biota" Sutton and Sedlak, June 2013; and RMP addendum "Monitoring Alternative Flame Retardants in SF Bay Water, Sediment, and Biota: Pathway Characterization – Wastewater and Stormwater," Sutton and Sedlak, June 2013.

# 9.0 Citizen Monitoring and Participation (C.8.f)

MRP Provision C.8.f states that:

*i.* “*Permittees shall encourage Citizen Monitoring.*

*ii.* *In developing Monitoring Projects and evaluating Status and Trends data, Permittees shall make reasonable efforts to seek out citizen and stakeholder information and comment regarding waterbody function and quality.*

iii. *Permittees shall demonstrate annually that they have encouraged citizen and stakeholder observations and reporting of waterbody conditions. Permittees shall report on these outreach efforts in the annual Urban Creeks Monitoring Report*.”

During the MRP term, SMCWPPP staff has actively sought opportunities to encourage volunteer monitoring and/or incorporate information from such monitoring into SMCWPPP’s water quality monitoring program. As part of this process, SMCWPPP staff has researched and documented related activities in San Mateo County. The County has a wealth of watershed stewardship organizations that primarily engage citizens and stakeholders in environmental education and restoration, and to a lesser extent, in classical water quality monitoring. Citizen monitoring of watershed resources in San Mateo County therefore occurs in several ways:

- In association with habitat restoration efforts, citizens monitor native plant survival and growth, and avian use of constructed bird boxes.
- The majority of citizen water quality monitoring focuses on identifying and cleaning up trash in water bodies, and sampling pathogen indicator organisms such as fecal coliform and *E. coli*. Many organizations conduct monthly trash cleanups in their local watersheds in addition to annual events coinciding with Earth Day, California Coastal cleanup day, and National River Cleanup Day. Groups that monitor pathogen indicators typically sample swimming beaches and associated creek confluences on a weekly basis. For example, the San Mateo County Department of Health coordinates with the San Mateo County Resource Conservation District (SMCRCD) and nine citizen volunteers, including those active with Surfrider Foundation and the Monterey Bay National Marine Sanctuary (MBNMS) to sample pathogen indicators weekly. During fall “first flush” events, the SMCRCD and the MBNMS coordinate to sample a broader suite of water quality parameters at 10 to 11 targeted storm drain outfalls in the San Mateo County designated Area of Biological Significance (ASBS). Such monitoring includes pathogen indicators, nutrients, and general water quality parameters.
- During the spring, the MBNMS coordinates with numerous volunteers as part of “snapshot day” to sample 27 sites on creeks and rivers in San Mateo County coastal watersheds for a broad suite of water quality analytes. Trained volunteers measure dissolved oxygen, pH, conductivity, air and water temperature, transparency/ turbidity, and collect water samples to be lab tested for nutrients (nitrates and orthophosphate) and bacteria. Every year Snapshot Day data are compiled to determine “Areas of Concern” - sites at where at least three of the nine analytes measured exceed associated water quality objectives. Snapshot Day data are used by the State of California, in conjunction with other data, to list water bodies as impaired under the Clean Water Act. Other resource managers use Snapshot Day data to further engage citizenry and agencies to address problems of pollution in waterways.

- Citizens volunteer with the San Gregorio Environmental Resource Center to conduct general water quality monitoring and measure stream discharge and stage weekly. This group was recently awarded an EPA grant to demonstrate the feasibility of increasing water quality and restoring habitat while maintaining agricultural productivity.
- Acterra is an environmental non-profit serving the Silicon Valley area that provides a broad range of volunteer opportunities (e.g., habitat restoration) for adults and youth. Through their Streamkeeper Program, Acterra encourages citizens to note observations on San Francisquito Creek about four types of indicators: animals (presence/absence of uncommon or threatened and endangered species), plants (notably invasives), chemical (indicators of pollution), physical (including evidence of erosion, human disturbance), and social (including evidence of different types of human disturbance).

In Water Years 2012 and 2013, SMCWPPP staff identified multiple sources of local water quality data collected by San Mateo County organizations that incorporate citizen monitoring data. The water quality data were reviewed to inform identification of creeks reaches most suitable for monitoring several MRP Provision C.8.c targeted parameters including pathogen indicators and general water quality (temperature, dissolved oxygen, pH and specific conductivity). The organizations included the San Mateo County Resource Conservation District, Monterey Bay National Marine Sanctuary, Surfrider Foundation San Mateo County Chapter, San Pedro Creek Watershed Coalition, San Gregorio Environmental Resource Center, Pacifica Beach Coalition, Half Moon Bay Coastside Foundation, San Mateo County Department of Health Services, and Acterra. During WY 2012 SMCWPPP staff focused on Pilarcitos Creek for monitoring general water quality and coordinated with the Pilarcitos Creek Restoration Workgroup to identify appropriate monitoring locations. The results were also discussed with this workgroup to assist and encourage their ongoing monitoring and management efforts in the watershed.

During the MRP permit term SMCWPPP staff has also coordinated with Acterra on several issues. SMCWPPP staff:

- discussed water quality conditions at Acterra's restoration site in San Mateo County on Arroyo Ojo de Agua Creek (this site was selected as a WY2013 pathogen indicator monitoring site);
- discussed providing Acterra with in-kind technical support for water quality monitoring methods including toxicity and pathogen indicator sampling;
- encouraged Acterra to submit a grant to USEPA to expand their Riparian Restoration/Water Quality Outreach and Monitoring Program;
- provided contacts to other watershed groups conducting monitoring in San Mateo County and encouraged Acterra to also contact these groups for technical advice and as potential collaborators in monitoring and grant applications; and
- is currently discussing internally and with Acterra the possibility of providing funding for Acterra to expand its volunteer coordination activities in San Mateo County.

# 10.0 Monitoring Costs, Benefits and Recommendations

Water quality monitoring required by provision C.8 of the MRP is intended to:

- assess the condition of water quality in the Bay area receiving waters (creeks and the Bay);
- identify and prioritize stormwater associated impacts, stressors, sources, and loads;
- identify appropriate management actions;
- and detect trends in water quality over time and the effects of stormwater control measure implementation.

On behalf of Permittees, SMCWPPP conducts creek water quality monitoring and monitoring projects in San Mateo County in collaboration with the Regional Monitoring Coalition (RMC) and actively participates in the San Francisco Bay Regional Monitoring Program (RMP), which focuses on assessing Bay water quality and associated impacts. This section provides a summary of monitoring costs and benefits, and provides recommendations for future monitoring activities per the next NPDES permit.

## 10.1 Monitoring Cost Summary

Table 10.1 presents costs to implement provision C.8 of the MRP that have been expended to-date (FY 2010-11 through FY 2012-13), are currently being expended (FY 2013-14), or are budgeted (FY 2014-15) by SMCWPPP on behalf of its Permittees. Costs presented include all aspects of implementing provision C.8 over the approximate MRP term, including monitoring program coordination and management, program/project planning, sample and data collection, laboratory analyses, quality assurance/control, data evaluation and analysis, data interpretation and reporting, and information management.[5] Direct financial contributions to the RMP by SMCWPPP on behalf of Permittees and NPDES permit fee surcharges used to fund the State's Surface Water Ambient Monitoring Program (SWAMP) are also included.

During the five-year MRP permit term, SMCWPPP anticipates expending considerable resources (approximately $2.8 M) towards complying with water quality monitoring requirements described in provision C.8. Average annual costs are roughly $567,000. These costs generate information designed to answer core management questions outlined in the MRP. A qualitative evaluation of the costs and benefits of the data collected via provision C.8, in terms of our ability to answer core management questions, is provided in Table 10.2 and discussed in the following section. The results of this evaluation also inform the recommendations for future monitoring described in section 10.3.

[5] Costs presented do not include costs incurred by Permittees to implement other water quality monitoring activities and programs required by other NPDES permits issued to Permittees (e.g., POTW monitoring, aquatic pesticide application monitoring, stream maintenance program monitoring)

Table 10.1. Approximate costs to SMCWPP to implement MRP Provision C.8 during approximate MRP term.

| Requirement | Associated MRP Subprovisions | Approximate Cost Per Approximate 5-year MRP Term | Approximate Average Cost per Fiscal Year | Percent of Total Cost |
|---|---|---|---|---|
| San Francisco Bay Estuary Receiving Water Monitoring (RMP Fees and Participation) | C.8.b | $500,000 | $100,000 | 17% |
| Creek Status Monitoring | C.8.c | $825,000 | $165,000 | 27% |
| Monitoring Projects (e.g., Source/Stressor ID) & Citizen Monitoring Encouragement | C.8.d and f | $200,000 | $40,000 | 7% |
| POC Loads and Long-Term Trends Monitoring | C.8.e | $750,000 | $150,000 | 25% |
| Data Management, QA/QC and Reporting | C.8.c, d, e, g, and h | $450,000 | $90,000 | 15% |
| NPDES Surcharge - Surface Water Ambient Monitoring Program (SWAMP) | NA | $300,000 | $60,000 | 10% |
| **Totals** | | **$3,025,000** | **$605,000** | **100%** |

Table 10.2. Qualitative cost-benefit evaluation of monitoring conducted under MRP provision C.8.

| Requirement | C.8 Subprovisions | Relative Costs of Implementing Provision ($ - $$$$) | Relative Benefit Towards Answering Core Management Questions (✓ - ✓✓✓✓ ) | Notes/Comments |
|---|---|---|---|---|
| San Francisco Bay Estuary Receiving Water Monitoring | C.8.b | $$$$ | ✓✓✓ | Provided useful information on the status and trends water quality in the Bay. Focusing monitoring on high priority issues has been and remains a challenge. |
| Creek Status Monitoring | C.8.c | $$$$ | ✓✓✓ | Provided useful information on the status of water quality in and the biological condition and health of urban creeks. Many parameters monitored, however, provided limited new information to assist stormwater management. |
| Stressor/Source Identification Studies | C.8.d.i | $$$ | ✓✓ | Challenging due to the lack of established methods to identify stressors and sources in aquatic systems with complex watershed/runoff processes. |
| BMP Effectiveness Investigation | C.8.d.i | $$ | ✓✓ | Provided useful information on the performance of specific stormwater treatment devices but costs were relatively high compared to overall benefit. |
| Geomorphic Project | C.8.d.ii | $$ | ✓ | Limited usefulness to stormwater managers, but provided some new information for potential future channel restoration projects. |
| POC Loads Monitoring | C.8.e.i | $$$$ | ✓✓ | Provided high quality data for a small number of small tributaries to the Bay and for regional watershed model calibration. Need to consider usefulness of this type of data collection moving forward given high costs. |
| Long-Term Trends Monitoring | C.8.e.ii | $ | ✓✓✓ | As implemented to-date, limited costs to Permittees due to State SPoT program resources funding monitoring. SPoT program data provide useful trends sites for sediment-related pollutants and toxicity. |
| Citizen Monitoring and Participation | C.8.f | $$ | ✓ | Encourages local volunteer monitoring efforts and coordination with Permittees but opportunities leading to useful data collection are limited. |
| NPDES Fee Surcharge for SWAMP | NA | $$$ | ✓ | No apparent benefit to local stormwater programs and managers. |

## 10.2 Recommendations

The following preliminary recommendations are provided based upon SMCWPPP's experience in implementing Provision C.8 of the MRP and related efforts during previous municipal stormwater NPDES permit terms. These recommendations are intended to assist Permittees and the Regional Water Board as they work together to improve the cost-effectiveness of water quality monitoring requirements during future permit terms.

- **Focus on Answerable High Priority Management Questions** – During the development of the MRP, both Permittees and Regional Water Board staff agreed that data collected via NPDES permit-required monitoring should provide information needed to assist Permittees in answering high priority management questions. These mutually-acceptable management questions were included in MRP Provision C.8. During the development of monitoring requirements for the next permit term, Regional Water Board staff and Permittees should reflect on which data types did and did not assist both entities in answering these questions. To assist in this evaluation, data outputs (e.g., graphs, tables) generated as a result of monitoring should be compared to high priority management questions. If specific types of monitoring data are not assisting Permittees or Regional Water Board staff in answering these high priority questions, then the associated monitoring parameters should not be included in the next permit. Those data types that do provide valuable and high priority information should be discussed further during the development of new monitoring requirements and to the extent possible, optimized.
- **Increase Coordination among Local, Regional and Statewide Monitoring Programs** – Limited public resources are available for collecting high priority water quality monitoring data in the Bay Area. Enhanced coordination among local (RMC), regional (RMP), and state (SWAMP) monitoring programs would assist public agencies in reducing monitoring costs. Specifically, avoiding duplicative tasks and leveraging limited resources of each monitoring program would likely reduce costs and create robust datasets that would more effectively answer key questions regarding stormwater, creek and Bay water quality and beneficial use impacts. Additionally, enhanced coordination should also promote information sharing and better coordinated planning among these programs, which would help optimize the use of the limited available public resources.
- **Further Evaluate the Need for POC Loads Monitoring** – Requirements associated with provision C.8.e, POC Monitoring, include extensive, expensive monitoring of POCs at fixed loading stations. These data collection efforts only provide robust information regarding POC loading for the limited number of watersheds monitored. As a result, this type of monitoring is not particularly effective at addressing the highest priority management questions currently included in the MRP. Regional Water Board staff and Permittees should collectively evaluate the need for such site-specific data and whether the costs of collecting these data are worth the benefits. This evaluation could foreseeably reduce Permittee monitoring costs, or at a minimum redirect resources toward higher priority monitoring or management activities.
- **Continue Tiered Practicable Approach to Creek Status/Trends Monitoring and SSID Projects** – Assessing the status and trends of indicators of urban creek health, identifying the stressors and sources associated with observed water quality and biological impacts, and assessing the effectiveness of stormwater control measures are key objectives of the MRP Provision C.8 requirements. Creek status and trends monitoring parameters currently included in the MRP should be reevaluated to ensure

that they provide timely, cost-effective information regarding the status of water quality and beneficial uses. Types of status monitoring data that reveal potential water quality impacts associated with stormwater runoff discharges should be prioritized and when appropriate further focused investigation should be considered. The types of focused investigations that attempt to identify stressors/sources associated with stormwater runoff discharges and high priority impacts should be further prioritized to allow Permittees to focus limited resources on the highest priority issues. The current types of caps which establish maximum numbers of stressor/source identification projects required of Permittees should be continued into the next permit.

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SAN MATEO COUNTYWIDE
Water Pollution Prevention Program

# Appendix A

## SMCWPPP Creek Status Monitoring Report

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

# SMCWPPP Creek Status Monitoring Report

***Water Years 2012 and 2013 (October 2011 – September 2013)***

Submitted in Compliance with

Provision C.8.g.iii, NPDES Permit No. CAS612008

**March 15, 2014**

# Preface

In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA) joined together to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP)[1]. The RMC includes the following participants:

- Clean Water Program of Alameda County (ACCWP)
- Contra Costa Clean Water Program (CCCWP)
- San Mateo County Wide Water Pollution Prevention Program (SMCWPPP)
- Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
- Fairfield-Suisun Urban Runoff Management Program (FSURMP)
- City of Vallejo and Vallejo Sanitation and Flood Control District (Vallejo)

This SMCWPPP Creek Status Monitoring Report complies with the MRP Reporting Provision C.8.g for Status Monitoring data (MRP Provision C.8.c) collected in Water Years 2012 and 2013 (October 1, 2011 and September 30, 2013). Data presented in this report were produced under the direction of SMCWPPP using targeted and probabilistic monitoring designs as described herein.

In accordance with the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2011), monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Program Plan (QAPP; BASMAA, 2012a) and BASMAA RMC Standard Operating Procedures (SOPs; BASMAA, 2012b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP[2]. Data presented in this report were also submitted in electronic SWAMP-comparable formats by SMCWPPP to the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) on behalf of San Mateo County Co-permittees and pursuant to Provision C.8.g.

[1] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley, which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

[2] The current SWAMP QAPP is available at: http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/swamp_qapp_master090108a.pdf

# List of Acronyms

| | |
|---|---|
| ACCWP | Alameda County Clean Water Program |
| AFDM | Ash Free Dry Mass |
| AFS | American Fisheries Society |
| ARP | Alum Rock Park |
| BASMAA | Bay Area Stormwater Management Agency Association |
| B-IBI | Benthic Macroinvertebrate Index of Biological Integrity |
| BMI | Benthic Macroinvertebrate |
| CCCWP | Contra Costa Clean Water Program |
| CDFW | California Department of Fish and Wildlife |
| CEDEN | California Environmental Data Exchange Network |
| CFU | Colony Forming Units |
| CRAM | California Rapid Assessment Method |
| CSBP | California Stream Bioassessment Protocol |
| CSCI | California Stream Condition Index |
| CTR | California Toxics Rule |
| DPS | Distinct Population Segment |
| DQO | Data Quality Objectives |
| EDD | Electronic Data Delivery |
| EMAF | Ecological Monitoring and Assessment Framework |
| EPT | Ephemeroptera, Plecoptera, Tricoptera |
| FSURMP | Fairfield Suisun Urban Runoff Management Program |
| GRTS | Generalized Random Tessellation Stratified |
| HDI | Human Disturbance Index |
| IMR | Integrated Monitoring Report |
| MPC | Monitoring and Pollutants of Concern Committee |
| MQO | Measurement Quality Objective |
| MRP | Municipal Regional Permit |
| MUN | Municipal |
| MWAT | Maximum Weekly Average Temperature |
| NIST | National Institute of Standards and Technology |
| NPDES | National Pollution Discharge Elimination System |
| O/E | Observed to Expected |
| PAH | Polycyclic Aromatic Hydrocarbons |

| | |
|---|---|
| PEC | Probable Effects Concentrations |
| PHAB | Physical habitat assessments |
| pMMI | Predictive Multi-Metric Index |
| POTW | Publicly Owned Treatment Works |
| PRM | Pathogen-related Mortality |
| PSA | Perennial Streams Assessment |
| QAPP | Quality Assurance Project Plan |
| RMC | Regional Monitoring Coalition |
| RMP | Regional Monitoring Program |
| RPD | Relative Percent Difference |
| RWB | Reachwide Benthos |
| RWQCB | Regional Water Quality Control Board |
| SAFIT | Southwest Association of Freshwater Invertebrate Taxonomist |
| SCCWRP | Southern California Coastal Water Research Project |
| SCVURPPP | Santa Clara Valley Urban Runoff Pollution Prevention Program |
| SCVWD | Santa Clara Valley Water District |
| SFEI | San Francisco Estuary Institute |
| SFRWQCB | San Francisco Bay Regional Water Quality Control Board |
| SMCWPPP | San Mateo County Water Pollution Prevention Program |
| SOP | Standard Operating Protocol |
| SQT | Sediment Quality Triad |
| SSID | Stressor/Source Identification |
| STA | Standard Taxonomic Assessment |
| STE | Standard Taxonomic Effort |
| STV | Statistical Threshold Value |
| SWAMP | Surface Water Ambient Monitoring Program |
| TEC | Threshold Effects Concentrations |
| TKN | Total Kjeldahl Nitrogen |
| TNS | Target Non-Sampleable |
| TS | Target Sampleable |
| TU | Toxicity Unit |
| USEPA | Environmental Protection Agency |
| WQO | Water Quality Objective |

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# Executive Summary


In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA), including the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), joined together to form the Regional Monitoring Coalition (RMC). The RMC was formed to coordinate and oversee water quality monitoring required by the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP). In compliance with MRP Provision C.8.c, SMCWPPP conducted Creek Status Monitoring during Water Years 2012 and 2013 (October 1, 2011 to September 30, 2013) using a targeted (non-probabilistic) and probabilistic monitoring design developed for the RMC. The monitoring program was designed to address two management questions:

1) ***Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?***

2) ***Are conditions in local receiving water supportive of or likely supportive of beneficial uses?***

This SMCWPPP Creek Status Monitoring Report provides results from all Creek Status monitoring activities performed by SMCWPPP in Water Year 2012 (WY2012) and Water Year 2013 (WY2013).

The targeted monitoring design focuses on sites selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns. Targeted monitoring parameters consist of water temperature, general water quality, pathogen indicators and riparian assessments. Hourly water temperature measurements were recorded during the dry season using HOBO® temperature data loggers installed at four sites in Pilarcitos Creek in WY2012 and four sites in San Mateo Creek in WY2013. General water quality monitoring (temperature, dissolved oxygen, pH and specific conductivity) was conducted using YSI continuous water quality equipment (sondes) for two 2-week periods (spring and late summer) at two sites in each year in the same creeks. Water samples were collected at five sites each year for analysis of pathogen indicators (*E. coli* and fecal coliform). In WY2012, the pathogen sites were spread throughout San Mateo County. In WY2013, all five pathogen sites were located in San Pedro Creek. Riparian assessments were conducted at probabilistic sites using the California Rapid Assessment Method (CRAM).

The probabilistic monitoring design was developed to remove bias from site selection such that ecosystem conditions can be objectively assessed on local (i.e., SMCWPPP) and regional (i.e., RMC) scales. Probabilistic parameters consist of bioassessment, nutrients and conventional analytes, chlorine, water and sediment toxicity, and sediment chemistry. Twenty-three sites were sampled in Water Years 2012 and 2013. A small number of these sites were sampled by the San Francisco Regional Water Quality Control Board (SFRWQCB) as part of the Surface Water Ambient Monitoring Program (SWAMP), in collaboration with SMCWPPP.

The first management question is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in Table 8.1 of the MRP. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of stressor source identification projects.

The second management question is addressed primarily through calculation of indices of biological integrity (IBI) using benthic macroinvertebrate data collected at probabilistic sites, and

sites sampled prior to MRP implementation. Biological condition scores were compared to physical habitat and water quality data collected synoptically with bioassessments to evaluate whether any correlations exist that may explain the variation in IBI scores.

**Biological Condition**

- Under the level of MRP-required monitoring, the RMC probabilistic design requires at least four years of data to develop a statistically-robust characterization of biological conditions of the creeks within SMCWPPP. Therefore, the **overall biological condition assessment** that can be derived based on the Water Years 2012 and 2013 bioassessment data should be considered preliminary.
- Southern California benthic macroinvertebrate index of biological integrity (SoCal B-IBI) scores were calculated to assess biological condition at probabilistic sites. Ten sites (43%) scored as very poor or poor (scores of 0 to 39). All of these sites are located in urban areas, with half the sites characterized as highly modified channels. Ten sites (43%) were scored as very good or good (scores of 60 to 100) with a majority of these sites classified as non-urban.
- California Stream Condition Index (CSCI) scores were calculated for MRP probabilistic sites as well as a large historical dataset (2002 to 2009) to evaluate the utility of this new tool. Overall, the CSCI scores correlated well with SoCal B-IBI scores. The CSCI scores showed greater variability within each condition category, suggesting it may be more responsive to stressors associated with physical habitat condition and water quality.
- The mean CSCI scores were higher for perennial sites compared to non-perennial sites (0.82 versus 0.57) and higher for non-urban sites compared to urban sites (1.0 versus 0.55).
- Total Physical Habitat (PHAB) and California Rapid Assessment Method (CRAM) scores were moderately correlated with biological condition scores. High CRAM score (79 out of 100) and very poor CSCI score (0.19) at one site (202R00908) may indicate that water quality stressor(s) are impacting biological condition.
- Diatom IBI scores do not correlate well with CSCI or SoCal B-IBI scores. None of the physical habitat or water quality stressor variables correlated well with the Diatom IBI scores.

**Nutrients and Conventional Analytes**

- Nutrients (nitrogen and phosphorus), algal biomass indicators, and other conventional analytes were measured in samples collected concurrently with bioassessments which are conducted in the spring season. MRP Trigger thresholds for chloride, unionized ammonia, and nitrate were not exceeded.
- The parameters in this group of constituents that correlates well with SoCal B-IBI and CSCI scores include chloride, nitrate, and total Kjeldahl nitrogen.

**Water Toxicity**

- Water toxicity samples were collected from three sites during each year of the program at a frequency of twice per year. No water toxicity samples exceeded the MRP trigger thresholds.

**Sediment Toxicity and Chemistry/Sediment Triad Analysis**

- Sediment toxicity and chemistry samples were collected concurrently with the summer water toxicity samples. No MRP trigger thresholds were exceeded.

- Sediment toxicity was evaluated with bioassessment scores and sediment chemistry data (TEC and PEC quotients, and pyrethroid TU equivalents) as part of the Sediment Triad Analysis. One or more aspects of the Sediment Triad Analysis were exceeded at each site suggesting that all four sites should be considered for future evaluation for stressor source identification projects.

**Spatial and Temporal Variability of Water Quality Conditions**

- There was minimal spatial variability in water temperature across the five sites in Pilarcitos Creek and across the four sites in San Mateo Creek.

- Dissolved oxygen concentrations at the De Anza Park site (204SMA059) in San Mateo Creek were consistently lower compared to levels measured at the site below the dam. At the De Anza site, DO levels had diurnal fluctuations that appear to be driven by stratification and mixing caused by changes in air temperature.

**Potential Impacts to Aquatic Life**

- There were no exceedances of the Mean Weekly Average Temperature (MWAT) threshold at the two sites in Pilarcitos Creek or two sites in San Mateo Creek. These results suggest that water temperature is not a limiting factor for the resident steelhead population.

- Dissolved oxygen concentrations at both sites monitored in Pilarcitos Creek did not exceed WARM or COLD Water Quality Objectives. The WQO for COLD was exceeded at the De Anza Park site (204SMA059) for 24% - 36% of the measurements made during the summer and spring sampling event, respectively. In WY 2014, SMCWPPP will conduct further investigation on the spatial and temporal extent of reduced dissolved oxygen concentrations at the De Anza Park site.

- Values for pH were within Water Quality Objectives at both sites in Pilarcitos Creek and San Mateo Creek.

**Potential Impacts to Water Contact Recreation**

- Pathogen indicator densities were measured at five sites spread throughout San Mateo County in WY2012. In WY2013, pathogen indicator sites were focused in San Pedro Creek where a bacteria TMDL was recently adopted. Threshold triggers for fecal coliform and/or *E. coli* were exceeded at all sites in WY2012 and at four sites in WY2013.

- It is important to recognize that pathogen indicator thresholds are based on human recreation at beaches receiving bacteriological contamination from human wastewater, and may not be applicable to conditions found in urban creeks. As a result, the comparison of pathogen indicator results to water quality objectives and criteria for full body contact recreation, may not be appropriate and should be interpreted cautiously.

# 1.0 Introduction

This San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) Creek Status Monitoring Report complies with Reporting Provision C.8.g.v of the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP). This report is being submitted as part of an Integrated Monitoring Report (IMR) and contains Creek Status Monitoring data collected during the term of the MRP, i.e., Water Years 2012 and 2013 (October 1, 2011 to September 30, 2013).

MRP Provision C.8.c requires Permittees to conduct creek status monitoring that is intended to answer the following management questions:

1. Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?

2. Are conditions in local receiving water supportive of or likely supportive of beneficial uses?

SMCWPPP (formerly STOPPP) was established in 1990 to reduce the pollution carried by stormwater into local creeks, the San Francisco bay, and the Pacific Ocean. The program is a partnership of the City/County Association of Governments (C/CAG), each incorporated city and town in the county, and the County of San Mateo, which share a common NPDES permit. SMCWPPP has been conducting monitoring in local creeks since 1999 to comply with requirements specified in its NPDES municipal separate stormwater sewer system (MS4) permit first issued in 1999 by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB).

Creek status monitoring required by the current MRP builds upon monitoring previously conducted and is coordinated through the Regional Monitoring Coalition (RMC) and began on October 1, 2011. Creek status monitoring parameters, methods, occurrences, durations and minimum number of sampling sites are described in Table 8.1 of MRP Provision C.8.c. Monitoring results are evaluated to determine whether triggers are met requiring additional Monitoring Projects described in MRP Provision C.8.d.i.

Provision C.8.a (Compliance Options) of the MRP allows Permitees to address monitoring requirements through a “regional collaborative effort,” their Stormwater Program, and/or individually. The RMC was formed in early 2010 as a collaboration among a number of the Bay Area Stormwater Agencies Association (BASMAA) members and MRP Permittees (Table 1.1) to develop and implement a regionally coordinated water quality monitoring program to improve stormwater management in the region and address water quality monitoring required by the MRP[3]. With notification of participation in the RMC, Permittees were required to commence water quality data collection by October 2011. Implementation of the RMC’s Creek Status and Long-Term Trends Monitoring Plan allows Permittees and the Water Board to modify their existing creek monitoring programs, and improve their ability to collectively answer core

[3] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the five-year MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

management questions in a cost-effective and scientifically-rigorous way. Participation in the RMC is facilitated through the BASMAA Monitoring and Pollutants of Concern Committee (MPC).

Table 1.1. Regional Monitoring Coalition participants.

| Stormwater Programs | RMC Participants |
|---|---|
| Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) | Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and, Santa Clara County |
| Clean Water Program of Alameda County (ACCWP) | Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and, Zone 7 |
| Contra Costa Clean Water Program (CCCWP) | Cities of Antioch, Brentwood, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, Danville, and Moraga; Contra Costa County; and, Contra Costa County Flood Control and Water Conservation District |
| San Mateo County Wide Water Pollution Prevention Program (SMCWPPP) | Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County |
| Fairfield-Suisun Urban Runoff Management Program (FSURMP) | Cities of Fairfield and Suisun City |
| Vallejo Permittees | City of Vallejo and Vallejo Sanitation and Flood Control District |

The goals of the RMC are to:

1. Assist Permittees in complying with requirements in MRP Provision C.8 (Water Quality Monitoring);

2. Develop and implement regionally consistent creek monitoring approaches and designs in the Bay Area, through the improved coordination among RMC participants and other agencies (e.g., Water Board) that share common goals; and

3. Stabilize the costs of creek monitoring by reducing duplication of effort and streamlining reporting.

The RMC's monitoring strategy for complying with MRP Provision C.8.c is described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2011). The strategy includes local "targeted" monitoring and regional ambient/probabilistic monitoring. The combination of these two components allows each individual RMC participating program to assess the status of beneficial uses in local creeks within its jurisdictional area, while also contributing data to answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks). Table 1.2 provides a list of which parameters are included in the regional and local programs. This report includes data collected in San Mateo County under both monitoring components.

Table 1.2. Creek Status Monitoring parameters in compliance with MRP Provision C.8.c and associated monitoring program.

| Monitoring Elements of MRP Provision C.8.c | Monitoring Component | |
|---|---|---|
| | Regional Ambient (Probabilistic) | Local (Targeted) |
| Bioassessment & Physical Habitat Assessment | X | |
| Chlorine | X | |
| Nutrients | X | |
| Water Toxicity | X | |
| Sediment Toxicity | X | |
| Sediment Chemistry | X | |
| General Water Quality (Continuous) | | X |
| Temperature (Continuous) | | X |
| Pathogen Indicators | | X |
| Stream Survey (CRAM)[1] | | X |

Notes: 1. Stream surveys under the SMCWPPP Monitoring Program were conducted at Regional Monitoring Program sites.

## 1.1 Designated Beneficial Uses

There are 34 watersheds in San Mateo County draining an area of about 450 square miles. The San Mateo Range, which runs north/south, divides the county roughly in half. The eastern half (“Bayside”) drains to San Francisco Bay and is characterized by relatively flat, urbanized areas along the Bay. The western half (“coastside”) drains to the Pacific Ocean and consists of approximately 50 percent parkland and open space, with agriculture and relatively small urban areas.

Beneficial Uses in San Mateo County creeks are designated by the SFRWQCB for specific water bodies and generally apply to all its tributaries. Uses include aquatic life, recreation, human consumption, and habitat. Table 1.3 lists Beneficial Uses designated by the SFRWQCB (2013) for water bodies monitored by SMCWPPP in Water Years 2012 and 2013.

The remainder of this report describes the two components of the monitoring design (targeted and probabilistic) (Section 2.0); monitoring methods (Section 3.0); data analysis and interpretation methods (Section 4.0); results and discussion, including a statement of data quality, biological condition assessment, and stressor analysis (Section 5.0), and summary conclusions (Section 6.0).

Table 1.3. Creeks Monitored by SMCWPPP and their Beneficial Uses (SFRWQCB 2013).

| Waterbody | AGR | MUN | FRSH | GWR | IND | PROC | COMM | SHELL | COLD | EST | MAR | MIGR | RARE | SPWN | WARM | WILD | REC-1 | REC-2 | NAV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bayside Creeks** | | | | | | | | | | | | | | | | | | | |
| Belmont Creek | | | | | | | | | | | | | | | E | E | E | E | |
| Laurel Creek | | | | | | | | | | | | | | | E | E | E | E | |
| Colma Creek | | | | | | | | | | | | | | | E | E | E | E | |
| Easton Creek | | | | | | | | | | | | | | | E | E | E | E | |
| Arroyo Ojo de Agua | | | | | | | | | | | | | | | E | E | E | E | |
| Redwood Creek | | | | | | | | | | | | | | | E | E | E | E | |
| Bear Gulch Creek | | E | | | | | | | E | | | E | E | E | E | E | E | E | |
| Corte Madera Creek | | | | | | | | | E | | | E | | E | E | E | E | E | |
| West Union Creek | | | | | | | | | E | | | E | E | E | E | E | E | E | |
| Polhemus Creek | | | | | | | | | E | | | | | | E | E | E | E | |
| San Mateo Creek | | | E | | | | | | E | | | E | E | E | E | E | E | E | |
| Sanchez Creek | | | | | | | | | | | | | | | E | E | E | E | |
| **Coastside Creeks** | | | | | | | | | | | | | | | | | | | |
| Butano Creek | | | | | | | | | E | | | E | E | | E | E | E | E | |
| Little Butano Creek | | | | | | | | | E | | | | E | E | E | E | E | E | |
| Calera Creek | | | | | | | | | | | | | E | | E | E | E | E | |
| Denniston Creek | E | E | | | | | | | E | | | E | E | E | E | E | E | E | |
| Milagra Creek | | | | | | | | | | | | E | E | | E | E | E | E | |
| Tarwater Creek | | | | | | | | | E | | | E | E | E | E | E | E | E | |
| Pilarcitos Creek | E | E | | | | | | | E | | | E | E | E | E | E | E | E | |
| La Honda Creek | | | | | | | | | E | | | E | E | E | E | E | E | E | |
| San Gregorio Creek | E | | | | | | | | E | | | E | E | E | E | E | E | E | |
| Alpine Creek | | | | | | | | | E | | | E | E | E | E | E | E | E | |
| Woodhams Creek | | | | | | | | | E | | | | | | E | E | E | E | |
| San Pedro Creek | | E | | | | | | | E | | | E | E | E | E | E | E | E | |
| Dry Creek | E | E | | | | | | | E | | | E | E | E | E | E | E | E | |

**Notes:**

COLD = Cold Fresh Water Habitat
FRSH = Freshwater Replenishment
GWR - Groundwater Recharge
MIGR = Fish Migration
MUN = Municipal and Domestic Water
EST = Estuarine
NAV = Navigation
RARE= Preservation of Rare and Endangered Species
REC-1 = Water Contact Recreation
REC-2 = Non-contact Recreation
WARM = Warm Freshwater Habitat
WILD = Wildlife Habitat
E = Existing Use

# 2.0 Monitoring Design

## 2.1 Targeted Monitoring Design

During Water Year 2012 (WY2012; October 1, 2011 – September 30, 2012) and Water Year 2013 (WY2013; October 1, 201 - September 30, 2013) water temperature, general water quality, and pathogen indicators were monitored at selected sites using a targeted monitoring design based on the directed principle[4] to address the following management questions:

1. What is the spatial and temporal variability in water quality conditions during the spring and summer season?

2. Do general water quality measurements indicate potential impacts to aquatic life?

3. What are the pathogen indicator concentrations at creek sites where there is potential for water contact recreation to occur?

4. What are the riparian conditions at bioassessment sampling stations? Are riparian assessments good indicators for condition of aquatic life use? Can they help identify stressors to aquatic life uses?

### 2.1.1 Targeted Site Selection

**General Water Quality**

General water quality data (dissolved oxygen, specific conductance, pH, and temperature) were collected at a total of two locations in Pilarcitos Creek during WY2012 and two locations in San Mateo Creek during WY2013. Initial site selection in Pilarcitos Creek was coordinated with local Resource Conservation District staff. Sites selection was based on publically accessible areas to the creek, and areas managed by the Midpeninsula Regional Open Space District (MROSD). Site selection in San Mateo Creek was based on previous monitoring conducted by SFBRWQCB and SMCWPPP (De Anza Historical Park), as well as a lack of water quality data (USGS stream gage site), based on consultation with San Francisco Public Utilities Commission (SFPUC) staff.

**Temperature**

Water temperature was monitored at five sites within the Pilarcitos Creek and four sites in San Mateo Creek watersheds during WY2012 and WY2013, respectively. A steelhead/rainbow trout fish population is supported in both creeks, with the primary rearing and spawning habitat occurring in the reaches downstream of dams of both watersheds.

In WY2012, five temperature monitoring locations were established in Pilarcitos Creek. The establishment of these sites was primarily based on publically accessible areas to the creek, and areas managed by the MROSD to obtain access in privately owned land. In WY2013,

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[4] Directed Monitoring Design Principle: A deterministic approach in which points are selected deliberately based on knowledge of their attributes of interest as related to the environmental site being monitored. This principle is also known as "judgmental," "authoritative," "targeted," or "knowledge-based."

monitoring locations were established within an urban reach of San Mateo Creek, which was upstream and downstream of existing SFPUC temperature monitoring sites. The City of Hillsborough assisted SMCWPPP staff in identifying creek locations within in the reach that had public access.

**Pathogen Indicators**

Pathogen indicator samples were collected at five sites located in municipal or county owned parks in areas with good public access to creeks and potential for recreational water contact. Water samples were collected at the same sites in both water years to evaluate inter-annual variability.

## 2.2 Probabilistic Monitoring Design

Targeted monitoring may not give an accurate view of background conditions because site selection is biased toward sites where historical or existing water quality concerns have been identified. Therefore, the RMC augments targeted monitoring designs with an ambient (probabilistic) creek status design that was developed to remove bias from site selection. This design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its program area (County boundary) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks.

The RMC regional probabilistic monitoring design was developed to address the management questions listed below:

1. What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?
   - i. What is the condition of aquatic life in the urbanized portion of the RMC area; are water quality objectives met and are beneficial uses supported?
   - ii. What is the condition of aquatic life in RMC participant counties; are water quality objectives met and are beneficial uses supported?
   - iii. To what extent does the condition of aquatic life in urban and non-urban creeks differ in the RMC area?
   - iv. To what extent does the condition of aquatic life in urban and non-urban creeks differ in each of the RMC participating counties?
2. What are major stressors to aquatic life in the RMC area?
   - i. What are major stressors to aquatic life in the urbanized portion of the RMC area?
3. What are the long-term trends in water quality in creeks over time?

These questions will be addressed for the RMC area after a suitable number of sites have been sampled, which is expected to occur after 3 or 4 years.

Table 2.1 illustrates the total number of sites that each RMC Permittee *planned* to sample within the MRP term at the outset of the monitoring program, including sampling efforts planned by SFRWQCB (approximately 2 sites per county per year). Approximately 80 percent of the sites are in urban areas and 20 percent are in non-urban areas[5]. Table 2.1 also illustrates the number of sampling years required to establish statistically representative sample sizes (30 samples) for each of the classified strata in the regional monitoring design[6]. In San Mateo County, a statistically representative sample of urban sites is anticipated in Year 4 (WY2015) of the program; a statistically representative sample of non-urban sites is not anticipated within the 5-year program. Due to unforeseen field circumstances, the actual number of sites sampled and the percentage of urban and non-urban sites may vary. Such outcomes can be addressed in subsequent sampling years.

Table 2.1. Projected number of samples per monitoring year[a]; shaded cells indicate when a minimum sample size may be available to develop a statistically representative data set to address management questions related to condition of aquatic life.

| Monitoring Year | RMC Area (Region-wide) | | Santa Clara County | | Alameda County | | Contra Costa County | | San Mateo County | | Fairfield, Suisun City and Vallejo [b] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Land Use* | *Urban* | *Non-Urban* | *Urban* | *Non-Urban* | *Urban* | *Non-Urban* | *Urban* | *Non-Urban* | *Urban* | *Non-Urban* | *Urban* | *Non-Urban* |
| Year 1 (WY2012) | 48 | 22 | 16 | 6 | 16 | 6 | 8 | 4 | 8 | 4 | 0 | 2 |
| Year 2 (WY2013) | 100 | 44 | 32 | 12 | 32 | 12 | 16 | 8 | 16 | 8 | 4 | 4 |
| Year 3[c] (WY2014) | 156 | 66 | 48 | 18 | 48 | 18 | 24 | 12 | 24 | 12 | 12 | 6 |
| Year 4 (WY2015) | 204 | 88 | 64 | 24 | 64 | 24 | 32 | 16 | 32 | 16 | 12 | 8 |
| Year 5 (WY2016) | 256 | 110 | 80 | 30 | 80 | 30 | 40 | 20 | 40 | 20 | 16 | 10 |

[a] Assumes SFRWQCB samples two non-urban sites annually in each RMC County.
[b] Assumes: FSURMP and Vallejo only monitor urban sites; FSURMP monitors 4 sites in Year 2, 3 and 5; and Vallejo monitors 4 sites in Year 3.
[c] WY2014 is the final year of monitoring under the MRP 5-Year Permit.

### 2.2.1 RMC Area

The RMC area encompasses 3,407 square miles of land in the San Francisco Bay Area. This includes the portions of the five participating counties that fall within the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) boundary, as well as the eastern portion of Contra Costa County that drains to the Central Valley region (Figure 2.1)[7]. Creek status and trends monitoring is being conducted in non-tidally influenced, flowing water bodies (i.e., creeks, streams and rivers) interspersed among the RMC area. The water bodies monitored were

[5] Some sites classified as urban, using the GIS may be considered for reclassification as non-urban based on actual land uses of the drainage area despite location inside municipal jurisdictional boundaries.

[6] For each of the strata, it is necessary to obtain a sample size of at least 30 in order to evaluate the condition of aquatic life within known estimates of precision. This estimate is defined by a power curve from a binomial distribution (BASMAA 2012a).

[7] GIS layers used to develop figures in this report are available upon request by contacting Nick Zigler, nzigler@eoainc.com.

drawn from a master list that included all perennial and non-perennial creeks and rivers that run through both urban and non-urban areas within the RMC area.

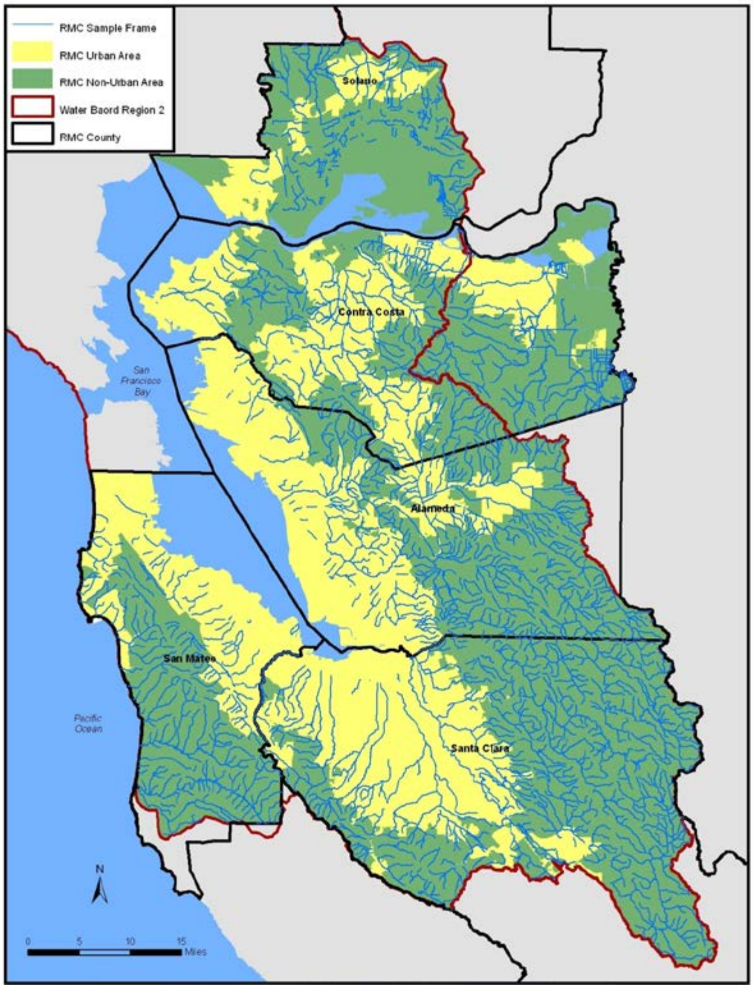


Figure 2.1 Map of BASMAA RMC area showing each member program boundary and urban and non-urban areas.

### 2.2.2 Probabilistic Site Selection

The regional design was developed using the Generalized Random Tessellation Stratified (GRTS) approach developed by the United States Environmental Protection Agency (USEPA) and Oregon State University (Stevens and Olson 2004). GRTS offers multiple benefits for coordinating amongst monitoring entities including the ability to develop a spatially balanced design that produces statistically representative data with known confidence intervals. The GRTS approach has been implemented recently in California by several agencies including the statewide Perennial Streams Assessment (PSA) conducted by SWAMP (Ode et al. 2011) and the Southern California Stormwater Monitoring Coalition's (SMC) regional monitoring program conducted by municipal stormwater programs in Southern California (SMC 2007). For the purpose of developing the RMC's probabilistic design, the 3,407-square mile RMC area is considered to represent the "sample universe."

Sample sites were selected and attributed using the GRTS approach from a sample frame consisting of a creek network geographic information system (GIS) data set within the RMC boundary (BASMAA 2011). This approach was agreed to by SFRWQCB staff during RMC workgroup meetings although it differs from that specified in MRP Provision C.8.c.iv., e.g., sampling on the basis of individual watersheds in rotation and selecting sites to characterize segments of a waterbody(s). The sample frame includes non-tidally influenced perennial and non-perennial creeks within five management units representing areas managed by the storm water programs associated with the RMC. The sample frame was stratified by management unit to ensure that MRP Provision C.8.c sample size requirements (SFRWQCB 2009) would be achieved.

The National Hydrography Plus Dataset (1:100,000) was selected as the creek network data layer to provide consistency with both the Statewide PSA and the SMC, and the opportunity for future data coordination with these programs. The RMC sample frame was classified by county and land use (i.e., urban and non-urban) to allow for comparisons between these strata. Urban areas were delineated by combining urban area boundaries and city boundaries defined by the U.S. Census (2000). Non-urban areas were defined as the remainder of the areas within the sample universe (i.e., RMC area). Some sites classified as urban fall near the non-urban edge of the city boundaries and have little upstream development. For the purposes of consistency, these urban sites were not re-classified. Therefore, data values within the urban classification represent a wide range of conditions.

Based on discussion during RMC Workgroup meetings, with SFRWQCB staff present, RMC participants weighted their sampling efforts so that annual sampling efforts are approximately 80% in urban areas and 20% in non-urban areas for the purpose of comparison. RMC participants coordinated with the SFRWQCB by identifying additional non-urban sites from their respective counties and providing a list of sites for SWAMP to conduct site evaluations. The SFRWQCB attempted to sample at least 10 non-urban sites within RMC jurisdiction, but the total number of targeted sites was variable due to access restrictions and flow issues that resulted in many sites not getting sampled.

### 2.2.3 Site Evaluation

Sites identified in the regional sample draw were evaluated by each RMC participant in chronological order using a two-step process described in RMC Standard Operating Procedure FS-12 (BASMAA 2012b), consistent with the procedure described by Southern California Coastal Water Research Project (SCCWRP) (2012). Each site was evaluated to determine if it met the following RMC sampling location criteria:

1. The location (latitude/longitude) provided for a site is located on or is within 300 meters of a non-impounded receiving water body[8];
2. Site is not tidally influenced;
3. Site is wadeable during the sampling index period;

[8] The evaluation procedure permits certain adjustments of actual site coordinates within a maximum of 300 meters.

4. Site has sufficient flow during the sampling index period to support standard operation procedures for biological and nutrient sampling.
5. Site is physically accessible and can be entered safely at the time of sampling;
6. Site may be physically accessed and sampled within a single day;
7. Landowner(s) grant permission to access the site[9].

In the first step, these criteria were evaluated to the extent possible using a "desktop analysis." Site evaluations were completed during the second step via field reconnaissance visits. Based on the outcome of site evaluations, sites were classified into one of three categories:

- **Target** – Target sites were grouped into two subcategories:
  - **Target sampleable (TS)** - Sites that met all seven criteria and were successfully sampled.
  - **Target Non-Sampleable (TNS)** - Sites that met criteria 1 through 4, but did not meet at least one of criteria 5 through 7 were classified as TNS.
- **Non-Target (NT)** - Sites that did not meet at least one of criteria 1 through 4 were classified as non-target status.
- **Unknown (U)** - Sites were classified with unknown status when it could be reasonably inferred either via desktop analysis or a field visit that the site was a valid receiving water body and information for any of the seven criteria was unconfirmed.

Table 2.2 lists the total number of sites evaluated in San Mateo County in Water Years 2012 and 2013, and their classification categories. A handful of the sites classified as non-urban were evaluated by the SFRWQCB for potential SWAMP sampling. Results of the site evaluation are illustrated in Figure 2.2 and described in further detail in Attachment A.

Table 2.2. Results of Probabilistic Site Evaluations for Water Years 2012 and 2013 by SMCWPPP.

| | Water Year 2012 | | Water Year 2013 | | TOTAL | |
|---|---|---|---|---|---|---|
| Classification | # of Sites | % | # of Sites | % | # of Sites | % |
| Target Sampleable (TS) | 13 | 45 | 14 | 45 | 27 | 45 |
| Target Non-Sampleable (TNS) | 8 | 28 | 10 | 32 | 18 | 30 |
| Non-Target (NT) | 8 | 28 | 7 | 23 | 15 | 25 |
| Unknown (U) | -- | -- | -- | -- | -- | -- |
| TOTAL | 29 | 100 | 31 | 100 | 60 | 100 |

[9] If landowners did not respond to at least two attempts to contact them either by written letter, email, or phone call, permission to access the respective site was effectively considered to be denied.

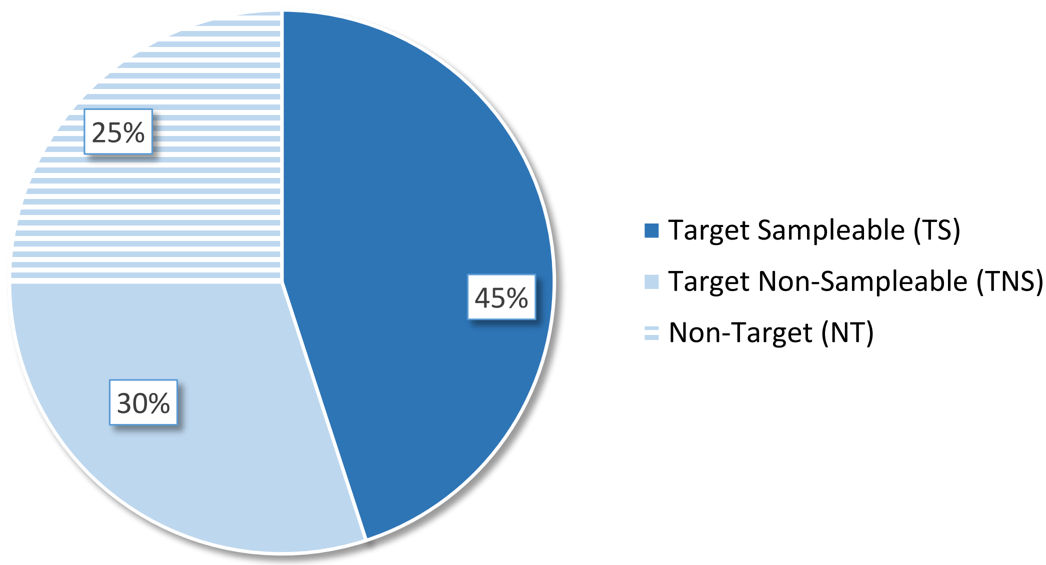


Figure 2.2. Results of San Mateo County site evaluations for Water Years 2012 and 2013.

The complete list of target and probabilistic monitoring sites sampled by SMCWPPP in WY2012 and WY2013 including WY2012 non-urban probabilistic monitoring sites sampled by the SFRWQCB is presented in Table 2.3. Monitoring locations with monitoring parameter(s) and year sampled are shown in Figure 2.3.

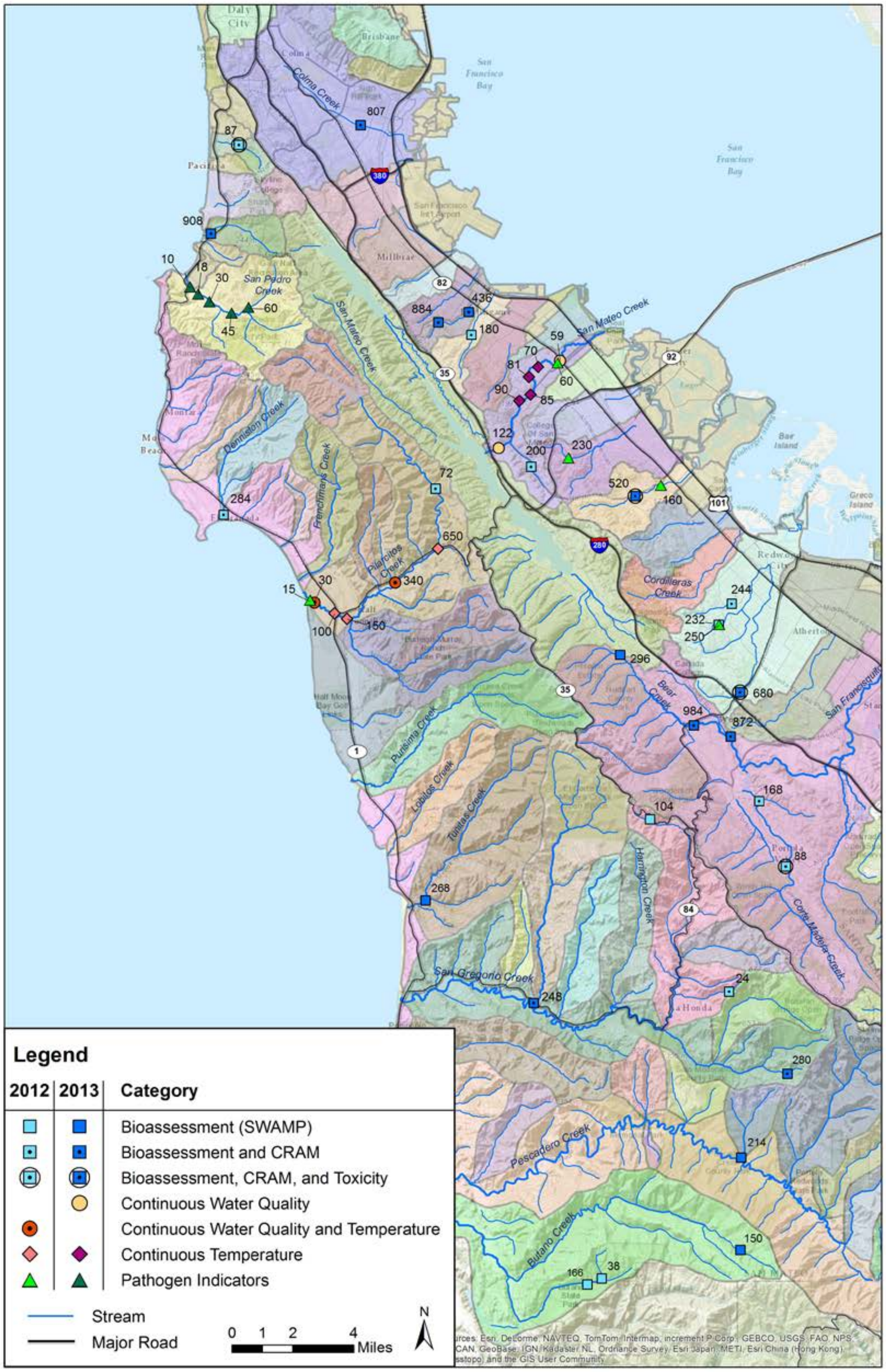


Figure 2.3. Map of SMCWPPP Program Area, major creeks, and sites monitored in WYs 2012 and 2013.

Table 2.3. Sites and parameters monitored in Water Years 2012 and 2013 in San Mateo County. Land use classification is provided for probabilistic sites only.

| Map ID | Station Number | Bay Ocean | Watershed | Creek Name | Land Use | Latitude | Longitude | Probabilistic | | Targeted | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Bioassessment, Nutrients, General WQ | Toxicity, Sediment Chemistry | CRAM | Temp | Continuous WQ | Pathogen Indicators | Water Year |
| 160 | 204BEL160 | Bay | Belmont Creek | Belmont Creek | | 37.51618 | -122.27904 | | | | | | x | 2012 |
| 520 | 204R00520 | Bay | Belmont Creek | Belmont Creek | U | 37.51220 | -122.29121 | x | x | x | | | | 2013 |
| 807 | 204R00807 | Bay | Colma Creek | Colma Creek | U | 37.65227 | -122.42204 | x | | x | | | | 2013 |
| 436 | 204R00436 | Bay | Easton Creek | Easton Creek | U | 37.58173 | -122.37066 | x | | x | | | | 2013 |
| 884 | 204R00884 | Bay | Easton Creek | Easton Creek | U | 37.57775 | -122.38511 | x | | x | | | | 2013 |
| 230 | 204LAU230 | Bay | Laurel Creek | Laurel Creek | | 37.52658 | -122.32298 | | | | | | x | 2012 |
| 232 | 204R00232 | Bay | Redwood Creek | Arroyo Ojo De Aqua | U | 37.46109 | -122.25504 | x | | x | | | | 2012 |
| 250 | 204AOA250 | Bay | Redwood Creek | Arroyo Ojo de Aqua | | 37.46109 | -122.25504 | | | | | | x | 2012 |
| 680 | 204R00680 | Bay | Redwood Creek | Redwood Creek | U | 37.43798 | -122.24128 | x | x | x | | | | 2013 |
| 244 | 204R00244 | Bay | Redwood Creek | Trib to Arroyo Ojo De Aqua | U | 37.47147 | -122.24532 | x | | x | | | | 2012 |
| 984 | 202R00984 | Bay | San Francisquito Creek | Bear Gulch Creek | U | 37.42543 | -122.26349 | x | | x | | | | 2013 |
| 872 | 205R00872 | Bay | San Francisquito Creek | Bear Gulch Creek | U | 37.42125 | -122.24588 | x | | x | | | | 2013 |
| 88 | 205R00088 | Bay | San Francisquito Creek | Corte Madera Creek | U | 37.372 | -122.21964 | x | x | x | | | | 2012/13[1] |
| 168 | 205R00168 | Bay | San Francisquito Creek | Corte Madera Creek | U | 37.3968 | -122.23231 | x | | x | | | | 2012 |
| 296* | 205R00296 | Bay | San Francisquito Creek | West Union Creek | NU | 37.45211 | -122.29852 | x | | | | | | 2013 |
| 200 | 204R00200 | Bay | San Mateo Creek | Polhemus Creek | U | 37.52325 | -122.3409 | x | | x | | | | 2012 |
| 59 | 204SMA059 | Bay | San Mateo Creek | San Mateo Creek | | 37.56331 | -122.32707 | | | | | x | | 2013 |
| 70 | 204SMA070 | Bay | San Mateo Creek | San Mateo Creek | | 37.56096 | -122.33751 | | | | x | | | 2013 |
| 81 | 204SMA081 | Bay | San Mateo Creek | San Mateo Creek | | 37.55722 | -122.34191 | | | | x | | | 2013 |
| 85 | 204SMA085 | Bay | San Mateo Creek | San Mateo Creek | | 37.55053 | -122.34119 | | | | x | | | 2013 |
| 90 | 204SMA090 | Bay | San Mateo Creek | San Mateo Creek | | 37.54816 | -122.34644 | | | | x | | | 2013 |
| 122 | 204SMA122 | Bay | San Mateo Creek | San Mateo Creek | | 37.53033 | -122.356308 | | | | | x | | 2013 |
| 60 | 204SMA060 | Bay | San Mateo Creek | San Mateo Creek | | 37.56244 | -122.32828 | | | | | | x | 2012 |
| 180 | 204R00180 | Bay | Sanchez Creek | Sanchez Creek | U | 37.57313 | -122.36934 | x | | x | | | | 2012 |

| Map ID | Station Number | Bay Ocean | Watershed | Creek Name | Land Use | Latitude | Longitude | Probabilistic | | Targeted | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Bioassessment, Nutrients, General WQ | Toxicity, Sediment Chemistry | CRAM | Temp | Continuous WQ | Pathogen Indicators | Water Year |
| 150* | 202R00150 | Ocean | Butano Creek | Butano Creek | NU | 37.22664 | -122.24120 | x | | | | | | 2013 |
| 166* | 202R00166 | Ocean | Butano Creek | Little Butano Creek | NU | 37.21363 | -122.31411 | x | | | | | | 2012 |
| 38* | 202R00038 | Ocean | Butano Creek | Little Butano Creek | NU | 37.21590 | -122.30728 | x | | | | | | 2012 |
| 908 | 202R00908 | Ocean | Calera Creek | Calera Creek | U | 37.61128 | -122.49336 | x | | x | | | | 2013 |
| 284 | 202R00284 | Ocean | Denniston Creek | Denniston Creek | U | 37.50515 | -122.48723 | x | | x | | | | 2012 |
| 87 | 202R00087 | Ocean | Milagra Creek | Milagra Creek | U | 37.64474 | -122.48009 | x | x | x | | | | 2012 |
| 214* | 202R00214 | Ocean | Pescadero Creek | Tarwater Creek | NU | 37.26166 | -122.24082 | x | | | | | | 2013 |
| 30 | 202PIL030 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.47195 | -122.44399 | | | | x | x | | 2012 |
| 100 | 202PIL100 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.46788 | -122.43456 | | | | x | | | 2012 |
| 150 | 202PIL150 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.46584 | -122.42858 | | | | x | | | 2012 |
| 340 | 202PIL340 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.47945 | -122.40549 | | | | x | x | | 2012 |
| 650 | 202PIL650 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.49225 | -122.38523 | | | | x | | | 2012 |
| 72 | 202R00072 | Ocean | Pilarcitos Creek | Pilarcitos Creek | NU | 37.51493 | -122.38637 | x | | x | | | | 2012 |
| 15 | 202PIL015 | Ocean | Pilarcitos Creek | Pilarcitos Creek | | 37.47282 | -122.44616 | | | | | | x | 2012 |
| 104* | 202R00104 | Ocean | San Gregorio Creek | La Honda Creek | NU | 37.38989 | -122.28430 | x | | | | | | 2012 |
| 248 | 202R00248 | Ocean | San Gregorio Creek | San Gregorio Creek | NU | 37.32028 | -122.33978 | x | | x | | | | 2013 |
| 280 | 202R00280 | Ocean | San Gregorio Creek | Tributary to Alpine Creek | NU | 37.29353 | -122.21885 | x | | x | | | | 2013 |
| 24 | 202R00024 | Ocean | San Gregorio Creek | Woodhams Creek | NU | 37.32468 | -122.24666 | x | | x | | | | 2012 |
| 10 | 202SPE010 | Ocean | San Pedro Creek | San Pedro Creek | | 37.59113 | -122.50331 | | | | | | x | 2013 |
| 18 | 202SPE018 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58841 | -122.49944 | | | | | | x | 2013 |
| 30 | 202SPE030 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58556 | -122.49409 | | | | | | x | 2013 |
| 45 | 202SPE045 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58125 | -122.48350 | | | | | | x | 2013 |
| 60 | 202SPE060 | Ocean | San Pedro Creek | San Pedro Creek | | 37.58344 | -122.47548 | | | | | | x | 2013 |
| 268* | 202R00268 | Ocean | Tunitas Creek | Dry Creek | NU | 37.35917 | -122.39124 | x | | | | | | 2013 |

* indicates site sampled by SFRWQCB through the SWAMP program.

# 3.0 Monitoring Methods

Water quality data were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC Standard Operating Procedures (SOPs; BASMAA 2012b) and associated Quality Assurance Project Plan (QAPP; BASMAA 2012a). These documents and the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2011) are updated as needed to maintain their currency and optimal applicability. Where applicable, monitoring data were collected using methods comparable to those specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP[10], and were submitted in SWAMP-compatible format to the SFRWQCB. The SOPs were developed using a standard format that describes health and safety cautions and considerations, relevant training, site selection, and sampling methods/procedures, including pre-fieldwork mobilization activities to prepare equipment, sample collection, and de-mobilization activities to preserve and transport samples. The SOPs relevant to the monitoring discussed in this report are listed in Table 3.1.

Table 3.1. Standard Operating Procedures (SOPs) pertaining to creek status monitoring.

| SOP # | SOP |
|---|---|
| FS-1 | Benthic Macroinvertebrate and Algae Bioassessments, and Physical Habitat Measurements |
| FS-2 | Water Quality Sampling for Chemical Analysis, Pathogen Indicators, and Toxicity Testing |
| FS-3 | Field Measurements, Manual |
| FS-4 | Field Measurements, Continuous General Water Quality |
| FS-5 | Continuous Temperature Measurements |
| FS-6 | Collection of Bedded Sediment Samples |
| FS-7 | Field Equipment Cleaning Procedures |
| FS-8 | Field Equipment Decontamination Procedures |
| FS-9 | Sample Container, Handling, and Chain of Custody Procedures |
| FS-10 | Completion and Processing of Field Datasheets |
| FS-11 | Site and Sample Naming Convention |
| FS-12 | Ambient Creek Status Monitoring Site Evaluation |

[10]The current SWAMP QAPP is available at:
http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/swamp_qapp_master090108a.pdf

## 3.1 Field Data Collection Methods

### 3.1.1 Bioassessments

In accordance with the RMC QAPP (BASMAA 2012a) bioassessments were conducted during the spring index period (approximately April 15 – July 15) and at a minimum of 30 days after any significant storm (roughly defined as at least 0.5-inch of rainfall within a 24-hour period). During WY2012, the last significant storm occurred on April 12$^{th}$-13$^{th}$ and bioassessments began during the week of May 14$^{th}$, 2012. During WY2013, the last significant storm occurred on March 7$^{th}$ with subsequently smaller storm on April 4$^{th}$, 2013. Bioassessments began during the week of May 20$^{th}$, 2013.

**Benthic Macroinvertebrates**

Each bioassessment sampling site consisted of an approximately 150-meter stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. The sampling position within each transect alternated between 25%, 50% and 75% distance of the wetted width of the stream. Benthic macroinvertebrates (BMIs) were collected from a 1 square foot area approximately 1 m downstream of each transect (see SOP FS-1, BASMAA 2012b). The benthos were disturbed by manually rubbing coarse substrate followed by disturbing the upper layers of substrate to a depth of 4-6 inches to dislodge any remaining invertebrates into the net. Slack water habitat procedures were used at transects with deep and/or slow moving water (Ode 2007). Material collected from the eleven subsamples was composited in the field by transferring the entire sample into one or two 1000 ml wide-mouth jar(s) and preserving it with 95% ethanol.

**Algae**

Filamentous algae and diatoms were collected using the Reach-Wide Benthos (RWB) method described in SOP FS-1 (BASMAA 2012b). Algae samples were collected synoptically with BMI samples. The sampling position within each transect was the same as used for BMI sampling; however, samples were collected six inches upstream of the BMI sampling position and prior to BMI collection from that location. The algae were collected using a range of methods and equipment, depending on the particular substrate occurring at the site (e.g., erosional, depositional, large and/or immobile) per SOP FS-1. Erosional substrates included any material (substrate or organics) that was small enough to be removed from the stream bed, but large enough in size to isolate an area equal in size to a rubber delimiter (12.6 cm2 in area). When a sample location along a transect was too deep to sample, a more suitable location was selected, either on the same transect or from one further upstream.

Algae samples were collected at each transect prior to moving on to the next transect. Sample material (substrate and water) from all eleven transects was combined in a sample bucket, agitated, and a suspended algae sample was then poured into a 500 mL cylinder, creating a composite sample for the site. A 45 mL subsample was taken from the algae composite sample and combined with 5 mL glutaraldehyde into a 50 mL sample tube for taxonomic identification of soft algae. Similarly, a 40 mL subsample was extracted from the algae composite sample and combined with 10 mL of 10% formalin into a 50 mL sample tube for taxonomic identification of diatoms. Laboratory processing included identification and enumeration of 300 natural units of soft algae and 600 diatom valves to the lowest practical taxonomic level.

The algae composite sample was also used for collection of chlorophyll a and ash free dry mass (AFDM) samples following methods described in Fetscher et al (2009). For the chlorophyll a sample, 25 mL of the algae composite volume was removed and run through a glass fiber filter (47 mm, 0.7 um pore size) using a filtering tower apparatus. The AFDM sample was collected using a similar process using pre-combusted filters. Both samples were placed in whirlpaks, covered in aluminum foil and immediately placed on ice for transportation to laboratory.

### 3.1.2 Physical Habitat

Physical habitat assessments (PHAB) were conducted at each BMI bioassessment sampling event using the PHAB protocols described in Ode (2007) (see SOP FS-1, BASMAA 2012b). Physical habitat data were collected at each of the 11 transects and at 10 additional inter-transects (located between each main transect) by implementing the “Basic” level of effort, with the following additional measurements/assessments as defined in the “Full” level of effort (as prescribed in the MRP): water depth and pebble counts, cobble embeddedness, flow habitat delineation, and instream habitat complexity. At algae sampling locations, additional assessment of presence of micro- and macroalgae was conducted during the pebble counts. In addition, water velocities were measured at a single location in the sample reach (when possible) using protocols described in Ode (2007).

### 3.1.3 Physico-chemical Measurements

General water quality parameters (dissolved oxygen, temperature, specific conductivity, and pH) were measured concurrent with BMI bioassessment sampling using multi-parameters probes according to SOP FS-3 (BASMAA 2012b). Direct field measurements or grab samples for field measurement purposes are collected from a location where the stream visually appears to be completely mixed. Ideally this is at the centroid of the flow, but site conditions do not always allow centroid collection. Measurements should occur upstream of sampling personnel and equipment and upstream of areas where bed sediments have been disturbed, or prior to such bed disturbance. Field meters are calibrated prior to use and results are recorded on the Field Meter Calibration Record form.

### 3.1.4 California Rapid Assessment Method for Riverine Wetlands (CRAM)

Assessments using the California Rapid Assessment Method (CRAM) were conducted at the same locations (and reach lengths) that were monitored for the RMC probabilistic design (i.e., biological and physical habitat assessments, nutrients and physical chemical water quality). CRAM assessments were conducted between July 29th through August 1st, 2013. CRAM was conducted at bioassessment locations to assess the utility of using CRAM data to explain the aquatic biological condition. CRAM is performed within a defined riparian Assessment Area (AA) and is composed of the following subcategories: 1) buffer and landscape context; 2) hydrology; 3) physical structure; and 4) biotic structure. Procedures describing methods for scoring riparian attributes are described in Collins et al. (2008).

### 3.1.5 Nutrients and Conventional Analytes

Water samples were collected at probabilistic sites for nutrients and conventional analytes using the Standard Grab Sample Collection Method as described in SOP FS-2 (BASMAA 2012b). Sample containers were rinsed using ambient water and completely filled and recapped below water surface whenever possible. An intermediate container was used to collect water for all sample containers with preservative already added in advance by laboratory. Sample container size and type, preservative type and associated holding times for each analyte are described in Table 1 of SOP FS-9, including field filtration where applicable. Syringe filtration method was used to collect samples for analyses of Dissolved Ortho-Phosphate and Dissolved Organic Carbon. All sample containers were labeled and stored on ice for transportation to laboratory.

### 3.1.6 Chlorine

Water samples were collected and analyzed for free and total chlorine using CHEMetrics test kits (K-2511 for low range [0 to 0.20 mg/L], and K-2504 for high range [0 to 1 mg/L and 0 to 5 mg/L]) according to SOP FS-3 (BASMAAS 2012b). The method requires a unique sample for each parameter. If concentrations exceed 0.08 mg/L the site is immediately resampled; if concentrations exceed the upper limit of the low range test kit (0.20 mg/L) the site is immediately resampled using the high range test kit. Chlorine measurements in water are conducted up to twice annually: during spring bioassessments and concurrently with dry season toxicity and sediment chemistry monitoring.

### 3.1.7 Water Toxicity

Samples were collected at probabilistic sites for water toxicity. The required number of 4-L labeled amber glass bottles were filled and placed on ice to cool to <6°C. Bottle labels include station ID, sample code, matrix type, analysis type, project ID, and date and time of collection. The laboratory was notified of the impending sample delivery to meet the 24-hour sample delivery time requirement. Procedures used for sampling and transporting samples are described in SOP FS-2 (BASMAA 2012b).

### 3.1.8 Sediment Toxicity & Chemistry

Sediment samples were collected at probabilistic sites during the dry season for toxicity and chemical analysis. Before conducting sampling, field personnel surveyed the proposed sampling area for appropriate fine-sediment depositional areas before stepping into the stream, to avoid disturbing possible sediment collection sub-sites. Personnel carefully entered the stream and started sampling at the closest appropriate reach, continuing upstream. Sediment samples were collected from the top 2 cm of sediment in a compositing container, thoroughly homogenized, and then aliquotted into separate jars for chemical or toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA 2012b). Sample jars were submitted to respective laboratories per SOP FS-13 (BASMAA 2012b).

### 3.1.9 Continuous Temperature Monitoring

Digital temperature loggers (Onset HOBO Water Temp Pro V2) were programmed to record data at 60-minute intervals and were deployed at targeted sites from April through September. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-5 (BASMAA 2012b).

### 3.1.10 Continuous General Water Quality Measurements

Water quality monitoring equipment recording dissolved oxygen, temperature, conductivity, and pH at 15-minute intervals (YSI 6600 data sondes) was deployed at targeted sites for two 2-week periods: once during spring season and once during summer. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-4 (BASMAA 2012b).

### 3.1.11 Pathogen Indicators Sampling

Sampling techniques for pathogen indicators (fecal coliform and *E. Coli*) included direct filling of containers at targeted sites and immediate transfer of samples to analytical laboratories within specified holding time requirements. Procedures used for sampling and transporting samples are described in RMC SOP FS-2 (BASMAA 2012b).

## 3.2 Laboratory Analysis Methods

RMC participants, including SMCWPPP, agreed to use the same laboratory for individual parameters, developed standards for contracting with the labs, and coordinated quality assurance issues. All samples collected by RMC participants that were sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods as described in the RMC QAPP (BASMAA 2012a). Analytical laboratory methods, reporting limits and holding times for chemical water quality parameters are also reported in BASMAA (2012a). Analytical laboratory contractors included:

- BioAssessment Services, Inc. – BMI identification
- EcoAnalysts, Inc. – Algae identification
- CalTest, Inc. – Sediment Chemistry, Nutrients, Chlorophyll a, Ash Free Dry Mass
- Pacific EcoRisk, Inc. - Water and Sediment Toxicity
- BioVir Laboratories, Inc. – Pathogen indicators

# 4.0 Data Analysis and interpretation Methods

This section describes methods used to analyze the monitoring data. The analyses include a preliminary condition assessment involving analysis of the biological data to characterize biological conditions within San Mateo County. The condition assessment is based upon bioassessment scores and seeks to answer management question #2 ***(Are conditions in local receiving water supportive of or likely supportive of beneficial uses?***). The physical, chemical, and toxicity data are analyzed to identify potential stressors that may be impacting water quality and biological conditions and to answer management question #1 ***(Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?***). An important part of data analysis is review of all field data sheets and laboratory reports for compliance with the SOPs and QAPP.

As the cumulative sample sizes increase through monitoring conducted in future years (Table 2.1), it will be possible to develop a statistically representative data set to address the management questions comparing urban and non-urban conditions and long-term trends.

## 4.1 Biological Condition Indicators

Assemblages of freshwater organisms are commonly used to assess the biological integrity of waterbodies because they provide direct measures of ecological condition (Karr and Chu 1999). Benthic macroinvertebrates (BMIs) are an essential link in the aquatic food web, providing food for fish and consuming algae and aquatic vegetation (Karr and Chu, 1999). The presence and distribution of BMIs can vary across geographic locations based on elevation, creek gradient, and substrate (Barbour et al., 1999). These organisms are sensitive to disturbances in water and sediment chemistry, and physical habitat, both in the stream channel and along the riparian zone. Because of their relatively long life cycles (approximately one year) and limited migration, BMIs are particularly susceptible to site-specific stressors (Barbour et al., 1999). Algae are increasingly being used as indicators of water quality as they form the autotrophic base of aquatic food webs and exhibit relatively short life cycles that respond quickly to chemical and physical changes (Fetscher et al. 2013b). Diatoms have been found to be particularly useful for interpreting some causes of environmental degradation (Hill et al. 2000).

Indices of biological integrity (IBIs) are analytical tools that calculate a site condition score based on a series of biological metrics representing taxonomic richness, composition, tolerance and functional feeding groups. IBI development in California is more established for BMIs (i.e., B-IBIs) than for algae. Benthic macroinvertebrate IBIs have been developed and tested extensively for four regions of California, including Southern California (Ode et al. 2005), Northern California (Rehn et al. 2005), Eastern Sierra Nevada (Herbst et al. 2009) and Central Valley (Rehn et al. 2008).

In the absence of a San Francisco Regional IBI, the RMC applied the NoCal and SoCal B-IBIs to assess BMI data collected at probabilistic sites during WY2012. Since both of these tools were developed for geographic areas different than the San Francisco Bay area, there is some uncertainty in how they perform at a more local scale, such as San Mateo County, or for site-specific evaluations within a watershed.

A new assessment tool for BMI data is being developed by the State Water Board to support the development of the State's Biological Objectives Policy. The California Stream Condition Index (CSCI) is an assessment tool based on benthic macroinvertebrates that is designed to provide both site-specificity and statewide consistency (i.e., can be applied to all perennial wadeable streams within all ecoregions of California). The performance of the CSCI is supported by the use of a large reference data set that represents the full range of natural conditions in California; and by the development of site-specific models for predicting biological communities. The site-specific model is based on two components: 1) taxonomic completeness, as measured by the ratio of observed-to-expected taxa (O/E); and 2) ecological structure, measures as a predictive multi-metric index (pMMI) that is based on reference conditions (Mazor et al. 2013). The CSCI is computed as the average of the sum of O/E and pMMI.

The State Board is continuing to evaluate the performance of CSCI in a regulatory context. To further test the performance of the CSCI as a biological condition assessment tool, SMCWPPP obtained a preliminary draft version of the CSCI to evaluate BMI data collected for this project. Specifically, the CSCI is compared to B-IBI and evaluated for performance across a gradient of environmental conditions in San Mateo County.

The State Water Board is developing and testing assessment tools for benthic algae data as a measure of biological condition and identification of potential stressors. A comprehensive set of stream algal IBIs that include metrics for both diatoms and soft-algae, have recently been developed and tested in Southern California (Fetscher et al. 2013a). The study evaluated a total of 25 IBIs comprising of either single-assemblage metrics (i.e., either diatoms or soft algae) or combinations of metrics presenting both assemblages (i.e, “hybrid” IBI). The study identified four high performing IBIs including three hybrid IBIs and one single-assemblage IBI for diatoms. The performance was assessed by the IBIs responsiveness to stress.

The high performing single assemblage diatom IBI (herein referred to as “D18”) was used to evaluate the algae samples collected at SMCWPPP probabilistic sites. The hybrid IBIs were not used due to numerous algal species, primarily soft algae that were identified by the contracting laboratory EcoAnalysts, Inc., that did not match the SWAMP master taxonomic list. The discrepancies between the two taxonomic lists will be resolved in early 2014. The diatom IBI results should be considered preliminary until additional research shows that these tools perform well for data collected in San Mateo County.

### 4.1.1 Benthic Macroinvertebrate Data Analysis

<u>BMI Data Sources</u>
The SMCWPPP compiled BMI data from three sources: 1) SMCWPPP Creek Status monitoring conducted in 2012 and 2013 under MRP Provision C.8 (n=20 sites); 2) SFRWQCB Creek Status monitoring conducted in 2012 (n=3 sites); and 3) historical SMCWPPP and SFRWQCB monitoring projects conducted between 2002 and 2009 (n= 52 sites). The combined data resulted in a total of 90 sampling events at 75 unique sites[11].

Historical data were collected using three different standardized field methods: California Stream Bioassessment Protocol (CSBP), Targeted Riffle, and Reachwide Benthos (RWB). Laboratory analytical methods remained consistent for all sampling events conduct under each project. All BMIs were identified at a Level 1 Standard Taxonomic Level of Effort, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family

[11] Twelve sites from the historical data set were sampled more than once and three sites were sampled more than twice.

(Chironomidae). The taxonomic resolution and life stage information for all BMI data was compared and revised when necessary to match the Surface Water Ambient Monitoring Program (SWAMP) master taxonomic list.

Northern and Southern California Index of Biological Integrity

All BMI data were compiled, formatted and forwarded to the Moss Landing Marine Laboratory[12] where Southern California (SoCal) B-IBI and the Northern California (NoCal) Benthic Macroinvertebrate Index of Biotic Integrity (B-IBI) scores were calculated using the new SWAMP reporting module.[13] The reporting module includes a routine that subsamples to a standardized number of 500 BMIs prior to the calculation of metrics used in B-IBIs. The metrics used to calculate each B-IBI are shown in Table 1. Upstream watershed area and ecoregion data were also used to meet the input requirements for the NoCal B-IBI.

Table 4.1. Metrics used to calculate SoCal B-IBI and NoCal B-IBI.

| SoCal B-IBI | NoCal B-IBI |
|---|---|
| • EPT Taxa<br>• Number Coleoptera Taxa<br>• Number Predator Taxa<br>• Percent Intolerant<br>• Percent Non-Insecta Taxa<br>• Percent Collector-Filter + Collector-Gather Individuals<br>• Percent Tolerant Taxa (8-10) | • EPT Taxa<br>• Number Coleoptera Taxa<br>• Percent Predators<br>• Percent Intolerant<br>• Percent Non-Insecta Taxa<br>• Percent Non-Gastropoda Scrapers<br>• Number Diptera Taxa<br>• Percent Shredder Taxa |

California Stream Condition Index Score

California Stream Condition Index (CSCI) scores were calculated using the same BMI data used to calculate the B-IBIs described above. Delineations for the drainage area upstream of each BMI sampling location were compiled or created in ArcGIS. Watershed delineations for the historical bioassessment sampling locations and the Water Board Creek Status Monitoring sampling locations (n=55) was obtained from Water Board staff. Watershed area delineations for each SMCWPPP site sampled via Creek Status Monitoring (n=20) were created using 30 meter Digital Elevation Model (DEM) data and the ArcHydro tool in ArcGIS. In most cases, the watershed/catchments polygons created in ArcGIS required editing to adjust the downstream edge of the drainage area to the sampling locations. When necessary, existing data sources,

[12] Moss Landing Marine Laboratory supports SWAMP in the management of bioassessment data.

[13] The NoCal and SoCal B-IBI scores calculated for the 10 sites sampled by SMCWPPP in WY2012 and reported in the WY2012 Urban Creeks Status Monitoring Report (BASMAA 2013) are not identical to the B-IBI scores presented is this memorandum. One explanation is that slightly different methods were applied, with the tabulation and scoring of metrics completed manually in Urban Creeks Monitoring Report and the tabulations conducted via the recently developed SWAMP Reporting Module. Another explanation may relate to potential differences in the BMI taxa list (e.g., taxa level and the distinction of unique taxa) which could affect the scoring of each B-IBI metric. In an effort to remain consistent with statewide analyses of bioassessment data by SWAMP, the metrics and B-IBI scores generated by the SWAMP Reporting Module were used for the analyses presented in this report.

including watershed/catchment data developed by SFEI and the Oakland Museum, were used to modify the DEM derived watershed boundaries. These were typically in the low gradient urban areas along the San Francisco Bay.

To develop the CSCI score, fourteen different GIS datasets were received from the California Department of Fish and Wildlife, and compiled and analyzed by EOA in ArcGIS to calculate a range of environmental attributes for each sampling location. Attributes calculated for each site included site elevation, average air temperature, and precipitation values. Elevation range was calculated from the difference in highest and lowest elevations in the watershed. The other eleven attributes were associated with soil properties that were averaged across the watershed using a zonal statistics tool in ArcGIS (http://www.arcgis.com/). The environmental variables data and BMI data were formatted and used as input files for "R" Studio statistical package and the necessary program scripts provided by staff from the Southern California Costal Water Research Project (SCCWRP), the organization that provided technical support to the State of California on the development of the CSCI. The program includes a subsampling routine that produces a standardized number of 500 BMIs for each site. The program output includes a summary table that averages CSCI scores over 20 iterations and calculates two indices that together form the CSCI Score – Observed over Expected (O/E) and a Multi-metric Index (pMMI). The output table also flags sites with inadequate numbers of unambiguous taxa (i.e., CSCI requires at least 360 unambiguous taxa).

<u>Evaluation of Assessment Tools</u>

The NoCal B-IBI, SoCal B-IBI and CSCI assessment tools were compared to evaluate the overall response of BMI data found at sampling locations in San Mateo County. Assessment tools were evaluated at different flow conditions (perennial versus non-perennial) and land use classes (urban versus non-urban) to evaluate their performance over the range of environmental conditions.

<u>Assessing Biological Condition</u>

The condition categories for SoCal B-IBI (Rehn et al. 2008) (Table 4.2) were used to assess biological condition for the trigger evaluations presented in this report and the WY2012 Urban Creeks Status Monitoring Report (BASMAA 2013).

Table 4.2. Condition categories for evaluating SoCal B-IBI scores.

| Condition Category | Southern California B-IBI |
|---|---|
| Very Good | 80-100 |
| Good | 60-79 |
| Fair | 40-59 |
| Poor | 20-39 |
| Very Poor | 0-19 |

The State Water Board has not developed condition categories or thresholds to categorize biological conditions using CSCI scores. For this report, CSCI was classified into three scoring ranges to evaluate the relative biological condition of sites (Table 4.3).

Table 4.3. Condition categories used to evaluate CSCI scores.

| CSCI Score | Category | Characterization of Sites |
| --- | --- | --- |
| > 0.83 | Good | Non-urban/low urban |
| 0.55 – 0.83 | Fair | Moderate urban disturbance |
| < 0.55 | Poor | Highly urban/modified channels |

The SoCal B-IBI scores and CSCI scores were compared for perennial vs non-perennial sites for all sites (n=75) sampled in San Mateo County between 2002 and 2013. Average scores were used for sites with multiple sampling events. For the same data, SoCal B-IBI and CSCI scores were evaluated for sites classified as urban and non-urban using the RMC sample frame, and for different ranges of percent watershed imperviousness. A comparison of CSCI scores between probabilistic sites and historical sites was conducted to assess whether the biological condition measured at the larger set of historical sites could be used to validate MRP probabilistic site conditions in San Mateo County.

### 4.1.2 Algae Bioassessment

The diatom IBI ("D18"), developed by SCCWRP for the Draft Southern California Algae IBI, was used to assess biological condition for each SMCWPPP probabilistic site. The diatom IBI includes the following metrics:

- Proportion halobiontic (preference for saline environment)
- Proportion low total phosphorus indicators
- Proportion nitrogen heterotrophs
- Proportion requiring >50% dissolved oxygen saturation
- Proportion sediment tolerant (highly motile)

The algae data were compiled, formatted and sent to the Moss Landing Marine Laboratory where "D18" diatom IBI scores were calculated using the SWAMP Reporting Module. No condition categories have been established for algae IBIs to date, nor has the State Water Board proposed their use in a regulatory context.

## 4.2 Physical Habitat Indicators

Physical habitat indicators include measurements/assessments made during the bioassessment and during the California Riparian Assessment Method (CRAM). Physical habitat measurements were used to assess both the physical habitat condition and evaluated as potential stressors to biological condition indicators (B-IBI and CSCI).

Riparian condition data (CRAM) was used to assess the overall condition of health of stream ecosystem resources and to develop hypotheses regarding the causes of their observed conditions. Riparian assessment data can also supplement biological and physical habitat data collected at bioassessment sites to investigate potential stressors to aquatic health. Previous studies in Southern California (Solek et al. 2011) have demonstrated high correlation between benthic macro-invertebrate communities (as measured by IBI) and riparian condition.

Physical Habitat Condition

Three qualitative PHAB parameters, epifaunal substrate/cover, sediment deposition, and channel alteration, are assessed during each bioassessment. Each parameter can be scored for a total of 0-20 and a combination of the PHAB parameters result in scores that range from 0 – 60. Higher PHAB scores reflect higher quality habitat.

CRAM is also applied to bioassessment reach. CRAM score is based on the assessment and scoring of four different attributes: 1) Buffer and Landscape Connectivity; 2) Hydrology; 3) Physical Structure; and 4) Biotic Structure. The four attribute scores are summed and averaged to obtain the total CRAM score.

Stressor Assessment

Physical habitat endpoints were calculated to obtain a reachwide measure of physical habitat condition. Additional variables that characterize the relative amount of development within the watershed drainage areas upstream of each sampling location were derived using a GIS. Pearson Coefficient Correlations, Spearman rank correlations, and multiple regressions were used to estimate the degree of correlation between physical habitat endpoints and water quality parameters with the biological condition indicators.

## 4.3 Stressor/WQO Assessment

Water and sediment chemistry and toxicity data generated during Water Years 2012 and 2013 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or diminished biological conditions, including exceedances of water quality objectives (WQOs). Per Table 8.1 of the MRP (SFRWQCB 2009), creek status monitoring data must be evaluated with respect to specified "Results that Trigger a Monitoring Project in Provision C.8.d.i." The trigger criteria listed in Table 8.1 were used as the principal means of evaluating the creek status monitoring data to identify sites where water quality impacts may have occurred. The relevant trigger criteria are listed in Table 4.4. For the purposes of the stressor assessment SoCal IBI scores below 40 (0-19 = very poor, 20-39 = poor) were considered as indicators of substantially degraded aquatic communities. Additional details on selected parameters (nutrients, toxicity, sediment chemistry, temperature, dissolved oxygen and pathogen indicators) are provided below Table 4.4.

Table 4.4. Standards and Thresholds Used for Trigger Evaluation

| Monitoring Parameter | Standard/Threshold | Units | Source |
|---|---|---|---|
| Bioassessment | | | |
| SoCal IBI | Very poor (0-19) and poor (20-39) | NA | Rehn et al. 2005 |
| CSCI | TBD | NA | Mazor et al. 2013 |
| Nutrients and Conventional Analytes | 20% of results at each monitoring site exceed one or more established standard or threshold - applies to these parameters jointly | | |
| Ammonia, unionized | 0.025 | mg/L | SF Bay Basin Plan Ch. 3, p. 3-7 |

| Monitoring Parameter | Standard/Threshold | Units | Source |
|---|---|---|---|
| Chloride | 230 (4 day avg.; applies to freshwater aquatic life) | mg/L | USEPA Nat'l. Rec. WQ Criteria |
| Chloride | 250 (secondary maximum contaminant level; MUN waters, Title 22 Drinking Waters) | mg/L | SF Bay Basin Plan Ch. 3, Table 3-5; CA Code Title 22; USEPA Drinking Water Stds. Secondary MCL |
| Nitrate as N | 10 (applies to MUN and Title 22 Drinking Waters only) | mg/L | SF Bay Basin Plan Ch. 3, Table 3-5; CA Code Title 22; USEPA Drinking Water Stds. Primary MCL; USEPA Nat'l. Rec. WQ Criteria (Human Health) |
| Chlorine | | | |
| Free & Total Chlorine | > 0.08 for initial result, > 0.08 for retest result (if needed) | mg/L | USEPA |
| Water Column Toxicity | | | |
| *Selenastrum capricomutum* (Growth), *Ceriodaphnia dubia* (Survival/Reproduction), Fathead Minnow (Survival/Growth) & *Hyalella azteca* (Survival) | < 50% of Control Result for initial test, < 50% of Control Result for retest (if needed) | NA | MRP Table 8.1 |
| Sediment Toxicity | | | |
| *Hyalella azteca* (Survival/Growth) | Toxicity results are statistically different than, and < 20% of Control | | MRP Table H-1 |
| Sediment Chemistry | | | |
| Grain Size and TOC | None | NA | |
| MacDonald et al. 2000 Analytes; Pyrethroids from MRP Table 8.4 | Three or more chemicals exceed Threshold Effects Concentrations (TECs), mean Probable Effects Concentrations (PEC Quotient greater than 0.5, or pyrethroids Toxicity Unit (TU) sum is greater than 1.0 | NA | MRP Table H-1 |
| General Water Quality Parameters | 20% of results at each monitoring site exceed one or more established standard or threshold - applies individually to each parameter | | |
| Conductivity | None | NA | |
| Dissolved Oxygen | WARM < 5.0, COLD < 7.0 | mg/L | SF Bay Basin Plan Ch. 3, p. 3-4 |
| pH | > 6.5, < 8.5 [1] | pH | SF Bay Basin Plan Ch. 3, p. 3-4 |

| Monitoring Parameter | Standard/Threshold | Units | Source |
|---|---|---|---|
| Temperature | COLD water 7-day mean < $19^o$; COLD and WARM shall not increase > $2.8^o$ above natural receiving water temp | $^oC$ | USEPA 1977 & SF Bay Basin Plan, Ch. 3, p. 3-6 |
| Temperature | Same as General Water Quality for Temperature (See Above) | | |
| Pathogen Indicators | | | |
| Fecal coliform | ≥ 400 | MPN/ 100ml | SF Bay Basin Plan Ch. 3 |
| *E. coli* | ≥ 410 | MPN/ 100ml | USEPA 2012 |

[1] Special consideration will be used at sites where imported water is naturally causing higher pH in receiving waters.

### 4.3.1 Nutrients and Conventional Analytes

A search for relevant water quality standards or accepted thresholds was conducted using available sources, including the San Francisco Basin Water Quality Control Plan (Basin Plan) (SFRWQCB 2013), the California Toxics Rule (CTR) (USEPA 2000), and various USEPA sources. Of the eleven water quality constituents monitored in association with the bioassessment monitoring (referred to collectively as "Nutrients" in MRP Table 8.1), water quality standards or established thresholds are available only for ammonia (unionized form), chloride, and nitrate (for waters with MUN beneficial use only).

For ammonia, the 0.025 mg/L standard provided in the Basin Plan applies to the unionized fraction, as the underlying criterion is based on unionized ammonia, which is the more toxic form. Conversion of monitoring data from the measured total ammonia to unionized ammonia was therefore necessary. The conversion was based on a formula provided by the American Fisheries Society (AFS, internet source), and includes calculation from total ammonia, as well as field-measured pH, temperature, and specific conductance.

For chloride, a Secondary Maximum Contaminant Level (MCL) of 250 mg/L applies to those waters with MUN beneficial use and Title 22 drinking water, per the Basin Plan (Table 3-5), Title 22 of the California Code of Regulations (CDPH, internet source), and the USEPA Drinking Water Quality Standards (USEPA, internet source). For all other waters, the water quality criterion of 230 mg/L established by USEPA (2009) (USEPA Water Quality Criteria) for the protection of aquatic life is assumed to apply. The aquatic life criterion is a four-day average value, while the Secondary MCL is a maximum value.

The nitrate Primary MCL applies to those waters with MUN beneficial use, per the Basin Plan (Table 3-5), Title 22 of the California Code of Regulations, and the USEPA Drinking Water Quality Standards.

### 4.3.2 Water and Sediment Toxicity

The laboratory determines whether a sample is "toxic" by statistical comparison of the results from multiple test replicates of selected aquatic species in the environmental sample to multiple test replicates of those species in laboratory control water. The threshold for determining statistical significance between environmental samples and control samples is fairly small, with statistically significant toxicity often occurring for environmental test results that are as high as

90% of the Control. Therefore, there is a wide range of possible toxic effects that can be observed – from 0% to approximately 90% of the Control values.

For water sample toxicity tests, MRP Table 8.1 identifies toxicity results of less than 50% of the Control as requiring follow-up action. For sediment sample tests, MRP Table H-1 identifies toxicity results more than 20% less than the control as requiring follow-up action.[14] Therefore, samples that are identified by the lab as toxic (based on statistical comparison of samples vs. Control at $p = 0.05$) are evaluated to determine whether the result was less than 50% of the associated Control (for water samples) or statistically different and more than 20% less the Control (for sediment samples).

### 4.3.3 Sediment Chemistry

Sediment chemistry results are evaluated as potential stressors in three ways, based on the following criteria from MRP Table H-1. Any sample that meets one or more of the criteria are then compared to the sediment toxicity and bioassessment results for that site. These comparisons are performed in the Sediment Triad Assessment presented in Section 5.4.5.

- Calculation of threshold effect concentration (TEC) quotients; determine whether site has three or more TEC quotients greater than or equal to 1.0;[15]
- Calculation of probable effect concentration (PEC) quotients; determine whether site has mean PEC quotient greater than or equal to 0.5; and,
- Calculation of pyrethroid toxic unit (TU) equivalents as sum of TU equivalents for all measured pyrethroids; determine whether site has sum of TU equivalents greater than or equal to 1.0.

For sediment chemistry trigger criteria, TECs and PECs are as defined in MacDonald et al., 2000. For all non-pyrethroid contaminants specified in MacDonald et al. (2000), the ratio of the measured concentration to the respective TEC value was computed as the TEC quotient. All results where a TEC quotient was equal to or greater than 1.0 were identified. PEC quotients were also computed for all non-pyrethroid sediment chemistry constituents, using PEC values from MacDonald et al. (2000). For each site the mean PEC quotient was then computed, and sites where the mean PEC quotient was equal to or greater than 0.5 were identified. Pyrethroid TU equivalents were computed for individual pyrethroid results, based on available literature values for pyrethroids in sediment LC50 values.[16] Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC50 values were derived on the basis of TOC-normalized pyrethroid concentrations. Therefore, the pyrethroid concentrations as reported by the lab were divided by the measured total organic carbon (TOC) concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each

[14] Footnote #162 to Table H-1 of the MRP reads, “Toxicity is exhibited when Hyallela (sic) survival statistically different than and < 20 percent of control”; this is assumed to be intended to read “…statistically different than and more than 20 percent less than control”.

[15] This assumes that there is a typographical error in Table H-1 and that the criterion is meant to read, “3 or more chemicals exceed TECs”.

[16] The LC50 is the concentration of a given chemical that is lethal on average to 50% of test organisms.

pyrethroid. Then for each site, the TU equivalents for the various individual pyrethroids were summed, and sites where the summed TU was equal to or greater than 1.0 were identified.

### 4.3.4 Temperature

Sullivan et al. (2000) is referenced in Table 8.1 of the MRP as a potential source for applicable threshold(s) to use for evaluating water temperature data, specifically for creeks that have salmonid fish communities. The report summarizes results from previous field and laboratory studies investigating the effects of water temperature on salmonids of the Pacific Northwest and lists acute and chronic thresholds that can potentially be used to define temperature criteria. The authors identified annual maximum temperature (acute) and maximum 7-day weekly average temperature (MWAT) chronic indices as biologically meaningful thresholds. They found the MWAT index to be most correlated with growth loss estimates for juvenile salmonids, which can be used as a threshold for evaluating the chronic effects of temperature on summer rearing life stage.

Previous studies conducted by EPA (1977) identified a MWAT of 19°C for steelhead and 18°C for coho salmon. Using risk assessment methods, Sullivan et al (2000) identified lower thresholds of 17°C and 14.8°C for steelhead and coho respectively. The risk assessment method applied growth curves for salmonids over a temperature gradient and calculated the percentage in growth reduction compared to the growth achieved at the optimum temperature. The risk assessment analysis estimated that temperatures exceeding a threshold of 17°C would potentially cause 10% reduction in average salmonid growth compared to optimal conditions. In contrast, exceedances of the 19°C threshold derived by EPA (1977) would result in a 20% reduction in average fish growth compared to optimal conditions.

The San Francisco Bay Region Water Quality Control Board (Water Board) is currently applying the temperature thresholds suggested by Sullivan et al. (2000) (i.e., MWAT of 17°C and 14.8°C for steelhead and coho salmon, respectively) to evaluate temperature data for the 303(d) listing process of impaired waterbodies (SFRWQCB 2013). The Water Board has also applied these thresholds in evaluating temperature data collected at reference sites in the San Francisco Bay Area (SFRWQCB 2012).

Several important factors should be considered when selecting the appropriate temperature thresholds for evaluating data collected from creeks that support salmonid fish communities in the San Francisco Bay Area region. The thresholds presented in Sullivan et al. (2000) are based on data collected from creeks in the Pacific Northwest region, which exhibits different patterns of temperature associated with climate, geography and watershed characteristics compared to creeks supporting steelhead and salmon in Central California. Furthermore, a single temperature threshold may not apply to all creeks in the San Francisco Bay Area due to high variability in climate and watershed characteristics within the region. .

Sullivan et al.'s (2000) risk assessment approach to establishing water temperature thresholds for salmonids focuses on juvenile growth rates. Several studies, however, demonstrate that Central California Coast (CCC) Steelhead Distinct Population Segment (DPS)[17] have adapted feeding behaviors and life history strategies to deal with higher water temperatures

[17] CCC steelhead DPS includes all populations between Russian River and south to Aptos Creek. Also included are all drainages of San Francisco, San Pablo and Suisun Bays eastward at the confluence of the Sacramento and San Joaquin Rivers.

characteristic of the southern end of their range. Smith and Li (1983) have observed that juvenile steelhead will tolerate warmer temperatures when food is abundant by moving into riffle habitats to increase feeding success. Steelhead will also move into coastal estuaries to feed during the summer season when stream conditions become stressful to the fish (Moyle 2008). Sogard et al. (2012) determined that steelhead growth rates were higher during winter-spring season compared to summer fall season in Central California coastal creeks, whereas the opposite was true for steelhead in creeks of the Central Valley. Railsback and Rose (1999) concluded that juvenile growth rate during the summer season was more dependent on food availability and consumption than temperature.

These studies demonstrate that the application of temperature thresholds to evaluate steelhead growth and survival is challenging, and may promote management actions that do not improve ecological conditions. In cases where low flow conditions in concert with high temperatures during summer season are impacting steelhead populations, management actions that improve food availability (e.g., increase summer flow) may better address factors that are more critically limiting steelhead production. For monitoring, fish size thresholds at critical life stages such as smolting may be a much better indicator for understanding viability of steelhead populations (Atkinson et al. 2011).

We recommend using thresholds identified in EPA (1977) (i.e., MWAT of 19°C for steelhead and 18°C for coho salmon) for interpretation of temperature data collected during the Creek Status Monitoring Project in 2012. These thresholds are consistent with results from thermal tolerance studies by Myrick and Cech (2000) that demonstrated maximum growth rates for California rainbow trout population to be near 19°C. Myrick (1998) also demonstrated that growth rates for steelhead at 19°C were greatly increased when food ration level was highest.

More data and analyses of temperature and salmonid growth rates is needed from creeks in the Central California Coast and San Francisco Bay Region to better understand the effects of temperature on salmonid fish population dynamics. In addition, other indicators (e.g., fish size) should be evaluated in combination with temperature to effectively evaluate salmonid ecological conditions. For these reasons, we recommend not using thresholds identified by Sullivan et al (2000) as they are based on a risk analysis that assumes optimal growth rates for salmonids using data that are likely not applicable to local watershed conditions.

The Basin Plan's water temperature Water Quality Objective states that "temperature shall not be increased by more than 2.8°C above natural receiving water temperature". This criterion is difficult to apply to sites where natural receiving water temperature is not known. This criterion may be applicable in situations where temperature is dramatically altered (e.g., imported water) and water temperature data is collected above and below a POTW outfall. In addition, there is no recommended criterion to use for warm water fish communities, which are more adapted to higher temperatures. At this time, SMCWPPP intends to continue prioritizing temperature monitoring at sites that are designated with a cold water habitat (COLD) beneficial use (SFRWQCB 2013) or that support salmonid fish communities.

### 4.3.5 Dissolved Oxygen

The Basin Plan (SFRWQCB 2013) lists Water Quality Objectives for dissolved oxygen in non-tidal waters as follows: 5.0 mg/L minimum for waters designated as warm water habitat (WARM) and 7.0 mg/L minimum for waters designated as COLD. Although these WQOs provide suitable thresholds to evaluate triggers, further evaluation may be needed to determine the overall extent and degree that COLD and/or WARM beneficial uses are supported at a site. For example, further analyses may be necessary at sites in lower reaches of a waterbody that may not support salmonid spawning or rearing habitat, but may be important for upstream or downstream fish migration. In these cases, dissolved oxygen data will be evaluated for the salmonid life stage and/or fish community that is expected to be present during the monitoring period. Such evaluations of both historical and current ecological conditions will be made, where possible, when evaluating water quality information.

### 4.3.6 Pathogen Indicators

The Basin Plan WQOs are based on a sampling protocol where a minimum of five consecutive samples are collected equally spaced over a 30-day period. However, the RMC monitoring design for pathogen indicators was to collect single water samples at individual water bodies, which is not consistent with this sampling protocol. For the purposes of this evaluation, fecal coliform maximum densities of 400 MPN/100ml and 4,000 MPN/100ml in a single sample were used as a REC-1 and REC-2 evaluation criteria, respectively.

While the Basin Plan does not include adopted WQOs for *E. coli*, EPA has recommended criteria for *E. coli* in primary contact recreational waters to protect human health (USEPA 2012). The 2012 USEPA recommendations supersede the 1986 recommendations and no longer distinguish between different levels of beach usage. USEPA recommended water quality criteria for E. coli consist of a geometric mean of 126 CFU/100ml for samples collected in any 30-day interval and a statistical threshold value (STV) of 410 CFU/100ml. The STV approximates the $90^{th}$ percentile of data and is used as evaluation criteria. In this evaluation, the Most Probable Number (MPN) of bacteria colonies given by the analytical method is compared directly with the Colony Forming Units (CFUs) of the USEPA recommendations.

On August 24, 2012, the Regional Water Board adopted a Bacteria TMDL for San Pedro Creek and Pacifica State Beach (Resolution No. R2-2012-0089). The TMDL establishes allowable exceedances of single-sample numeric targets for fecal coliform bacteria at the mouth of San Pedro Creek based on Basin Plan WQOs for REC-1 (400 MPN/100ml) and for *E. coli* based on 1986 EPA criteria for water contact recreation at designated beaches (235 MPN/100ml). The number of allowable exceedances is based on 1) bacteriological water quality at a designated reference system and 2) historical water quality at a particular site. The frequency of sampling (daily or weekly) and weather (dry or wet) is considered in the allowable exceedances. Consistent with the Bacteria TMDL, the City of Pacifica and San Mateo County are in the process of developing TMDL Implementation and Bacteria Water Quality Monitoring Plans which must be submitted to the Regional Water Board no later than June 2014. Because these Plans to assess compliance with WQOs have not yet been developed, the TMDL numeric targets are shown for comparison, but not used in the trigger evaluation.

### 4.3.7 Quality Assurance/Quality Control

Data quality assessment and quality control procedures are described in detail in the BASMAA RMC QAPP (BASMAA 2012a). They generally involve the following:

Data Quality Objectives (DQOs) were established to ensure that data collected are of adequate quality and sufficient for the intended uses. DQOs address both quantitative and qualitative assessment of the acceptability of data. The qualitative goals include representativeness and comparability. The quantitative goals include specifications for completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination. To ensure consistent and comparable field techniques, pre-survey field training and in-situ field assessments were conducted. Field training and inter-calibration exercises were conducted to ensure consistency and quality of CRAM and bioassessment data.

Data were collected according to the procedures described in the relevant SOPs, including appropriate documentation of data sheets and samples, and sample handling and custody. Laboratories providing analytical support to the RMC were selected based on demonstrated capability to adhere to specified protocols. Standard methods for CRAM are included in Collins et al. (2008).

Duplicate samples were collected at 10% of the sites sampled to evaluate precision of field sampling methods. Ten percent of the total number of BMI samples collected was submitted to the California Department of Fish and Wildlife (CDFW) Aquatic Bioassessment Laboratory for independent assessment of taxonomic accuracy, enumeration of organisms and conformance to standard taxonomic level.

All data were thoroughly reviewed for conformance with QAPP requirements and field procedures were reviewed for compliance with the methods specified in the relevant SOPs. Data quality was assessed and qualifiers were assigned as necessary in accordance with SWAMP requirements.

Following completion of the field and laboratory work, the field data sheets and laboratory reports were reviewed by the SMCWPPP Quality Assurance Officer, and compared against the methods and protocols specified in the SOPs and QAPP. The findings and results were evaluated against the relevant DQOs to provide the basis for an assessment of programmatic data quality. A summary of data quality steps associated with water quality measurements is shown in Table 4.5. The data quality assessment consisted of the following elements:

- Conformance with field and laboratory methods as specified in SOPs and QAPP, including sample collection and analytical methods, sample preservation, sample holding times, etc.
- Numbers of measurements/samples/analyses completed vs. planned, and identification of reasons for any missed samples.
- Temperature data was checked for accuracy by comparing measurements taken by HOBOs with NIST thermometer readings in room temperature water and ice water prior to deployment.
- General water quality data was checked for accuracy by comparing measurements taken before and after deployment with measurements taken in standard solutions to evaluate potential drift in readings.
- Quality assessment laboratory procedures for accuracy and precision (i.e., laboratory duplicates, laboratory blanks, laboratory control samples, and matrix spikes) were implemented, and data which did not mean DQOs were assigned the appropriate flag.
- Field crews participated in two inter-calibration exercises prior to field assessments and attended a debriefing meeting at the end of field assessments to assess consistency among RMC field crews.

Table 4.5. Data Quality Steps Implemented for Temperature and General Water Quality Monitoring.

| Step | Temperature (HOBOs) | General Water Quality (sondes) |
|---|---|---|
| Pre-event calibration / accuracy check conducted | X | X |
| Readiness review conducted | X | X |
| Check field datasheets for completeness | X | X |
| Post-deployment accuracy check conducted | X | X |
| Post-sampling event report completed | X | X |
| Post-event calibration conducted | X | X |
| Data review – compare drift against SWAMP MQOs | | X |
| Data review – check for outliers / out of water measurements | X | X |

# 5.0 Results and Discussion

In this section, following a brief statement of data quality, the biological data are evaluated to produce a preliminary condition assessment for aquatic life in SMCWPPP creeks, based on the first two years of data collection. Historical bioassessment data collected by SMCWPPP since 2002 are added to the analysis to support the condition assessment. The physical, chemical, and toxicity monitoring data are then evaluated against the trigger criteria shown in Table 4.4 (Tables 8.1 and H-1 of the MRP) to provide a preliminary identification of potential stressors. Data evaluation and interpretation methods are described in Section 4.0. The results of the stressor assessment have been used to develop source identification projects.

## 5.1 Statement of Data Quality

A comprehensive QA/QC program was implemented by SMCWPPP, covering all aspects of the probabilistic and targeted monitoring. In general, QA/QC procedures were implemented as specified in the RMC QAPP (BASMAA, 2012a), and monitoring was performed according to protocols specified in the RMC SOPs (BASMAA, 2012b), and in conformity with SWAMP protocols. Details of the results of evaluations of laboratory-generated QA/QC results are included in Attachment B. Issues noted by the laboratories and/or field crews are summarized below.

### 5.1.1 Bioassessment

Prior to sampling in WY2012, field training and inter-calibration exercises were conducted to ensure consistency and quality of bioassessment data. The SMCWPPP field crew also participated in an interagency calibration exercise with four other crews prior to sampling in WY2013. While there are no quantitative methods to assess quality assurance of physical habitat conditions, it was clear from the results that measurements taken by the SMCWPPP field crew rarely deviated from those of other crews.

The field crew was audited once each field season by a representative of the California Department of Fish and Wildlife (CDFW) to ensure consistency with SWAMP protocols. This audit is also intended to ensure consistency among RMC participants. Audits conducted by the CDFW did not result in any notable issues needing to be addressed regarding field procedures. Field sampling protocols, sample handling, documentation and packaging/delivery of samples were all executed properly as required by the QAPP and in accordance with the RMC SOPs. All field instruments were properly calibrated and cleaned within the necessary time restrictions.

Some biological assessment sites had to be sampled along a shortened reach (less than 150 m), and in some cases, stream characterization points may have been moved along the reach due to physical limitations or obstructions. Efforts were made to minimize the distance between the target collection location and the more accessible replacement location. Collection of algae samples was difficult at several sites due to varying levels of algal growth, making it hard to collect a distinguishable clump for analysis.

A few issues with the BMI and algae laboratory analysis were noted, as follows:

- During BMI taxonomic analysis, only minor counting discrepancies and no taxonomic discrepancies were noted between the original BioAssessment Services results and the QA recount conducted by the CDFW Aquatic Bioassessment Laboratory.

- In accordance with the QAPP, BMIs were assessed to the Southwest Association of Freshwater Invertebrate Taxonomist (SAFIT) Standard Taxonomic Effort (STE) Level 1. In anticipation of the need for higher level effort (SAFIT STE Level 2), BMI from WY2012 were re-assessed to STE Level 2. BMI taxonomic analysis from WY2013 will also be re-analyzed to STE Level 2 at a later time.
- Several algae species that were found in SMCWPPP samples were not included in the SWAMP list of existing taxonomic identifications. They included a suffix indicating that it was a new species identified by the analytical laboratory (EcoAnalysts, Inc.).

### 5.1.2 Nutrients and Conventional Analytes

Caltest Labs analyzed all water chemistry samples for SMCWPPP in 2012 and 2013. Caltest performed all internal QA/QC requirements as specified in the QAPP and reported their findings to the RMC. Key water chemistry Measurement Quality Objectives (MQOs) are listed in RMC QAPP Tables 26-1, 26-2, 26-5, and 26-7.

Several issues were noted with respect to water chemistry analyses, as follows:

- In both years the SMCWPPP field crew noted several instances where free chlorine was measured with the Hach field kits at levels equal to or higher than total chlorine. Because unique samples are analyzed for the two parameters, it is unknown whether these differences are due to problems with the field kits or real variability in water quality. The samples are collected from the same location approximately two minutes apart. Alternative (colorimetric) methods will be implemented in future field work to improve chlorine measurement accuracy and validity. Several sites exceeded the trigger of 0.08 mg/L, but repeat chlorine measurements were not taken at every site that exceeded the trigger. The field crew has been informed to ensure that replicates are taken in 2014.
- An initial screening of water chemistry data reports in 2012 found that AFDM was not included in certain lab reports or EDDs; revised lab reports and EDDs were provided with AFDM results included. There were no issues with missing constituents in 2013.
- A limited number of lab sample results for nutrients and conventional parameters were reported as qualified data due to minor QA/QC issues not thought to affect the validity of sample results.
- In 2012, one nitrate matrix spike duplicate percent recovery (RP) exceeded the MQO.
- In 2013, nitrate and chloride matrix spikes (MS) and matrix spike duplicates (MSD) RP exceeded the MQO.
- One suspended sediment concentration laboratory duplicate recovery exceeded the MQP range in 2013.
- Laboratory reporting limits (RLs) for chloride and one orthophosphate sample are higher than QAPP target RLs due to dilutions.
- In accordance with the QAPP, field duplicates were collected at two (10%) of the 20 SMCWPPP sites sampled each year. Lab results of water chemistry field duplicate results are shown in Attachment B. The MQO for relative percent difference (RPD) was note exceeded for any constituents in 2012. In 2013, two constituents (SFDM and chlorophyll a) exceeded. Due to the nature of chlorophyll a and AFDM collection, discrepancies are to be expected and are attributed to collection of the duplicate in a different spot from the original sample. Discrepancies between other constituents are

attributed to timing, i.e., not collecting the duplicate at the exact moment the original sample is collected. Field crews will make an effort in subsequent years to collect the original and duplicate samples in an identical fashion.

- The QAPP requires field blanks to be collected and analyzed at a frequency of 5% of all samples collected for these parameters; this equates to a total of three such samples for the RMC total of 60. This requirement was exceeded in 2013, but not completely met in 2012. In 2012, ACCWP collected one water chemistry field blank sample, which Caltest analyzed for orthophosphate and dissolved organic carbon. Lab analysis of the water chemistry field blank detected no contaminants. Among the water chemistry field blanks collected in 2013, one was taken at a SMCWPPP site and analyzed for orthophosphate and dissolved organic carbon. Dissolved organic carbon was detected at levels between the method detection limit and the reporting limit.

### 5.1.3 Toxicity

Two aquatic toxicity samples, taken during storms, were affected during testing by pathogen-related mortality (PRM), a fairly common cause of interference in aquatic sample toxicity tests with ambient surface waters. The affected samples were not re-tested due to laboratory personnel's best professional judgment that the PRM observations were not associated with or indicative of stormwater toxicity.

Lab control treatment for the first *Ceriodaphnia dubia* toxicity test in WY2012 didn't meet test acceptability criteria for reproduction - the mean reproduction in the lab control was below the acceptable limit. The sample was re-tested. Whereby in the first sample there was no significant reduction in *C. dubia* reproduction; there was significant reduction in *C. dubia* reproduction in the second re-test of the sample, only for one site. This site was re-tested in WY2013 and had no significant reduction *in C. dubia* reproduction.

Both aquatic toxicity tests collected during the dry season in WY2012 and one aquatic toxicity sample taken during a storm in 2013 were affected during testing by pathogen-related mortality (PRM), a fairly common cause of interference in aquatic sample toxicity tests with ambient surface waters. The affected samples in 2012 were re-tested using a modified approach per Geis et al. (2003). The affected sample in 2013 was not re-tested due to laboratory personnel's best professional judgment that the PRM observations were not associated with or indicative of stormwater toxicity.

### 5.1.4 Sediment Chemistry

Caltest Laboratories performed all sediment chemistry analysis for SMCWPPP in 2012 and 2013, with the exception of the grain size distribution and total organic carbon (TOC) analyses, which were sub-contracted by Caltest to Soil Control Laboratories. Caltest conducted all QA/QC requirements as specified in the RMC QAPP and reported their findings to the RMC. Key sediment chemistry Measurement Quality Objectives (MQOs) are listed in RMC QAPP Tables 26-4, 26-6, and 26-7. Several issues were reported by the analytical laboratory (Caltest), and the sediment chemistry data were qualified accordingly. These issues included the following:

- Low level contamination noted in the Method Blank (arsenic, chromium) in 2012.

- Matrix spike recovery for arsenic and lead in 2012 exceeded MQO range due to possible matrix interference in the QC sample.
- Some MS/MSD recoveries were not calculated due to the high native concentration in the sample selected for MS/MSD versus the laboratory spike concentration (copper, chromium, nickel).
- In both years, several organochlorine pesticide compounds were not included in the spike mix: DDD, DDE, DDT, Chlordane, and Heptachlor epoxide.
- Sample analysis for DDTs was performed past the estract hold time in 2012.
- In 2013, several laboratory control sample percent recoveries for polycyclic aromatic hydrocarbons (PAHs) were exceeded the target range specified in the QAPP for synthetic organic compounds.
- Matrix spike recoveries for several pyrethroids were outside control limits for synthetic organic compounds in 2012. In 2013, matrix spike recoveries for several pesticides (pyrethroids and DDT) and PAHs were also outside control limits.
- During both years, many laboratory reporting limits (RL) are higher than QAPP target RLs due to the dry weight conversion, as well as target and non-target matrix interferences, which required the laboratories to concentrate less than normal. Most metals, pesticides (pyrethroid and organochlorine), and a few PAHs were affected.

In addition, RMC coordinators noted the following issues with sediment chemistry both years:

- Laboratory report lists the maximum RPD for inorganic analytes (metals) as 30% while the RMC QAPP lists 25%.
- Synthetic organics in the sediment laboratory report lists the maximum RPD from 30 to 50% for most analytes. The maximum RPDs in the laboratory report for gamma-BHC (Lindane) and p,p'-DDT are much higher at 52% and 59%,respectively. However, the RMC QAPP lists the Measurement Quality Objective (MQO) as less than 25% RPD.
- These discrepancies in maximum RPD resulted in several analytes not being flagged in laboratory reports when they should have been.

The RMC QAPP requires collection and analysis of duplicate sediment samples at a rate of 10% of total samples collected. SCVURPPP collected one sediment sample duplicate to account for the 10 sediment sites monitored by the RMC in 2012. In 2013, ACCWP collected one duplicate sediment chemistry samples on behalf of all RMC participants.

In 2012, Relative Percent Difference (RPD) was in exceedance of the MQO in two of the grain size test results (% Granule and % Sand) for the sediment chemistry field duplicate sample. In 2013, RPD was in exceedance of the MQO for several of the analytes, including multiple PAHs (acenaphthene, anthracene, benz(a)anthracene, chrysene, dibenzothiophene, fluoranthene, fluorene, naphthalene, pyrene, and phenanthrene), organochlorine pesticides (DDEs), mercury, and various particle size categories.

Lab results of the sediment chemistry field duplicates are shown in Attachment B. [Note that because of the variability in reporting limits, ND and DNQ data were not evaluated for sediment RPDs.] That RPDs fall outside of control limits for field duplicates should not be surprising in that the control limits associated with SWAMP comparable programs are identical between lab duplicates and field duplicates, even though sources of variability are much larger associated with field duplicates.

### 5.1.5 Targeted Monitoring

Field data sheets and laboratory reports were reviewed by the local Program Quality Assurance Officer, and the results evaluated against the relevant DQOs. Results were compiled for the qualitative metrics (representativeness and comparability), as well as the quantitative metrics (completeness, precision, accuracy). The following summarizes the results of the data quality assessment:

- Temperature data (from HOBOs) was collected at five targeted site locations in 2012 and four in 2013. As a result, over 100% of the expected data was captured.
- Continuous water quality data (temperature, pH, dissolved oxygen, specific conductivity) was collected at two sites during two week periods in the spring and summer season each year resulting in over 100% of the expected data results.
- Continuous water quality data met measurement quality objectives (accuracy) for all parameters with the exception of dissolved oxygen at one site during Spring 2012. Accuracy measurements for 2012 and 2013 are included in Table 5.1.
- The laboratory control sample percent recoveries and laboratory duplicate RPD for *E.Coli* and fecal coliform exceeded the target ranges specified in the QAPP.
- The RMC QAPP requires collection and analysis of duplicate pathogen samples at a rate of 5% of total samples collected. SCVURPPP collected a pathogen field duplicate in 2012 and SMCWPPP collected a duplicate in 2013. The RPD did not exceed the MQO specified in the QAPP for either year.
- The laboratory reporting limits (RL) for pathogens are slightly higher than QAPP target RLs. The target RL is 2 MPN/100mL, while the actual RL is 2.2 MPN/100mL. However, all samples were well above the reporting limit.

Table 5.1. Accuracy measurements taken for dissolved oxygen, pH and specific conductivity in WY2012 and WY2013. Bold values exceeded established Measurement Quality Objectives (MQOs).

| Parameter | MQO | WY2012 | | | | WY2013 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 205PIL030 | | 205PIL340 | | 204SMA059 | | 204SMA122 | |
| | | Event 1 | Event 2 | Event 1 | Event 2 | Event 1 | Event 2 | Event 1 | Event 2 |
| DO (mg/l) | ± 0.5 | **-1.16** | 0.47 | 0 | 0.14 | 0.01 | 0.08 | 0.22 | 0.02 |
| pH 7.0 | ± 0.2 | -0.01 | 0.03 | -0.01 | 0.04 | 0.01 | -0.01 | -0.16 | 0 |
| pH 10.0 | ± 0.2 | -0.01 | 0.03 | -0.03 | 0.06 | 0.03 | -0.03 | 0.11 | -0.02 |
| Specific Cond (uS/cm) | ± 0.5 % | 1.4% | -1.6% | 0% | 0.5% | 0.8% | 0% | -4.8% | -0.1% |

## 5.2 Condition Assessment

This section addresses the core management question ***"Are conditions in local receiving water supportive of or likely supportive of beneficial uses?"*** or more specifically, ***"What is the condition of aquatic life in creeks in San Mateo County?"*** The RMC probabilistic monitoring design provides an unbiased framework for data evaluation; however, the sample count (n=23) is not yet sufficient to evaluate the condition of aquatic life within known estimates of precision.

Furthermore, although the data set is not *yet* sufficient to develop statistically representative conclusions addressing the second core management question (***"To what extent does the condition of aquatic life in urban and non-urban creeks differ in San Mateo County?"),*** comparisons are made between the two types of sites.

### 5.2.1 Benthic Macroinvertebrates

Evaluation of Assessment Tools

Biological condition for BMI data, presented as NoCal B-IBI, SoCal B-IBI and CSCI scores for the 90 sampling events conducted in San Mateo County between 2002 and 2013 are listed in Attachment C. Descriptive statistics are shown in Table 5.2.

Table 5.2. Descriptive statistics for SoCal B-IBI scores and CSCI scores for the 90 sampling events conducted in San Mateo County between 2002 and 2013.

| Statistic | NoCal B-IBI Score | SoCal B-IBI Score | CSCI Score |
|---|---|---|---|
| Min | 6 | 0 | 0.19 |
| Median | 55 | 72 | 0.88 |
| Mean | 47 | 57 | 0.77 |
| Max | 86 | 100 | 1.19 |

The SoCal and NoCal B-IBI scores for 90 sampling events in San Mateo County were compared in order to explore and confirm the choice in tool selection for analyzing BMI data as condition indicators for this report. No significant differences between B-IBI scores calculated using these two tools was observed (Figure 5.1). To remain consistent with the analyses conducted in the WY2012 report (BASMAA 2013), the SoCal B-IBI was used as one of the primary indices used to evaluate biological condition in this report.

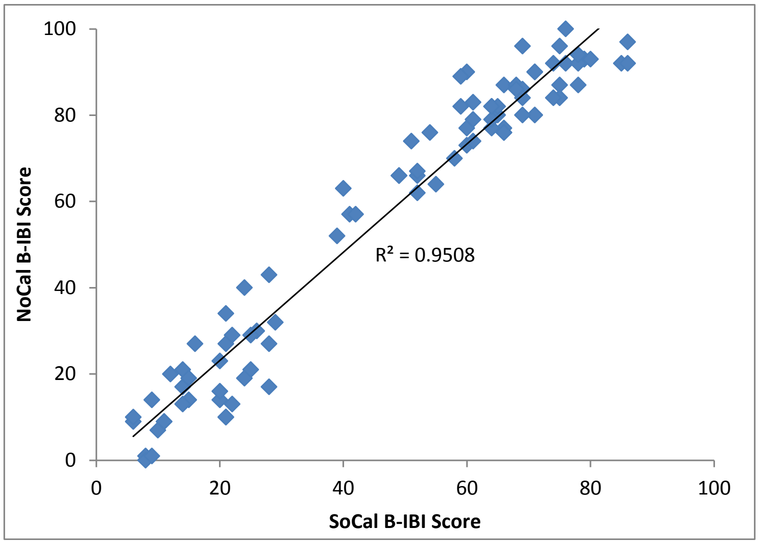


Figure 5.1. Comparison of NoCal and SoCal B-IBI scores calculated from BMI data collected at 90 sampling events in San Mateo County between 2002 and 2013.

A linear regression between SoCal B-IBI and CSCI scores for the 90 sampling events showed good correlation ($r^2$ =0.90) suggesting that the CSCI may be a useful tool to assess the condition of aquatic life in San Mateo County creeks (Figure 5.2). The SoCal IBI score was also compared to the two CSCI components and showed greater correlation with pMMI ($r^2$ = 0.90) compared to O/E ($r^2$ = 0.81). The distribution of CSCI scores, however show much greater variability among the sites compared to the SoCal B-IBI (Figure 5.3).

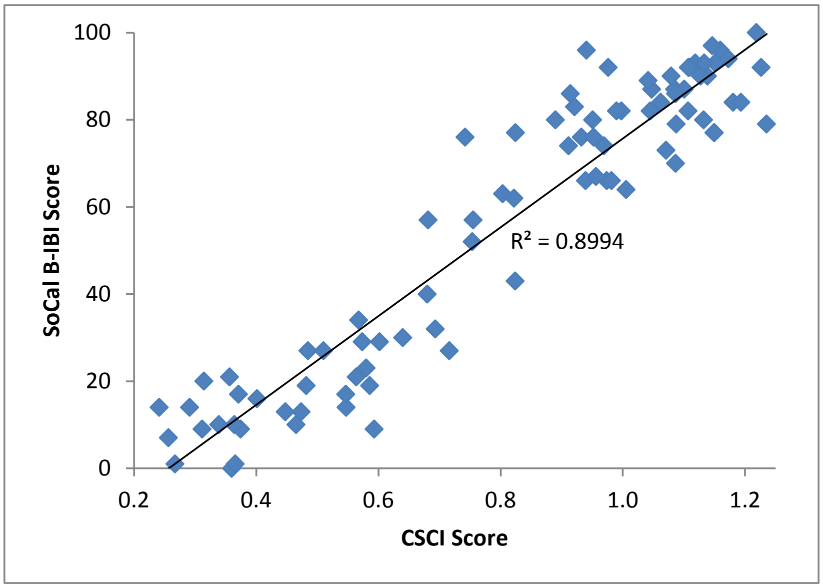


Figure 5.2. Linear regression between SoCal B-IBI and CSCI scores for the 90 sampling events conducted in San Mateo County between 2002 and 2013.

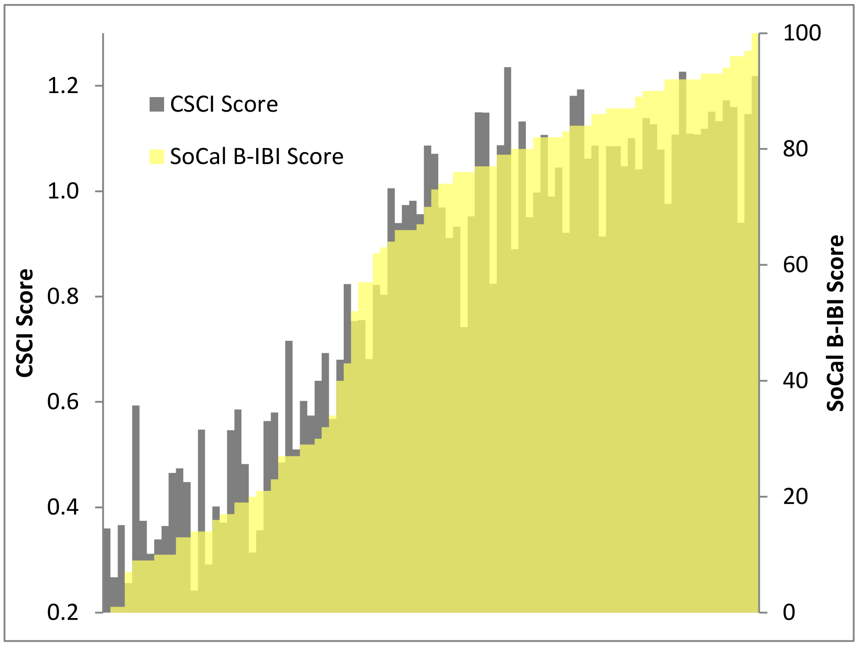


Figure 5.3. SoCal B-IBI and CSCI scores plotted for the 90 sampling events conducted in San Mateo County between 2002 and 2013. Data is sorted with B-IBI scores increasing from left to right.

These results suggest that the CSCI may be more responsive to the site specificity of BMI taxa due to the inclusion of a taxonomic completeness component (O/E) and/or the predictive ability of the pMMI as compared to the exclusive MMI approach of the SoCal B-IBI. Alternatively, the CSCI scores may not be accurately predicting the expected number of taxa resulting in an over- or under-estimated measure of taxonomic completeness. The O/E component was consistently higher than the pMMI component, which may be driving the variability in the overall CSCI score (Figure 5.4).

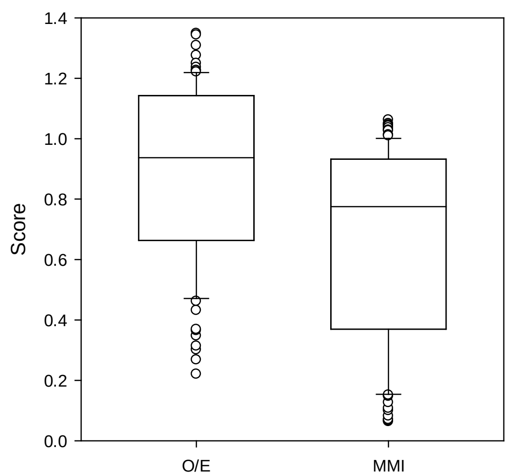


Figure 5.4. Box plots showing distribution of O/E and pMMI scores for 90 sampling events in San Mateo County conducted between 2002 and 2013.

Further analyses of the assessment tools were conducted using average SoCal B-IBI and CSCI scores at the 75 sites sampled between 2002 and 2013. Average scores were used for sites sampled more than once. The distribution of SoCal B-IBI and CSCI scores for perennial (n=69) and non-perennial (n=6) sites is shown in Figure 5.5.

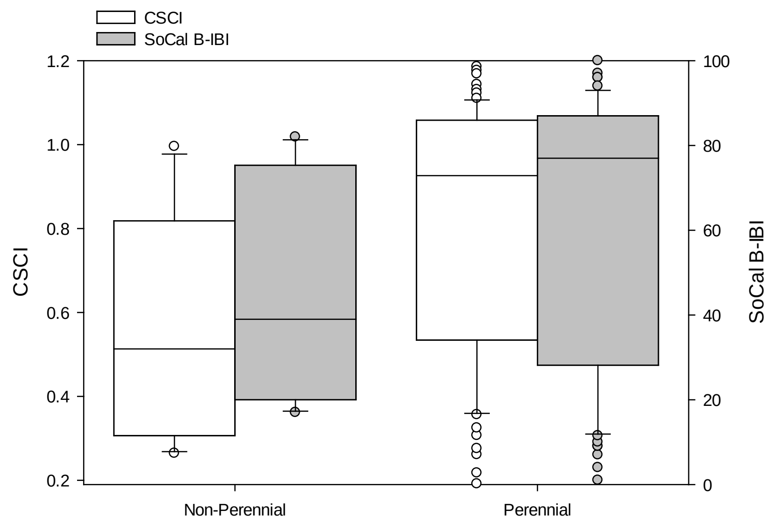


Figure 5.5. Box plots showing distribution of SoCal B-IBI and CSCI scores for perennial (n=69) and non-perennial (n=6) sites sampled in San Mateo County between 2002 and 2013. Average scores were used for sites sampled more than once.

The biological condition scores were higher for perennial sites compared to non-perennial sites, however the comparison is based on a very small number of non-perennial sites. The standard deviation, mean and coefficient of variation (CV) were calculated for each group (Table 5.3). The variability within the distribution of scores was lower for CSCI scores compared to SoCal B-IBI scores for both flow categories.

Table 5.3. Descriptive statistics for CSCI and SoCal B-IBI scores calculated at perennial (n=69) and non-perennial (n=6) sites.

| Statistic | Perennial | | Non-Perennial | |
|---|---|---|---|---|
| | CSCI | SoCal B-IBI | CSCI | SoCal B-IBI |
| Standard Deviation | 0.29 | 32.1 | 0.31 | 29.7 |
| Mean | 0.82 | 60.7 | 0.57 | 45.4 |
| Coeff Variation | 0.36 | 0.53 | 0.55 | 0.65 |

The distribution of SoCal B-IBI and CSCI scores for urban and non-urban sites is shown in Figure 5.6. In general, the biological scores were similar for both land use groups, with the exception of slightly lower median value for SoCal B-IBI score at the urban sites. The standard deviation, mean and coefficient of variation (CV) were calculated for each group (Table 5.4). The variability within the distribution of scores was lower for CSCI scores compared to SoCal B-IBI scores for urban sites, but similar for non-urban sites.

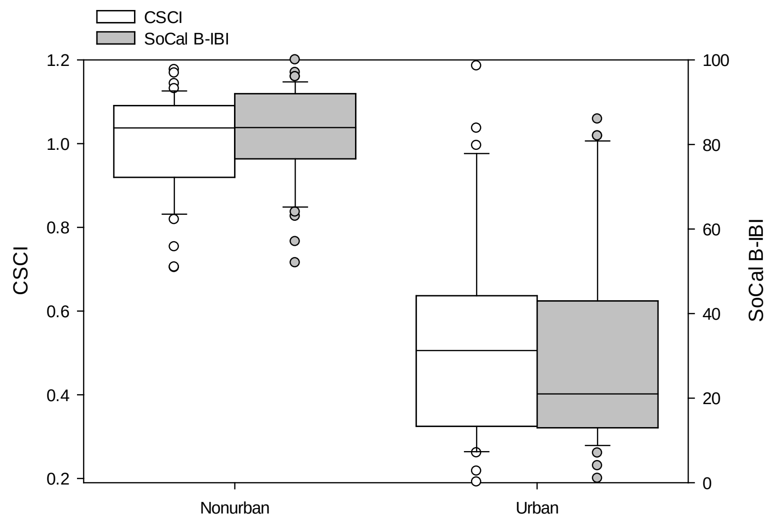


Figure 5.6. Box plots showing distribution of SoCal B-IBI and CSCI scores for urban (n=34) and non-urban (n=41) sites sampled in San Mateo County between 2002 and 2013. Average scores were used for sites sampled more than once.

Table 5.4. Descriptive statistics for CSCI and SoCal B-IBI scores calculated at urban (n=34) and non-urban (n=41) sites.

| Statistic | Urban | | Non-Urban | |
|---|---|---|---|---|
| | CSCI | SoCal B-IBI | CSCI | SoCal B-IBI |
| Standard Deviation | 0.26 | 26.0 | 0.12 | 11.7 |
| Mean | 0.55 | 31.8 | 1.00 | 82.5 |
| Coeff Variation | 0.48 | 0.82 | 0.12 | 0.14 |

The land use classification for sample sites is based on the RMC sample frame, which was developed using a combination of urban areas (as defined by Association of Bay Area Governments) and city boundaries. For some areas, city boundaries include parks and undeveloped areas. Thus sampling locations that are classified as urban may have a wide range of impacts associated with urban development.

Another measure associated with urbanization, imperviousness, was derived using the upstream watershed areas for each sampling location and overlaying with land use data in GIS database. Impervious coefficients were applied to land use classes described in the Alameda County Assessor Parcel data[18]. The percent watershed impervious area was calculated for all sites and used to compare biological condition scores at increasing levels of urbanization: >3%, 3-10% and >10% impervious (Figure 5.7).

[18] Land use classes for the Assessor Parcel data were revised by EOA to more accurately depict current land use throughout Alameda County as part of trash generation mapping project.

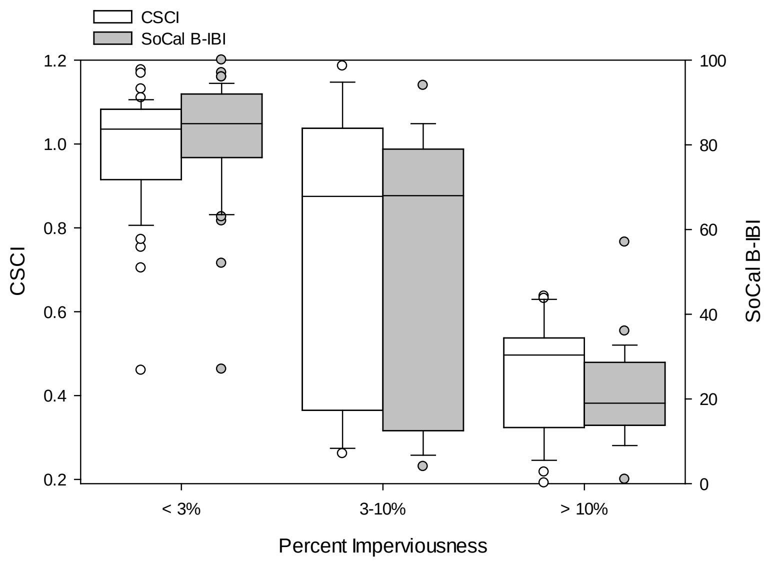


Figure 5.7. Box plots showing distribution of SoCal B-IBI and CSCI scores at sites sampled in San Mateo County between 2002 and 2013 for three classifications of urbanization, defined as % watershed imperviousness. Average scores were used for sites sampled more than once.

Both assessment tools had similar distribution of scores for the three classes of urbanization. The intermediate class (3-10% impervious area) consisted of wide range of scores, indicating a wide range of conditions can occur at sites in rural areas.

<u>Biological Condition</u>

Biological condition for BMI data, presented as SoCal B-IBI score and CSCI score, for the 23 probabilistic sites sampled in San Mateo County during WY2012 and WY2013 are listed in Table 5.5. Site characteristics related to land use classification, flow status, and channel modification status are presented in the table for reference. The range of SoCal B-IBI scores and CSCI scores, are 1 to 93 and 0.19 to 1.19, respectively.

Using the condition categories for CSCI presented in this report, 9 sites (39%) scored as good, 5 sites (22%) scored as fair, and 9 sites (39%) scores as poor. Six of the nine sites (67%) that were classified as good were non-urban sites. The sites rated as poor were very similar to the sites ranked as very poor using the SoCal B-IBI scores. Three of the poor sites (33%) were classified as having a highly modified channel (i.e., concrete lined bed and/or bank, channelized earthen levee).

The biological condition for the historical targeted dataset was also assessed (Attachment C). At some sites, the B-IBI scores were highly variable over time. For example, two sampling events at site 202SPE070 and site 204SMA020, had B-IBI scores that ranged from 74 to 90 and 0 to 14, respectively. Variability in IBI scores may reflect natural variation in the BMI community associated with factors such as temperature and precipitation. There were no apparent trends over time in B-IBI scores at sites sampled more than twice. Therefore average scores were used to assess biological condition category for all sites that had multiple sampling events. Condition scores for CSCI for both the targeted historical sites and probabilistic sites (n=90 sites) are shown in Figure 5.8.

The total number of sampling events for probabilistic and targeted sites by watershed is shown in Table 5.6. Seventy percent of the sampling events were targeted sites and majority of these sites were located in relatively rural watershed areas of San Mateo County (e.g., Pescadero, San Gregorio and Butano). As a result, the distribution of biological condition scores for targeted sites is higher compared to probabilistic sites (Figure 5.9).

Table 5.5. SoCal B-IBI and CSCI scores for probabilistic sites sampled in San Mateo County during Water Years 2012 and 2013 (n=23). Condition categories are indicated for each assessment tool.

| Station Code | Creek | Land Use | Modified Channel | Flow | CSCI | | SoCal B-IBI | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Score | Condition Category | Score | Condition Category |
| 205R00088 | Corte Madera | U | N | P | 1.19 | Good | 79 | Good |
| 202R00166 | Little Butano Creek | NU | N | P | 1.07 | Good | 93 | Very Good |
| 202R00248 | San Gregorio Creek | NU | N | P | 1.06 | Good | 82 | Very Good |
| 202R00072 | Pillarcitos Creek | NU | N | P | 1.02 | Good | 73 | Good |
| 205R00168 | Corte Madera Creek | U | N | NP | 1.00 | Good | 82 | Very Good |
| 205R00984 | Bear Gulch Creek | U | N | P | 0.93 | Good | 66 | Good |
| 202R00038 | Little Butano Creek | NU | N | P | 0.93 | Good | 92 | Very Good |
| 202R00280 | Tributary to Alpine Creek | NU | N | P | 0.91 | Good | 67 | Good |
| 202R00024 | Woodhams Creek | NU | N | P | 0.87 | Good | 83 | Very Good |
| 205R00872 | Bear Gulch Creek | U | N | P | 0.77 | Fair | 43 | Fair |
| 202R00284 | Denniston Creek | U | N | P | 0.77 | Fair | 62 | Good |
| 202R00104 | La Honda Creek | NU | N | NP | 0.71 | Fair | 57 | Fair |
| 202R00087 | Milagra Creek | U | N | P | 0.63 | Fair | 57 | Fair |
| 204R00520 | Belmont Creek | U | Y | P | 0.55 | Fair | 29 | Poor |
| 204R00244 | Trib to Arroyo Ojo de Aqua | U | Y | P | 0.54 | Poor | 9 | Very Poor |
| 204R00200 | Polhemus Creek | U | N | P | 0.54 | Poor | 19 | Very Poor |
| 204R00680 | Redwood Creek | U | N | P | 0.52 | Poor | 29 | Poor |
| 204R00180 | Sanchez Creek | U | Y | P | 0.50 | Poor | 14 | Very Poor |
| 204R00232 | Arroyo Ojo de Aqua | U | N | P | 0.50 | Poor | 17 | Very Poor |
| 204R00884 | Easton Creek | U | N | P | 0.43 | Poor | 19 | Very Poor |
| 204R00436 | Easton Creek | U | Y | P | 0.32 | Poor | 9 | Very Poor |
| 204R00807 | Colma Creek | U | Y | P | 0.22 | Poor | 1 | Very Poor |
| 202R00908 | Calera Creek | U | N | P | 0.19 | Poor | 14 | Very Poor |

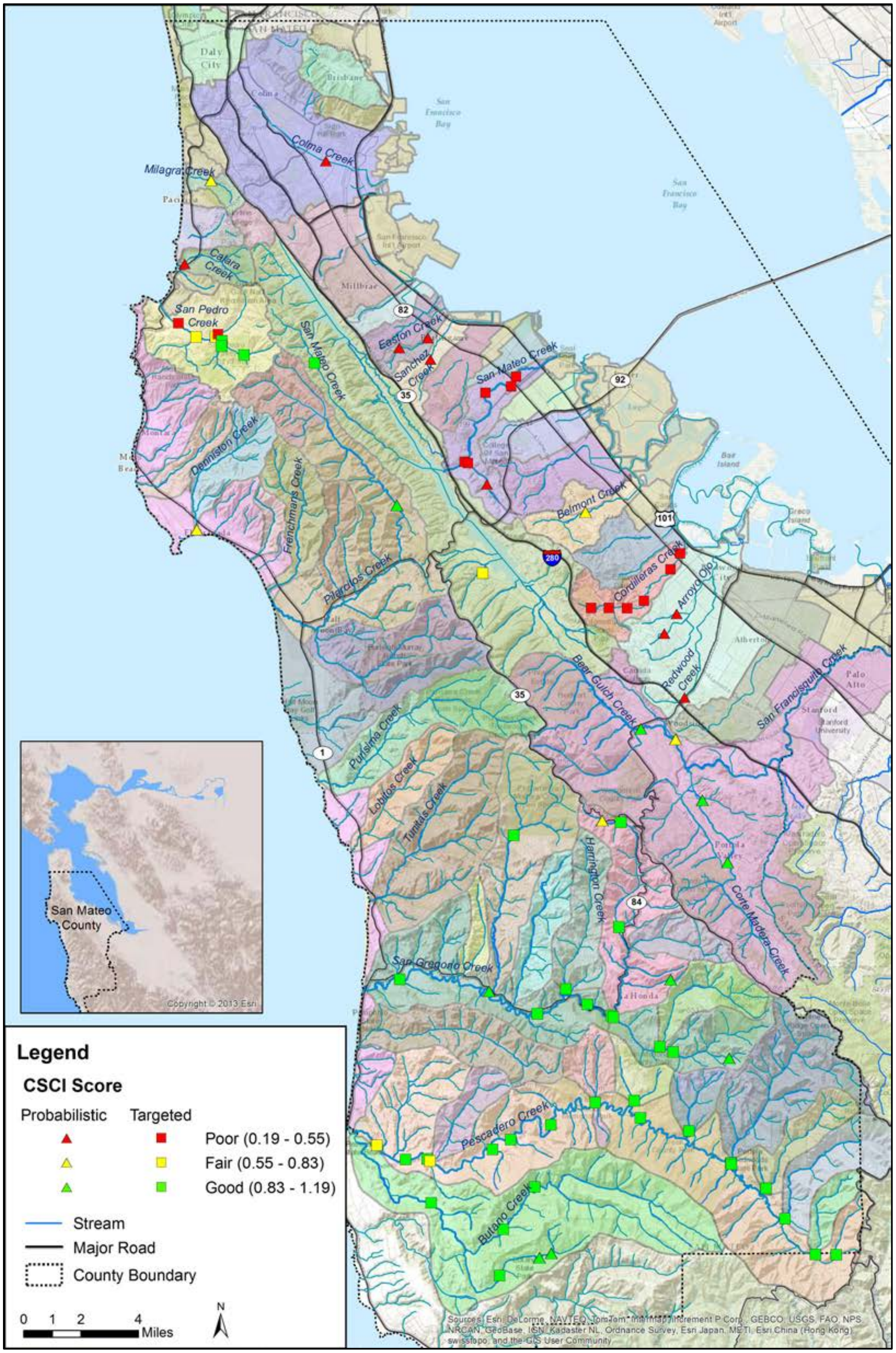


Figure 5.8. Bioassessment location and CSCI condition category for 75 sites sampled between 2002 and 2013, San Mateo County.

Table 5.6. Total number of probabilistic and targeted sites that have been sampled in San Mateo County watersheds between 2002 and 2013.

| Watershed | Probabilistic | Targeted |
|---|---|---|
| *Drains to Pacific Ocean* | | |
| Butano | 2 | 4 |
| Calera | 1 | 0 |
| Denniston | 1 | 0 |
| Milagra | 1 | 0 |
| Pescadero | 0 | 17 |
| Pillarcitos | 1 | 0 |
| San Gregorio | 4 | 11 |
| San Pedro | 0 | 14 |
| *Drains to San Francisco Bay* | | |
| Belmont | 1 | 0 |
| Colma | 1 | 0 |
| Cordilleras | 0 | 6 |
| Easton | 2 | 0 |
| Redwood | 3 | 0 |
| San Franciscquito | 4 | 0 |
| San Mateo (Below Crystal Springs R) | 1 | 9 |
| San Mateo (Above Crystal Springs R) | 0 | 6 |
| Sanchez | 1 | 0 |
| Total | 23 | 67 |

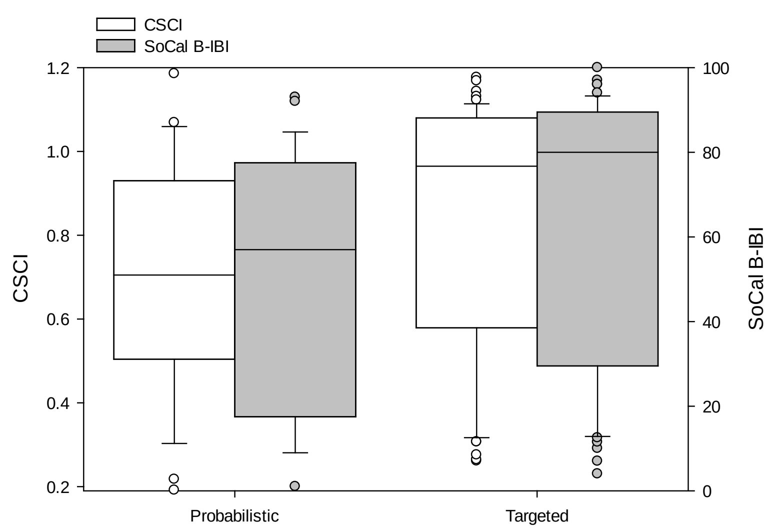


Figure 5.9. Box plots showing distribution of SoCal B-IBI and CSCI scores for targeted (n=67) and probabilistic (n=23) sites sampled in San Mateo County between 2002 and 2013.

### 5.2.2 Algae

The presentation of algae data is considered preliminary until taxonomic differences with the SWAMP master taxa list are reconciled. However, since diatom taxa are relatively well understood (as compared to soft algae), it was decided that diatom data could be used to generate a single assemblage diatom IBI. The SWAMP Reporting Module was able to calculate diatom "D18" IBI scores for 20 probabilistic sites sampled in San Mateo County during Water Years 2012 and 2013.

Site location and characteristics and diatom IBI scores are listed in Table 5.7. Diatom IBI scores across all the sites ranged from 26 to 74. Diatom IBI scores ranged from 32 to 72 at non-urban sites (n=4) and from 26 to 74 at urban sites. There were no apparent trends with diatom IBI score and any of the channel characteristics. The diatom IBI scores were poorly correlated with CSCI scores (Figure 5.9) and SoCal B-IBI scores. These results suggest that different stressors impact the diatom assemblage as compared to the BMI assemblage.

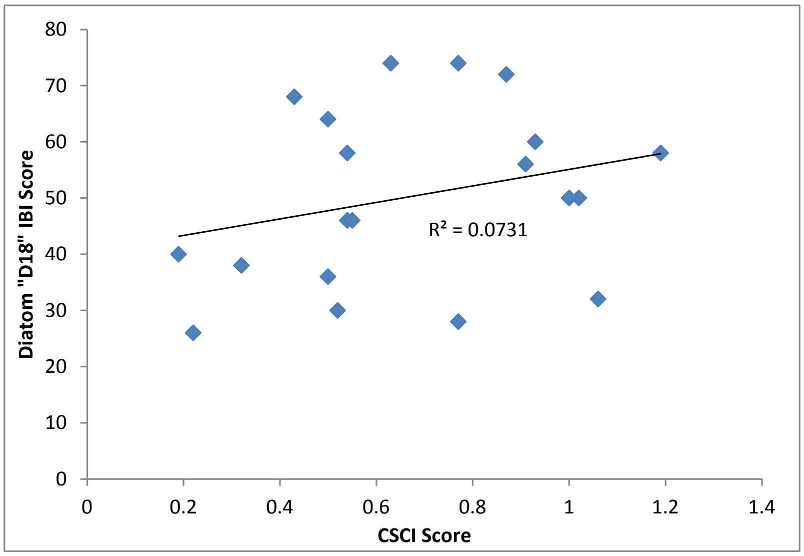


Figure 5.10. Linear regression of Diatom IBI score and CSCI score for 20 probabilistic sites in San Mateo County sampled during Water Years 2012 and 2013.

The diatom D18 IBI may not perform well in San Mateo County streams. Recent study findings indicate that the algal hybrid IBI (H20), also developed for streams within the PSA South Coast ecoregion, did not perform well in other ecoregions of the California (Fetscher et al. 2013b). Thus algal IBIs may need to be developed and tested for San Francisco Bay before applying to algal data collected by SMCWPPP and the RMC.

Table 5.7. Diatom IBI scores for 20 probabilistic sites sampled in San Mateo County during WY2012 and WY2013.

| Station Code | Creek | Land Use | Modified Channel | Flow Status | Diatom IBI Score |
|---|---|---|---|---|---|
| 202R00087 | Milagra Creek | U | N | P | 74 |
| 202R00284 | Denniston Creek | U | N | P | 74 |
| 202R00024 | Woodhams Creek | NU | N | P | 72 |
| 204R00884 | Easton Creek | U | N | P | 68 |
| 204R00180 | Sanchez Creek | U | Y | P | 64 |
| 205R00984 | Bear Gulch Creek | U | N | P | 60 |
| 204R00200 | Polhemus Creek | U | N | P | 58 |
| 205R00088 | Corte Madera | U | N | P | 58 |
| 202R00280 | Tributary to Alpine Creek | NU | N | P | 56 |
| 202R00072 | Pillarcitos Creek | NU | N | P | 50 |
| 205R00168 | Corte Madera Creek | U | N | NP | 50 |
| 204R00244 | Trib to Arroyo Ojo de Aqua | U | Y | P | 46 |
| 204R00520 | Belmont Creek | U | N | P | 46 |
| 202R00908 | Calera Creek | U | N | P | 40 |
| 204R00436 | Easton Creek | U | N | P | 38 |
| 204R00232 | Arroyo Ojo de Aqua | U | N | P | 36 |
| 202R00248 | San Gregorio Creek | NU | N | P | 32 |
| 204R00680 | Redwood Creek | U | N | P | 30 |
| 205R00872 | Bear Gulch Creek | U | N | P | 28 |
| 204R00807 | Colma Creek | U | Y | P | 26 |

## 5.3 Physical Habitat Condition

Individual attribute and total scores for PHAB and CRAM for 20 probabilistic sites are shown in Table 5.8. Total PHAB scores ranged from 13 to 53 and CRAM scores ranged from 28 to 89. Four of the six sites with highest total CRAM scores were non-urban sites. Total PHAB scores and Total CRAM scores were moderately correlated ($r^2$ = 0.61) (Figure 5.11)

Comparisons between total PHAB and total CRAM scores with biological condition scores, represented by CSCI score, are shown in Figures 5.12 and Figure 5.13, respectively. The correlation between PHAB score and CSCI score ($r^2$ = 0.56) and between total CRAM score and CSCI score ($r^2$ = 0.65) was much higher when site 202R00908 was removed from the analysis. Site 202R00908 had a high CRAM score (79) and a low CSCI score (0.19), indicating non-habitat related factors are potentially impacting biological condition. This site is located directly downstream of the Calera Creek Water Recycling Facility in the City of Pacifica.

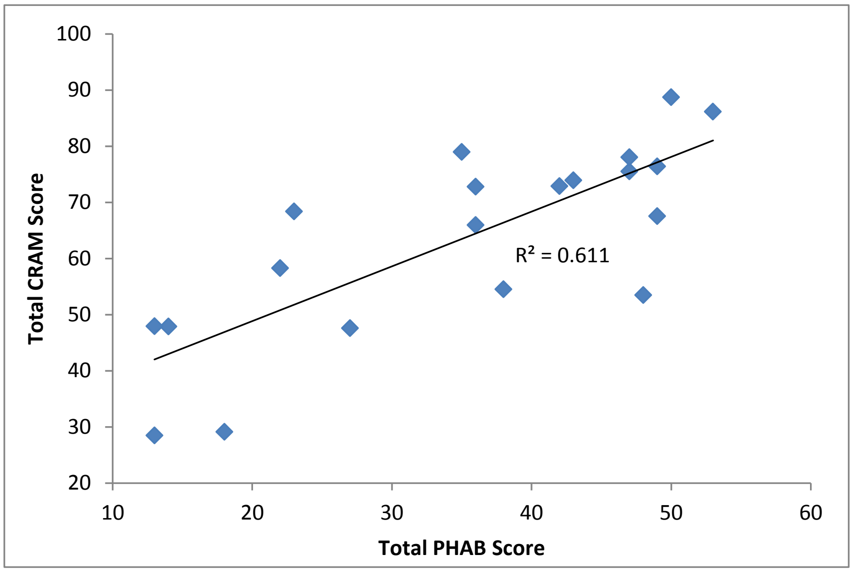


Figure 5.11. Total CRAM scores and Total PHAB scores are compared for all probabilistic sites.

Diatom IBI scores were poorly correlated to both PHAB and total CRAM scores, $r^2$ = 0.37 and $r^2$ = 0.27, respectively

The physical habitat endpoints calculated from habitat measurements conducted during bioassessments at 20 probabilistic sites are shown in Table 5.9. Stressor analysis of the habitat endpoints and biological scores is presented in the next section.

Table 5.8. PHAB, CRAM and CSCI scores at 20 probabilistic sites in San Mateo County between 2012 and 2013.

| Station Code | Land Use | PHAB | | | | CRAM | | | | | CSCI Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Channel Alteration | Epifaunal Substrate | Sediment Deposition | Total Score | Land | Hydro | Physical | Biotic | Total Score | |
| 202R00072 | NU | 20 | 16 | 14 | 50 | 92 | 83 | 88 | 92 | 89 | 1.02 |
| 202R00280 | NU | 20 | 19 | 14 | 53 | 93.3 | 83.3 | 87.5 | 80.5 | 86 | 0.91 |
| 202R00908 | U | 18 | 11 | 6 | 35 | 85.4 | 83.3 | 75 | 72.2 | 79 | 0.19 |
| 202R00248 | NU | 18 | 16 | 13 | 47 | 82.9 | 50 | 87.5 | 91.7 | 78 | 1.06 |
| 205R00088 | U | 19 | 15 | 15 | 49 | 79.1 | 66.7 | 62.5 | 97.3 | 76 | 1.19 |
| 202R00024 | NU | 20 | 12 | 15 | 47 | 100 | 67 | 63 | 72 | 76 | 0.87 |
| 205R00168 | U | 20 | 11 | 12 | 43 | 91.6 | 50 | 62.5 | 91.7 | 74 | 1.00 |
| 202R00087 | U | 19 | 13 | 10 | 42 | 100 | 50 | 50 | 91.6 | 73 | 0.63 |
| 204R00200 | U | 16 | 7 | 13 | 36 | 87.5 | 59.3 | 75 | 69.4 | 73 | 0.54 |
| 202R00284 | U | 15 | 6 | 2 | 23 | 79.2 | 58.3 | 75 | 61.1 | 68 | 0.77 |
| 205R00984 | U | 16 | 16 | 17 | 49 | 67.5 | 58.3 | 75 | 69.4 | 68 | 0.93 |
| 205R00872 | U | 14 | 12 | 10 | 36 | 70.8 | 50 | 62.5 | 80.6 | 66 | 0.77 |
| 204R00680 | U | 7 | 6 | 9 | 22 | 42.9 | 58.3 | 62.5 | 69.4 | 58 | 0.52 |
| 204R00884 | U | 8 | 11 | 19 | 38 | 43.1 | 58.3 | 50 | 66.7 | 55 | 0.43 |
| 204R00232 | U | 19 | 14 | 15 | 48 | 41.7 | 58.3 | 75 | 38.9 | 53 | 0.50 |
| 204R00436 | U | 0 | 6 | 7 | 13 | 25 | 50 | 50 | 66.7 | 48 | 0.32 |
| 204R00180 | U | 3 | 3 | 8 | 14 | 25 | 58.3 | 50 | 58.3 | 48 | 0.50 |
| 204R00520 | U | 6 | 11 | 10 | 27 | 25 | 41.7 | 62.5 | 61.1 | 48 | 0.55 |
| 204R00244 | U | 0 | 1 | 17 | 18 | 25 | 33.3 | 25 | 33.3 | 29 | 0.54 |
| 204R00807 | U | 0 | 0 | 13 | 13 | 25 | 33.3 | 25 | 30.6 | 28 | 0.22 |

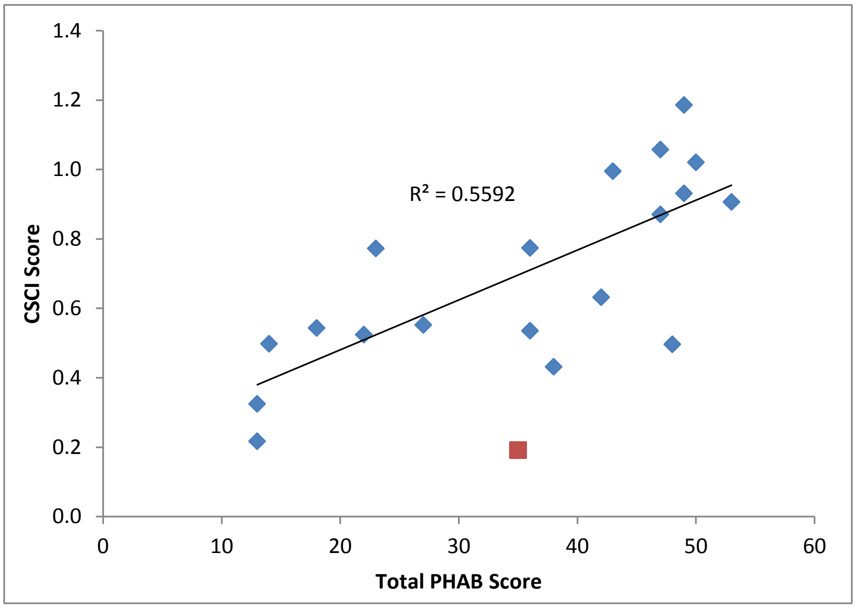


Figure 5.12. Comparison between total PHAB score and CSCI scores for 20 probabilistic sites in San Mateo County assessed in Water Years 2012 and 2013. Scores for site 202R00908 (identified as red symbol) was not included in the regression line.

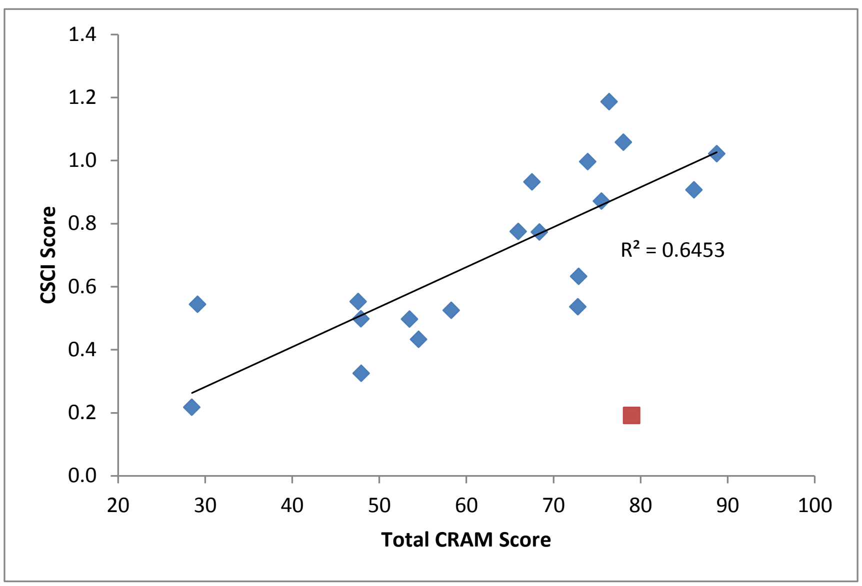


Figure 5.13. Comparison between total CRAM score and CSCI scores for 20 probabilistic sites in San Mateo County assessed in Water Years 2012 and 2013. Scores for site 202R00908 (identified as red symbol) was not included in the regression li

Table 5.9. Physical habitat condition scores and endpoints calculated from habitat measurements during bioassessments at 20 probabilistic sites in San Mateo County in Water Years 2012 and 2013.

| Station Code | Creek Name | Land Use | % Algae Cover | % Canopy Cover | % Sands & Fines | HDI Score | Entrench Ratio | Percent Urban | Percent Impervious | CSCI Score |
|---|---|---|---|---|---|---|---|---|---|---|
| 205R00088 | Corte Madera Creek | U | 22.86 | 85.29 | 23.81 | 1.94 | 1.43 | 10% | 4% | 1.19 |
| 202R00248 | San Gregorio Creek | NU | 27.23 | 83.16 | 27.88 | 1.07 | 1.27 | 3% | 2% | 1.06 |
| 202R00072 | Pilarcitos Creek | NU | 4.82 | 96.52 | 30.48 | 0.30 | 1.88 | 0% | 1% | 1.02 |
| 205R00168 | Corte Madera Creek | U | 24.05 | 84.09 | 40.00 | 1.14 | 1.35 | 27% | 7% | 1.00 |
| 205R00984 | Bear Gulch Creek | U | 20.82 | 94.92 | 26.47 | 0.76 | 1.9 | 12% | 4% | 0.93 |
| 202R00280 | Tributary to Alpine Creek | NU | 13.57 | 85.83 | 13.33 | 0.00 | 1.51 | 0% | 1% | 0.91 |
| 202R00024 | Woodhams Creek | NU | 20.62 | 98.38 | 15.24 | 0.09 | 1.46 | 0% | 1% | 0.87 |
| 205R00872 | Bear Gulch Creek | U | 25.37 | 95.45 | 28.85 | 1.50 | 1.36 | 25% | 6% | 0.77 |
| 202R00284 | Denniston Creek | U | 6.90 | 97.33 | 54.29 | 2.17 | 1.54 | 3% | 3% | 0.77 |
| 202R00087 | Milagra Creek | U | 5.24 | 98.53 | 13.33 | 0.95 | 1.03 | 43% | 27% | 0.63 |
| 204R00520 | Belmont Creek | U | 27.86 | 94.39 | 16.19 | 2.24 | 1.16 | 61% | 35% | 0.55 |
| 204R00244 | Trib to Arroyo Ojo De Agua | U | 54.05 | 69.56 | 2.86 | 2.32 | 1.04 | 90% | 43% | 0.54 |
| 204R00200 | Polhemus Creek | U | 14.89 | 99.73 | 11.43 | 1.68 | 1.48 | 66% | 41% | 0.54 |
| 204R00680 | Redwood Creek | U | 20.29 | 97.33 | 35.24 | 1.77 | 1.5 | 81% | 23% | 0.52 |
| 204R00180 | Sanchez Creek | U | 13.08 | 90.64 | 14.29 | 3.39 | 1.4 | 68% | 31% | 0.50 |
| 204R00232 | Arroyo Ojo De Agua | U | 19.05 | 98.26 | 22.86 | 2.37 | 1.49 | 84% | 41% | 0.50 |
| 204R00884 | Easton Creek | U | 26.32 | 97.59 | 1.94 | 2.65 | 1.66 | 97% | 44% | 0.43 |
| 204R00436 | Easton Creek | U | 25.49 | 90.64 | 16.35 | 3.14 | 1.25 | 97% | 42% | 0.32 |
| 204R00807 | Colma Creek | U | 49.29 | 3.07 | 1.90 | 3.37 | 1.11 | 62% | 45% | 0.22 |
| 202R00908 | Calera Creek | U | 27.50 | 94.39 | 50.51 | 0.71 | 2.31 | 15% | 10% | 0.19 |

## 5.4 Stressor/WQO Assessment

This section addresses the core management question ***"Are water quality objects, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?"*** or more specifically, ***"What are the major stressors to aquatic life in San Mateo County?"*** Potential stressors to aquatic life (such as PHAB measures, percent development, and water quality) were compared to biological condition scores to evaluate their importance as major stressors to aquatic life. In addition, each monitoring category required by MRP Provision C.8.c, Table 8.1 is associated with a specification for "Results that Trigger a Monitoring Project in Provision C.8.d.i" (Stressor/Source Identification). The definitions of these "Results that Trigger…", as shown in Table 8.1, are considered to represent "trigger criteria", meaning that the relevant monitoring results should be forwarded for consideration as potential Stressor/Source Identification Projects per Provision C.8.d.i. The trigger criteria/thresholds are listed in Table 4.4 of this report. The physical, chemical, and toxicity monitoring data collected during Water Years 2012 and 2013 were evaluated against the trigger criteria. When the data analysis indicated that the associated trigger criteria were met, those sites and results were identified as potentially warranting further investigation.

### 5.4.1 Potential stressors to biological condition

Physical habitat, general water quality, and water chemistry (e.g., nutrients) data were evaluated as potential stressors to biological condition. These data were collected synoptically with biological data during bioassessments and CRAM assessments at probabilistic sites during Water Years 2012 and 2013. Using the Sigma Plot statistical software platform, the variables were tested for normality using the Shapiro-Wilk Test. Pearson Correlation Coefficients (CC), which are most appropriate for normally distributed data, were calculated between each potential stressor variable and the biological condition indicators. Correlations were also evaluated using the Spearman rank method which is less precise than Pearson CC but is more appropriate for data that is not normally distributed (i.e., those variables having a logarithmic distribution). For both coefficients, values greater than ±0.6 indicate a strong relationship between variables. If the p-value is ≤0.05, the correlation is considered statistically significant.

Statistically significant variables with the highest correlations are indicated in bold in Table 5.10. Roughly the same large set of variables are significant in explaining CSCI and SoCal scores. This finding was expected considering the high correlation between the two scoring methods. These variables include: channel alteration score, epifaunal substrate score, CRAM Land, CRAM biotic, elevation, percent urban, chloride, and nitrate. Watershed precipitation was also highly correlated with CSCI and SoCal IBI.

A multiple regression analysis was also conducted using the same set of variables compared to CSCI scores. Results of the best subset regression suggest that sediment, percent impervious, and nitrate seem to be strongly influencing CSCI scores.

Table 5.10. Pearson and Spearman Correlation Coefficients for biological condition scores (SoCal B-IBI, CSCI and diatom IBI) and potential stressors. Statistically significant coefficients greater than ± 0.6 are indicated in bold.

| Independent Variables | Shapiro-Wilk | | CSCI | | | | SoCal IBI | | | | Diatom "D18" MMI Score | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Normal | p-value | Pearson Correlation Coefficient | p-value | Spearman Correlation | p-value | Pearson Correlation Coefficient | p-value | Spearman Correlation | p-value | Pearson Correlation Coefficient | p-value | Spearman Correlation | p-value |
| Bioassessment Tool | | | | | | | | | | | | | | |
| CSCI: | Yes | 0.52 | -- | -- | -- | -- | **0.93** | < 0.001 | **0.90** | < 0.001 | 0.27 | 0.25 | 0.24 | 0.30 |
| SoCal IBI: | No | 0.017 | **0.93** | < 0.001 | **0.90** | < 0.001 | -- | -- | -- | -- | 0.36 | 0.12 | 0.35 | 0.13 |
| Diatom "D18" MMI Score: | Yes | 0.32 | 0.27 | 0.25 | 0.24 | 0.30 | 0.36 | 0.12 | 0.35 | 0.13 | -- | -- | -- | -- |
| Potential Stressor | | | | | | | | | | | | | | |
| % Algae Cover: | No | 0.021 | -0.37 | 0.11 | -0.29 | 0.22 | -0.46 | 0.043 | -0.36 | 0.12 | -0.53 | 0.017 | -0.54 | 0.015 |
| % Canopy Cover: | No | < 0.001 | 0.27 | 0.24 | -0.13 | 0.58 | 0.30 | 0.21 | 0.11 | 0.65 | 0.42 | 0.069 | 0.44 | 0.051 |
| % Sands & Fines: | Yes | 0.27 | 0.25 | 0.29 | 0.33 | 0.16 | 0.37 | 0.11 | 0.41 | 0.072 | -0.068 | 0.78 | -0.14 | 0.54 |
| HDI Score: | Yes | 0.60 | -0.57 | 0.0081 | -0.58 | 0.0077 | **-0.72** | < 0.001 | **-0.70** | < 0.001 | -0.21 | 0.37 | -0.20 | 0.40 |
| Channel Alteration Score: | No | 0.0020 | **0.64** | 0.0024 | **0.61** | 0.0040 | **0.75** | < 0.001 | **0.78** | < 0.001 | 0.30 | 0.20 | 0.32 | 0.17 |
| Epifaunal Substrate Score: | Yes | 0.33 | **0.65** | 0.0020 | **0.67** | 0.0011 | **0.69** | < 0.001 | **0.70** | < 0.001 | 0.16 | 0.51 | 0.14 | 0.56 |
| Sediment Deposition Score: | Yes | 0.73 | 0.28 | 0.23 | 0.30 | 0.19 | 0.14 | 0.57 | 0.22 | 0.35 | 0.056 | 0.81 | 0.15 | 0.53 |
| CRAM Land: | No | 0.0050 | **0.61** | 0.0046 | 0.53 | 0.016 | **0.77** | < 0.001 | **0.72** | < 0.001 | 0.39 | 0.089 | 0.43 | 0.056 |
| CRAM Hydro: | Yes | 0.067 | 0.28 | 0.24 | 0.19 | 0.41 | 0.36 | 0.12 | 0.37 | 0.11 | 0.28 | 0.24 | 0.35 | 0.13 |
| CRAM Phys: | Yes | 0.057 | 0.52 | 0.019 | 0.48 | 0.034 | 0.57 | 0.0095 | 0.56 | 0.0104 | 0.081 | 0.74 | 0.049 | 0.83 |
| CRAM Biotic: | Yes | 0.10 | **0.68** | 0.0010 | **0.71** | < 0.001 | **0.75** | < 0.001 | **0.76** | < 0.001 | 0.24 | 0.31 | 0.11 | 0.64 |
| CRAM Total Normalized: | No | < 0.001 | 0.57 | 0.0088 | **0.64** | 0.0026 | **0.63** | 0.0029 | **0.76** | < 0.001 | -0.049 | 0.84 | 0.23 | 0.33 |
| Drainage Area (km2): | No | < 0.001 | 0.40 | 0.082 | 0.37 | 0.11 | 0.38 | 0.10 | 0.17 | 0.46 | -0.38 | 0.097 | -0.39 | 0.087 |
| Elevation (ft): | No | < 0.001 | 0.51 | 0.023 | **0.67** | 0.0012 | 0.58 | 0.0072 | **0.72** | < 0.001 | 0.37 | 0.11 | 0.34 | 0.14 |
| Watershed Precipitation (in): | No | 0.041 | **0.80** | < 0.001 | **0.68** | < 0.001 | **0.85** | < 0.001 | **0.77** | < 0.001 | 0.24 | 0.31 | 0.30 | 0.20 |
| Percent Urban: | No | 0.016 | **-0.71** | < 0.001 | **-0.73** | < 0.001 | **-0.82** | < 0.001 | **-0.78** | < 0.001 | -0.23 | 0.33 | -0.22 | 0.34 |
| Specific Conductivity: | Yes | 0.62 | -0.46 | 0.043 | -0.42 | 0.068 | -0.50 | 0.024 | -0.38 | 0.097 | -0.51 | 0.021 | -0.51 | 0.021 |
| UIA: | No | < 0.001 | -0.019 | 0.94 | -0.042 | 0.86 | -0.046 | 0.85 | -0.028 | 0.90 | 0.074 | 0.76 | -0.054 | 0.82 |
| Ash Free Dry Mass: | No | 0.028 | -0.21 | 0.36 | -0.13 | 0.58 | -0.18 | 0.45 | -0.087 | 0.71 | -0.48 | 0.032 | -0.40 | 0.079 |
| Chloride: | Yes | 0.14 | **-0.70** | < 0.001 | **-0.62** | 0.0035 | **-0.63** | 0.0030 | **-0.61** | 0.0048 | -0.43 | 0.057 | -0.44 | 0.052 |
| Chlorophyll a: | No | < 0.001 | -0.59 | 0.0061 | -0.47 | 0.036 | **-0.60** | 0.0051 | -0.52 | 0.020 | -0.39 | 0.091 | -0.45 | 0.048 |
| Dissolved Organic Carbon: | Yes | 0.11 | -0.57 | 0.0094 | -0.45 | 0.046 | -0.55 | 0.012 | -0.51 | 0.020 | -0.23 | 0.33 | -0.23 | 0.33 |
| Nitrate as N: | No | < 0.001 | -0.54 | 0.015 | **-0.69** | < 0.001 | -0.38 | 0.099 | **-0.68** | < 0.001 | -0.26 | 0.26 | 0.016 | 0.95 |
| Nitrogen, Total Kjeldahl: | No | < 0.001 | **-0.65** | 0.0018 | **-0.66** | 0.0017 | -0.55 | 0.013 | -0.59 | 0.0063 | -0.045 | 0.85 | 0.083 | 0.72 |
| OrthoPhosphate as P: | No | < 0.001 | -0.33 | 0.16 | 0.10 | 0.67 | -0.17 | 0.47 | 0.25 | 0.28 | -0.12 | 0.60 | 0.14 | 0.56 |
| Phosphorus as P: | No | < 0.001 | -0.37 | 0.11 | -0.078 | 0.74 | -0.20 | 0.40 | 0.12 | 0.60 | -0.13 | 0.59 | 0.15 | 0.53 |
| Suspended Sediment Concentration: | No | < 0.001 | -0.16 | 0.50 | -0.16 | 0.5 | -0.094 | 0.69 | -0.11 | 0.64 | **0.61** | 0.0043 | 0.59 | 0.0065 |

### 5.4.2 Nutrients and Conventional Analytes

Descriptive statistics for nutrient and conventional analyte concentrations measured in samples collected synoptically during bioassessments are listed in Table 5.12. Chlorophyll α and AFDM were measured in µg/L and mg/L, respectively, and were converted to volume per area units using a module developed by EOA. Trigger thresholds for chloride, unionized ammonia and nitrate are shown in Table 5.11 for reference. No samples exceeded the thresholds.

Table 5.11. Descriptive statists for water chemistry results in San Mateo County during water years 2012 and 2013.

| Nutrients and Conventional Analytes | Units | N | **N ≥ RL** | Min | Max | Mean[1] | Median[1] | Trigger Threshold | Trigger Exceedance |
|---|---|---|---|---|---|---|---|---|---|
| Alkalinity (as $CaCO_3$) | *(mg/L)* | 20 | 20 | 43 | 550 | 260 | 238 | -- | -- |
| Ash Free Dry Mass | *(g/m²)* | 23 | 23 | 17 | 481 | 144 | 122 | -- | -- |
| Chloride | *(mg/L)* | 23 | 23 | 13 | 130 | 54 | 47 | 230/250[2] | 0% |
| Chlorophyll α | *(mg/m²)* | 23 | 14 | 2.4 | 152 | 32 | 12 | -- | -- |
| Dissolved Organic Carbon | *(mg/L)* | 23 | 23 | 1.6 | 9.4 | 4.0 | 3.2 | -- | -- |
| Ammonia (as N) | *(mg/L)* | 23 | 6 | < 0.04 | 0.46 | 0.08 | 0.06 | -- | -- |
| Unionized Ammonia (as N)[3] | *(µg/L)* | 23 | 6 | 0.01 | 5 | 0.9 | 0.3 | 25 | 0% |
| Nitrate (as N) | *(mg/L)* | 23 | 18 | < 0.01 | 8.1 | 0.69 | 0.19 | 10 | 0% |
| Nitrite (as N) | *(mg/L)* | 23 | 1 | < 0.001 | 0.04 | 0 | 0 | -- | -- |
| Total Kjeldahl Nitrogen (as N) | *(mg/L)* | 23 | 17 | < 0.14 | 1.4 | 0.33 | 0.19 | -- | -- |
| OrthoPhosphate (as P) | *(mg/L)* | 23 | 21 | 0 | 3 | 0.23 | 0.09 | -- | -- |
| Phosphorus (as P) | *(mg/L)* | 23 | 23 | 0 | 3 | 0.23 | 0.08 | -- | -- |
| Suspended Sediment Concentration | *(mg/L)* | 20 | 12 | < 2 | 28 | 6.3 | 4.2 | -- | -- |
| Silica (as $SiO_2$) | *(mg/L)* | 20 | 20 | 9.1 | 68 | 25 | 22 | -- | -- |

1 Mean and median concentrations calculated using ½ the method detection limit (MDL) for samples below the detection limit (ND).
2 The nitrate and 250 mg/L chloride thresholds apply to Title 22 drinking waters and sites with MUN beneficial use only.
3 Unionized ammonia estimated from ammonia, pH, temperature, and specific conductance per Emerson et al., 1975.

Percent algal cover and chlorophyll α (mg/m$^2$) data were compared to assess whether a relationship exists between these two algal biomass indicators. Overall, the correlation is weak ($R^2$ = 0.09) suggesting that the two indicators are detecting different aspects of the algal condition.

### 5.4.3 Chlorine

Field testing for free chlorine and total chlorine residual was conducted at all probabilistic sites synoptic with spring bioassessment sampling and at a subset of the sites synoptic with dry season toxicity sampling. Chlorine concentrations and comparisons to the MRP Table 8.1 trigger threshold are listed in Table 5.12. The MRP trigger criterion for chlorine states, “After immediate resampling, concentrations remain >0.08 mg/L”. If a repeat chlorine measurement was not conducted, the original measurement was evaluated. Twelve measurements were collected in both water years resulting in a total of twenty-four measurements. Of the total, 13% exceeded the threshold for free chlorine, and 8% exceeded the threshold for total chlorine residual. (As noted previously, free chlorine measurements sometimes exceed total chlorine measurements, possibly as a result of method limitations or natural variability.) Several of the measurements were equal to but did not exceed the trigger criterion. The exceedances represent data from three urban sites. The free chlorine trigger was exceeded in Belmont Creek in July 2013 but not in May 2013, illustrating either natural variability over time or intermittent causes.

Table 5.12. Summary of SMCWPPP chlorine testing results in comparison to MRP trigger criteria, Water Years 2012 and 2013

| Station Code | Date | Creek | Free Chlorine (mg/L)[1, 2] | Total Chlorine Residual (mg/L)[1, 2] | Exceeds Trigger?[3] (0.08 mg/L) |
|---|---|---|---|---|---|
| 202R00024 | 6/6/2012 | Woodhams Creek | < 0.04 | < 0.04 | No |
| 202R00072 | 5/29/2012 | Pilarcitos Creek | < 0.04 | < 0.04 | No |
| 202R00087 | 5/30/2012 | Milagra Creek | < 0.04 | < 0.04 | No |
| 202R00087 | 7/25/2012 | Milagra Creek | 0.04 | 0.04 | No |
| 202R00248 | 5/23/2013 | San Gregorio Creek | < 0.04 | < 0.04 | No |
| 202R00280 | 5/22/2013 | Tributary to Alpine Creek | < 0.04 | < 0.04 | No |
| 202R00284 | 6/15/2012 | Denniston Creek | < 0.04 | < 0.04 | No |
| 202R00908 | 5/21/2013 | Calera Creek | > 0.2/> 0.2[4] | > 0.2/> 0.2[4] | Yes |
| 204R00180 | 5/30/2012 | Sanchez Creek | 0.04 | 0.04 | No |
| 204R00200 | 5/31/2012 | Polhemus Creek | 0.05[5] | 0.04 | No |
| 204R00232 | 6/12/2012 | Arroyo Ojo De Agua | < 0.04 | < 0.04 | No |
| 204R00244 | 6/12/2012 | Trib to Arroyo Ojo De Agua | 0.16[5] | 0.12 | Yes |
| 204R00436 | 5/20/2013 | Easton Creek | < 0.04 | < 0.04 | No |
| 204R00520 | 5/28/2013 | Belmont Creek | < 0.04 | < 0.04 | No |
| 204R00520 | 7/9/2013 | Belmont Creek | 0.2[5] | < 0.04 | Yes |
| 204R00680 | 5/28/2013 | Redwood Creek | < 0.04 | < 0.04 | No |
| 204R00680 | 7/9/2013 | Redwood Creek | 0.06 | 0.06 | No |
| 204R00807 | 5/21/2013 | Colma Creek | 0.06 | 0.08 | No |
| 204R00884 | 5/20/2013 | Easton Creek | < 0.04 | < 0.04 | No |
| 205R00088 | 6/4/2012 | Corte Madera Creek | < 0.04 | < 0.04 | No |
| 205R00088 | 7/25/2012 | Corte Madera Creek | 0.08 | 0.08 | No |
| 205R00168 | 6/4/2012 | Corte Madera Creek | < 0.04 | < 0.04 | No |
| 205R00872 | 8/27/2013 | Bear Gulch Creek | < 0.04 | < 0.04 | No |
| 205R00984 | 5/27/2013 | Bear Gulch Creek | < 0.04 | < 0.04 | No |
| Number of samples exceeding 0.08 mg/L: | | | 3 | 2 | -- |
| Percentage of samples exceeding 0.08 mg/L: | | | 13% | 8% | -- |

[1] The method detection limit for free and total chlorine is 0.04 mg/L.

[2] Original and repeat samples are reported where conducted.

[3] The trigger applies to both free and total chlorine measurements.

[4] The high range kit was unavailable at Calera Creek (202R00908) on 5/21/13.

[5] Free chlorine concentration higher than total chlorine concentration, possibly due to method limitations or natural variability.

### 5.4.4 Water and Sediment Toxicity

Water toxicity samples were collected from a subset of urban probabilistic sites twice per year, during storm events and summer dry conditions. Samples were tested for toxic effects using four species: an aquatic plant (*Selenastrum capricornutum*), two aquatic invertebrates (*Ceriodaphnia dubia* and *Hyalella azteca*), and one fish species (*Pimephales promelas* or fathead minnow). Both acute and chronic endpoints (survival and reproduction/growth) were analyzed for *Ceriodaphnia dubia* and *Pimephales promelas*. *Selenastrum capricornutum* are tested only for the chronic (growth) endpoint and *Hyalella azteca* are tested only for the acute (survival) endpoint.

Table 5.13 provides a summary of toxicity testing results for water samples. Three water sample were found to be chronically toxic to *Ceriodaphnia dubia,* two samples were acutely toxic to *Hyalella azteca,* one sample was chronically toxic to fathead minnows, and two samples were acutely toxic to *Pimephales promelas*. See below for the discussion on whether these samples exceed trigger thresholds.

Per EPA guidance, it is not required that samples with a significant reduction in *P. promelas* survival are evaluated for chronic endpoints. One of the toxic *P. promelas* test results were determined by the toxicity testing laboratory to have been caused by interference due to pathogen-related mortality (PRM), a common source of laboratory interference in receiving water samples. The lab reports for these samples include the following statement relative to the PRM-affected samples: "observations of PRM are not associated with or indicative of stormwater toxicity". This sample was re-tested using a method developed to minimize PRM interference (Geis et al., 2003) and no toxic response was observed, as discussed below.

During the dry season, sediment samples were collected at the same probabilistic sites and tested for sediment toxicity and an extensive list of sediment chemistry constituents. For sediment toxicity, testing was performed with just one species, *Hyalella azteca*. Both acute and chronic endpoints (survival and growth) were analyzed. Table 5.14 provides a summary of toxicity testing results for sediment samples. One WY2013 sediment sample was determined to be acutely toxic. See below for the discussion on whether this samples exceeds the trigger threshold. No chronic endpoint results indicated chronic toxicity at any site.

Table 5.13. Summary of SMCWPPP water toxicity results, Water Years 2012 and 2013.

| SMCWPPP Water Samples | | | Test Initiation Date | Toxicity relative to the Lab Control treatment? | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample Station | Creek | Sample Date | | *Selenastrum capricornutum* | *Ceriodaphnia dubia* | | *Hyalella azteca* | Fathead Minnow | |
| | | | | Growth | Survival | Reproduction | Survival | Survival | Growth |
| 202R00087 | Milagra | 3/17/12 | 3/17/12 | No | No | No | No | No | Yes |
| 205R00088 | Corte Madera | 3/17/12 | 3/17/12 | No | No | Yes | No | No | No |
| 202R00087 | Milagra | 7/25/12 | 7/26/12 | No | No | No | No | No | No |
| 205R00088 | Corte Madera | 7/25/12 | 7/26/12 | No | No | No | No | No | No |
| 205R00088 | Corte Madera[1] | 3/6/13 | 3/6/13 | -- | No | No | -- | -- | -- |
| 204R00520 | Belmont | 3/5/13 | 3/6/13 | No | No | Yes | Yes | No | No |
| 204R00680 | Redwood | 3/5/13 | 3/6/13 | No | No | Yes | Yes | Yes * | No |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 204R00520 | Belmont[2] | 4/4/13 | 4/5/13 | -- | -- | -- | No | -- | -- |
| 204R00520 | Belmont | 7/9/13 | 7/10/13 | No | No | No | No | Yes | N/A[3] |
| 204R00680 | Redwood | 7/9/13 | 7/10/13 | No | No | No | No | No | No |

-- = not sampled, N/A = not applicable

* PRM was observed in multiple replicates for this stormwater sample; toxicity was not observed in re-tests using Geis technique.

[1] Corte Madera Creek (205R00088) was re-sampled on 3/6/13 as follow-up to the *Ceriodaphnia dubia* toxicity detected on 3/17/12.

[2] Belmont Creek (204R00520) was re-sampled on 4/4/13 as follow-up to the *Hyalella azteca* toxicity detected on 3/5/13.

[3] As per EPA guidance, samples with a significant reduction in survival are not evaluated for growth toxicity.

Table 5.14. Summary of SMCWPPP dry season sediment toxicity results, Water Years 2012 and 2013.

| Dry Season Sediment Samples | | | Date of Analysis | Toxicity relative to the Lab Control treatment? | |
|---|---|---|---|---|---|
| | | | | *Hyalella azteca* | |
| Sample Station | Creek | Collection Date | | Survival | Growth |
| 202R00087 | Milagra | 7/25/12 | 7/28/12 | No | No |
| 205R00088 | Corte Madera | 7/25/12 | 7/28/12 | No | No |
| 204R00520 | Belmont | 7/14/13 | 7/10/13 | Yes | N/A* |
| 204R00680 | Redwood | 7/14/13 | 7/10/13 | No | No |

* Per EPA guidance, samples with a significant reduction in survival are not evaluated for chronic endpoints (i.e., growth).

Table 5.15 provides details results for the water and sediment tests that were found to be toxic to *Ceriodaphnia dubia* and *Hyalella azteca* relative to the laboratory control (via statistical comparison at p=0.5), along with comparisons to the relevant trigger criteria from MRP Tables 8.1 and H-1. The WY2012 water sample from Corte Madera Creek met the MRP Table 8.1 trigger of less than 50% of the control. Resampling at this station for *Ceriodaphnia dubia* toxicity during the WY2012 dry season and the WY2013 wet season did not indicate toxicity. The WY2013 wet season samples in Belmont and Redwood Creeks for *Ceriodaphnia dubia* toxicity did not meet the MRP Table 8.1 trigger criteria. However, the Belmont Creek *Hyalella azteca* sample did exceed the MRP Table 8.1 trigger. Belmont Creek was resampled for *Hyalella azteca* toxicity the following month and was not found to be toxic relative to the laboratory control.

All single sediment sample with toxicity relative to the lab control did not meet the MRP Table H-1 trigger criteria of more than 20% less than the control.

Table 5.15. Comparison between laboratory control and SMCWPPP water and sediment receiving sample toxicity results (*Hyalella azteca and Ceriodaphnia dubia*) in the context of MRP trigger criteria.

| Treatment/ Sample ID | Creek | Test Initiation Date (Time) | Species Tested | 10-Day Mean % Survival | Mean Reproduction | Comparison to MRP Table 8.1 Trigger Criteria |
|---|---|---|---|---|---|---|
| Lab Control | N/A | 3/25/12 (1400) | *Ceriodaphnia dubia* | 100 | 33.1 | N/A |
| 205R00088 | Corte Madera[1] | | | 100 | 16.3* | < 50% of Control |
| Lab Control | N/A | | | 100 | 36.6 | N/A |

| | | | | | | |
|---|---|---|---|---|---|---|
| 204R00520 | Belmont | 3/6/13 (1630) | *Ceriodaphnia dubia* | 100 | 29.3 | Not < 50% of Control |
| 204R00680 | Redwood | | | 80 | 27.9 | Not < 50% of Control |
| Lab Control | N/A | 3/7/13 (1010) | *Hyalella azteca* | 98 | NA | N/A |
| 204R00520 | Belmont[2] | | | **18*** | | **< 50% of Control** |
| 204R00680 | Redwood | | | 64* | | Not < 50% of Control |
| Lab Control | N/A | 7/14/13 (1500) | *Hyalella azteca* | 98.8 | NA | N/A |
| 204R00520 | Belmont | | | 83.8* | | Not more than 20% < Control |

1.

2. Corte Madera Creek was resampled for *Ceriodaphnia dubia* toxicity during the WY2013 wet season. Toxicity was not indicated in the resample.

3. Belmont Creek was resampled for *Hyalella azteca* toxicity in April 2013. Toxicity was not indicated in the resample.

Table 5.16 provides detailed results for the three *P. promelas* tests with statistically different results from laboratory controls, along with comparisons to the relevant trigger criteria from MRP Table 8.1. No sample was less than the association MRP threshold of less than 50% of the control values for either survival or growth. Two of the samples were found to be affected by PRM interference, based on visual examination of test organisms by the testing laboratory. SMCWPPP and the RMC are addressing the need for more extensive documentation of PRM interference in WY2014 through contractual agreements with the analytical laboratory.

Table 5.16. Comparison between laboratory control and SMCWPPP receiving water sample toxicity results for *Pimephales promelas* in the context of MRP trigger criteria.

| Treatment/ Sample ID | Creek | Test Initiation Date (Time) | Mean % Survival | Comparison to MRP Table 8.1 Trigger Criteria; Identification of PRM effects and PRM Method Re-tests |
|---|---|---|---|---|
| Lab Control | N/A | 3/17/12 (1700) | 97.5 | N/A |
| 202R00087 | Milagra | | 90 | Not < 50% of Control |
| Lab Control | N/A | 3/6/13 (1630) | 100 | N/A |
| 204R00680 | Redwood | | 65* (a) | Not < 50% of Control; PRM noted |
| Lab Control | N/A | 7/10/13 (1630) | 97.5 | N/A |
| 204R00520 | Belmont | | 50* (a) | Not < 50% of Control; PRM noted |

* The response at this test treatment was significantly less than the Lab Control at $p < 0.05$.

(a) PRM was observed in multiple replicates for this stormwater sample.

### 5.4.5 Sediment Chemistry & Sediment Triad Approach

Sediment chemistry results are evaluated as potential stressors based on TEC quotients, PEC quotients, and TU equivalents, according to criteria in Table H-1 of the MRP which are summarized in Section 4.3.3 of this report. Any sample that meets one or more of criteria are compared to the sediment toxicity and bioassessment results for that site. These comparisons are performed in the Sediment Triad Assessment presented below.

Table 5.17 lists TEC quotients for all non-pyrethroid sediment chemistry constituents, calculated as the measured concentration divided by the TEC value, per MacDonald et al. (2000). This table also provides a count of the number of constituents that exceed TEC values for each site, as evidenced by a TEC quotient greater than or equal to 1.0. The number of TEC quotients exceeded per site ranges from a low of zero to a high of ten, out of 27 constituents included in MacDonald et al. (2000). All four sites exceeded the relevant trigger criterion from MRP Table H-1, which is interpreted to stipulate three or more constituents with TEC quotients greater than or equal to 1.0.

Table 5.18 provides PEC quotients for all non-pyrethroid sediment chemistry constituents, and calculated mean values of the PEC quotients for each site. No sites meet the MRP Table H-1 action criteria with a mean PEC greater than 0.5.

Table 5.19 provides a summary of the calculated TU equivalents for the pyrethroids for which there are published LC50 values in the literature, as well as a sum of TU equivalents for each site. Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC50 values were derived on the basis of TOC-normalized pyrethroid concentrations. Therefore, the pyrethroid concentrations as reported by the lab were divided by the measured TOC concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid. The individual TU equivalents were summed to produce a total pyrethroid TU equivalent value for each site. None of the four sites meet the MRP Table H-1 action criterion with TU sums greater than or equal to 1.0.

Some of the calculated numbers for TEC quotients, PEC quotients, and pyrethroid TU equivalents may be artificially elevated due to the method used to account for filling in non-detect data (concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data so these statistics could be computed).

High levels of naturally-occurring chromium and nickel in geologic formations (i.e., serpentinite) and soils can contribute to TEC and PEC quotients, particularly for sites located higher in the watersheds where contributing watersheds contain a higher percent of natural sources.

Table 5.17. Threshold Effect Concentration (TEC) quotients for Water Years 2012 and 2013 sediment chemistry constituents, SMCWPPP. Bolded values indicate TEC quotient ≥ 1.0. Shaded cells indicate sum of TEC quotients ≥ 3.

| Site ID, Creek | TEC | WY2012 | | WY2013 | |
|---|---|---|---|---|---|
| | | 202R00087 | 205R00088 | 204R00520 | 204R00680 |
| | | Milagra | Corte Madera | Belmont | Redwood |
| **Metals (mg/kg DW)** | | | | | |
| Arsenic | *9.79* | 0.08 | 0.49 | 0.32 | 0.34 |
| Cadmium | *0.99* | 0.10 | 0.31 | 0.11 | 0.10 |
| Chromium | *43.4* | **9.95** | 0.58 | **1.13** | **3.46** |
| Copper | *31.6* | **1.65** | 0.54 | **1.01** | 0.76 |
| Lead | *35.8* | 0.08 | 0.16 | 0.47 | **1.15** |
| Mercury | *0.18* | 0.03 [b] | 0.37 | 0.35 | 0.19 |
| Nickel | *22.7* | **13.3** | **2.07** | **2.60** | **11.0** |
| Zinc | *121* | 0.65 | 0.49 | 0.82 | 0.64 |
| **PAHs (µg/kg DW)** | | | | | |
| Anthracene | *57.2* | 0.04 [a] | 0.06 [a] | 0.05 [a] | **1.15** |
| Fluorene | *77.4* | 0.03 [a] | 0.05 [a] | 0.04 [a] | 0.30 |
| Naphthalene | *176* | 0.01 [a] | 0.02 [a] | 0.02 [a] | 0.24 |
| Phenanthrene | *204* | 0.01 [a] | 0.13 [b] | 0.19 | **1.91** |
| Benz(a)anthracene | *108* | 0.02 [a] | 0.22 [b] | 0.62 | **4.63** |
| Benzo(a)pyrene | *150* | 0.01 [a] | 0.07 [b] | 0.10 | **1.13** |
| Chrysene | *166* | 0.01 [a] | 0.20 [b] | 0.33 | **2.41** |
| Dibenz[a,h]anthracene | *33.0* | 0.06 [a] | 0.11 [a] | 0.09 [a] | 0.09 [a] |
| Fluoranthene | *423* | 0.005 [a] | 0.13 | 0.28 | **2.29** |
| Pyrene | *195* | 0.01 [a] | 0.25 [b] | 0.62 | **4.51** |
| Total PAHs | *1,610* | 0.05 [c] | 0.23 [c] | 0.32 [c] | **2.65 [c]** |
| **Pesticides (µg/kg DW)** | | | | | |
| Chlordane | *3.24* | 0.86 [a] | 0.74 [a] | 0.4 [a] | 0.4 [a] |
| Dieldrin | *1.90* | 0.87 [a] | 0.76 [a] | 0.37 [a] | 0.37 [a] |
| Endrin | *2.22* | 0.32 [a] | 0.27 [a] | 0.34 [a] | 0.34 [a] |
| Heptachlor Epoxide | *2.47* | 0.45 [a] | 0.4 [a] | 0.13 [a] | 0.13 [a] |
| Lindane (gamma-BHC) | *2.37* | 0.40 [a] | 0.36 [a] | 0.14 [a] | 0.14 [a] |
| Sum DDD | *4.88* | 0.79 [c] | 0.71 [c] | 0.22 [c] | 0.21 [c] |
| Sum DDE | *3.16* | **1.39 [c]** | **1.23 [c]** | 0.29 [c] | 0.49 [c] |
| Sum DDT | *4.16* | 0.87 [c] | 0.77 [c] | 0.17 [c] | 0.17 [c] |
| Total DDTs | *5.28* | **2.24 [c]** | **2.00 [c]** | 0.51 [c] | 0.63 [c] |
| **Number of constituents with TEC quotient ≥ 1.0** | - | **5** | **3** | **3** | **11** |

[a] Concentration was below the method detection limit (MDL). TEC quotient calculated using ½ MDL.
[b] TEC quotient calculated from concentration below the reporting limit (DNQ-flagged).
[c] Total calculated using ½ MDLs.

Table 5.18. Probable Effect Concentration (PEC) quotients for Water Years 2012 and 2013 sediment chemistry constituents, SMCWPPP. Bolded values indicate individual PEC quotients > 1.0; mean PEC quotients did not exceed 0.5.

| Site ID, Creek | PEC | WY2012 | | WY2013 | |
|---|---|---|---|---|---|
| | | 202R00087 | 205R00088 | 204R00520 | 204R00680 |
| | | Milagra | Corte Madera | Belmont | Redwood |
| **Metals (mg/kg DW)** | | | | | |
| Arsenic | *33.0* | 0.02 | 0.15 | 0.09 | 0.10 |
| Cadmium | *4.98* | 0.02 | 0.06 | 0.02 | 0.02 |
| Chromium | *111* | **3.89** | 0.23 | 0.44 | **1.35** |
| Copper | *149* | 0.35 | 0.11 | 0.21 | 0.16 |
| Lead | *128* | 0.02 | 0.04 | 0.13 | 0.32 |
| Mercury | *1.06* | 0.01[b] | 0.06 | 0.06 | 0.03 |
| Nickel | *48.6* | **6.19** | 0.97 | **1.21** | **5.14** |
| Zinc | *459* | 0.17 | 0.13 | 0.22 | 0.17 |
| **PAHs (µg/kg DW)** | | | | | |
| Anthracene | *845* | 0.002[a] | 0.004[a] | 0.004[a] | 0.08 |
| Fluorene | *536* | 0.004[a] | 0.01[a] | 0.01[a] | 0.04 |
| Naphthalene | *561* | 0.004[a] | 0.01[a] | 0.01[a] | 0.08 |
| Phenanthrene | *1170* | 0.002[a] | 0.02[b] | 0.03 | 0.33 |
| Benz(a)anthracene | *1050* | 0.002[a] | 0.02[b] | 0.06 | 0.48 |
| Benzo(a)pyrene | *1450* | 0.001[a] | 0.01[b] | 0.01 | 0.12 |
| Chrysene | *1290* | 0.002[a] | 0.03[b] | 0.04 | 0.31 |
| Fluoranthene | *2230* | 0.001[a] | 0.02 | 0.05 | 0.43 |
| Pyrene | *1520* | 0.001[a] | 0.03[b] | 0.08 | 0.58 |
| Total PAHs | *22,800* | 0.003[c] | 0.02[c] | 0.02[c] | 0.19[c] |
| **Pesticides (µg/kg DW)** | | | | | |
| Chlordane | *17.6* | 0.16[a] | 0.14[a] | 0.07[a] | 0.07[a] |
| Dieldrin | *61.8* | 0.03[a] | 0.02[a] | 0.01[a] | 0.01[a] |
| Endrin | *207.0* | 0.003[a] | 0.003[a] | 0.004[a] | 0.004[a] |
| Heptachlor Epoxide | *16* | 0.07[a] | 0.06[a] | 0.02[a] | 0.02[a] |
| Lindane (gamma-BHC) | *4.99* | 0.19[a] | 0.17[a] | 0.07[a] | 0.07[a] |
| Sum DDD | *28* | 0.14[c] | 0.12[c] | 0.04[c] | 0.04[c] |
| Sum DDE | *31.3* | 0.14[c] | 0.12[c] | 0.03[c] | 0.05[c] |
| Sum DDT | *62.9* | 0.06[c] | 0.05[c] | 0.01[c] | 0.01[c] |
| Total DDTs | *572* | 0.02[c] | 0.02[c] | 0.005[c] | 0.01[c] |
| **Mean PEC quotient** | - | **0.44** | **0.10** | **0.11** | **0.38** |

[a] Concentration was below the method detection limit (MDL). PEC quotient calculated using ½ MDL.
[b] PEC quotient calculated from concentration below the reporting limit (DNQ-flagged).
[c] Total calculated using ½ MDLs.

Table 5.19. Calculated pyrethroid toxic unit (TU) equivalents for Water Years 2012 and 2013 pyrethroid concentrations, SMCWPPP. Total TU equivalents did not exceed 1.0.

| Pyrethroid | Unit | LC50 | WY2012 | | WY2013 | |
|---|---|---|---|---|---|---|
| | | | 202R00087 | 205R00088 | 204R00520 | 204R00680 |
| | | | Milagra | Corte Madera | Belmont | Redwood |
| Bifenthrin | µg/g dw | 0.52 | 0.24[b] | 0.04[b] | 0.66 | 0.12 |
| Cyfluthrin | µg/g dw | 1.08 | 0.04[a] | 0.02[b] | 0.18 | 0.02[a] |
| Cypermethrin | µg/g dw | 0.38 | 0.11[a] | 0.06[b] | 0.04[a] | 0.06[a] |
| Deltamethrin | µg/g dw | 0.79 | 0.06[a] | 0.04[b] | 0.03[a] | 0.18 |
| Esfenvalerate | µg/g dw | 1.54 | 0.03[a] | 0.02[b] | 0.01[a] | 0.01[a] |
| Lambda-Cyhalothrin | µg/g dw | 0.45 | 0.05[a] | 0.02[b] | 0.04[a] | 0.06[a] |
| Permethrin | µg/g dw | 10.83 | 0.004[a] | 0.02 | 0.02 | 0.06 |
| **Sum of Toxic Unit Equivalents per Site** | - | - | **0.54** | **0.23** | **0.98** | **0.53** |

[a] Concentration was below the method detection limit (MDL). TU equivalent calculated using ½ MDL.
[b] TU equivalent calculated from concentration below the reporting limit (DNQ-flagged).

### Sediment Triad Analysis

The three aspects of the STA (chemistry, toxicity, bioassessment) are presented in Table 5.20. As defined in MRP Table H-1, these results indicate that all of the four sites should be considered for future evaluation of stressor source identification projects.

Table 5.20. Summary of sediment triad analysis for Water Years 2012 and 2013, SMCWPPP. Bolded values indicate exceedance of threshold.

| Site ID | Waterbody | Chemistry | | | Toxicity | Bioassessment |
|---|---|---|---|---|---|---|
| | | # TEC Quotients ≥ 1.0: | Mean PEC Quotient | Sum of TU Equiv. | Sediment Toxicity | B-IBI Condition Category |
| Water Year 2012 | | | | | | |
| 202R00087 | Milagra Creek | 5 | 0.44 | 0.54 | No | Fair |
| 205R00088 | Corte Madera | 3 | 0.10 | 0.23 | No | Good |
| Water Year 2013 | | | | | | |
| 204R00520 | Belmont Creek | 3 | 0.11 | 0.98 | No | **Poor** |
| 204R00680 | Redwood Creek | 11 | 0.38 | 0.53 | No | **Poor** |

## 5.4.6 Temperature

Summary statistics for water temperature data collected at five sites in Pilarcitos Creek during WY2012 and at four sites in San Mateo Creek during WY2013 are shown in Table 5.21 and Table 5.22, respectively. Station locations are mapped in Figures 5.14 and 5.15. Hourly temperature data was collected between April and September for both years of the project.

Table 5.21 Descriptive statistics for continuous water temperature measured at five sites in Pilarcitos Creek from April 23rd through September 25th, 2012.

| | Creek Name | Pilarcitos Creek | | | | |
|---|---|---|---|---|---|---|
| | Site | 205PIL030 | 205PIL100 | 205PIL150 | 205PIL340 | 205PIL650 |
| | Start Date | 4/23/2012 | 4/23/2012 | 4/23/2012 | 4/23/2012 | 4/23/2012 |
| | End Date | 9/25/2012 | 9/25/2012 | 9/25/2012 | 9/25/2012 | 9/25/2012 |
| Temperature (°C) | Minimum | 10.1 | 10.0 | 10.1 | 10.0 | 9.8 |
| | Median | 13.6 | 13.5 | 13.5 | 13.3 | 13.2 |
| | Mean | 13.6 | 13.4 | 13.4 | 13.2 | 13.1 |
| | Maximum | 17.6 | 16.3 | 16.0 | 16.0 | 15.4 |
| | Max 7-day Mean | 14.7 | 14.5 | 14.5 | 14.4 | 14.4 |
| | N | 3716 | 3716 | 3716 | 3717 | 3717 |

The results from both creeks show that temperatures were relatively consistent between sites within each creek. Box plots showing the distribution of water temperature data at five sites in Pilarcitos Creek during WY2012 and at four sites in San Mateo Creek during WY2013 are shown in Figures 5.16 and 5.17, respectively. The acute temperature threshold (24.0 °C) is shown on both figures. Temperatures were below the acute threshold at all sites for both creeks.

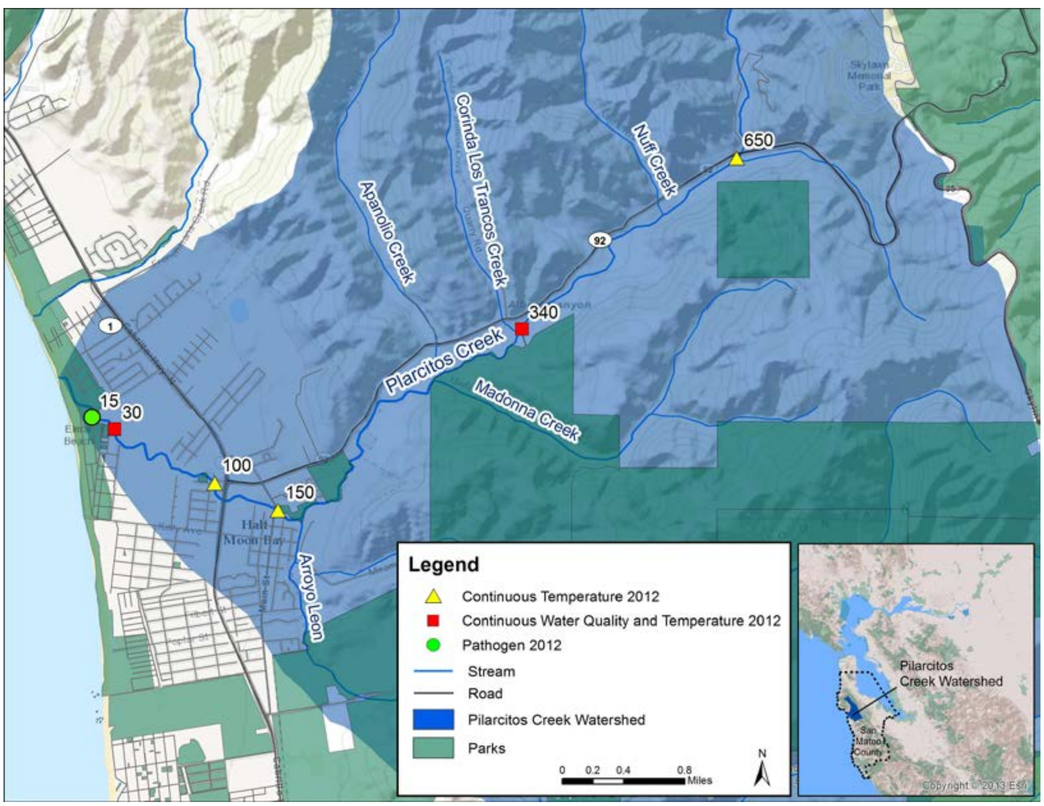


Figure 5.14. Continuous temperature stations in Pilarcitos Creek.

Box plots showing the distribution of water temperature data, calculated as the 7-day mean, for five sites in Pilarcitos Creek during WY2012 and at four sites in San Mateo Creek are shown in Figures 5.16 and 5.17, respectively. The chronic (maximum 7-day mean) temperature (MWAT) threshold (19.0 °C) is shown in both figures.

Table 5.22 Descriptive statistics for continuous water temperature measured at four sites in San Mateo Creek from April 26th through September 30th, 2013.

| | Creek Name | San Mateo Creek | | | |
|---|---|---|---|---|---|
| | Site | 204SMA070 | 204SMA081 | 204SMA085 | 204SMA090 |
| | Start Date | 4/26/2013 | 4/26/2013 | 4/26/2013 | 4/26/2013 |
| | End Date | 9/30/2013 | 9/30/2013 | 9/30/2013 | 9/30/2013 |
| Temperature (°C) | Minimum | 12.6 | 12.1 | 11.7 | 11.7 |
| | Median | 16.1 | 16.2 | 16.4 | 16.6 |
| | Mean | 16.1 | 16.2 | 16.5 | 16.6 |
| | Maximum | 20.4 | 20.2 | 22.0 | 22.0 |
| | Max 7-day Mean | 18.5 | 18.6 | 19.4 | 19.5 |
| | N | 3765 | 3765 | 3765 | 3765 |

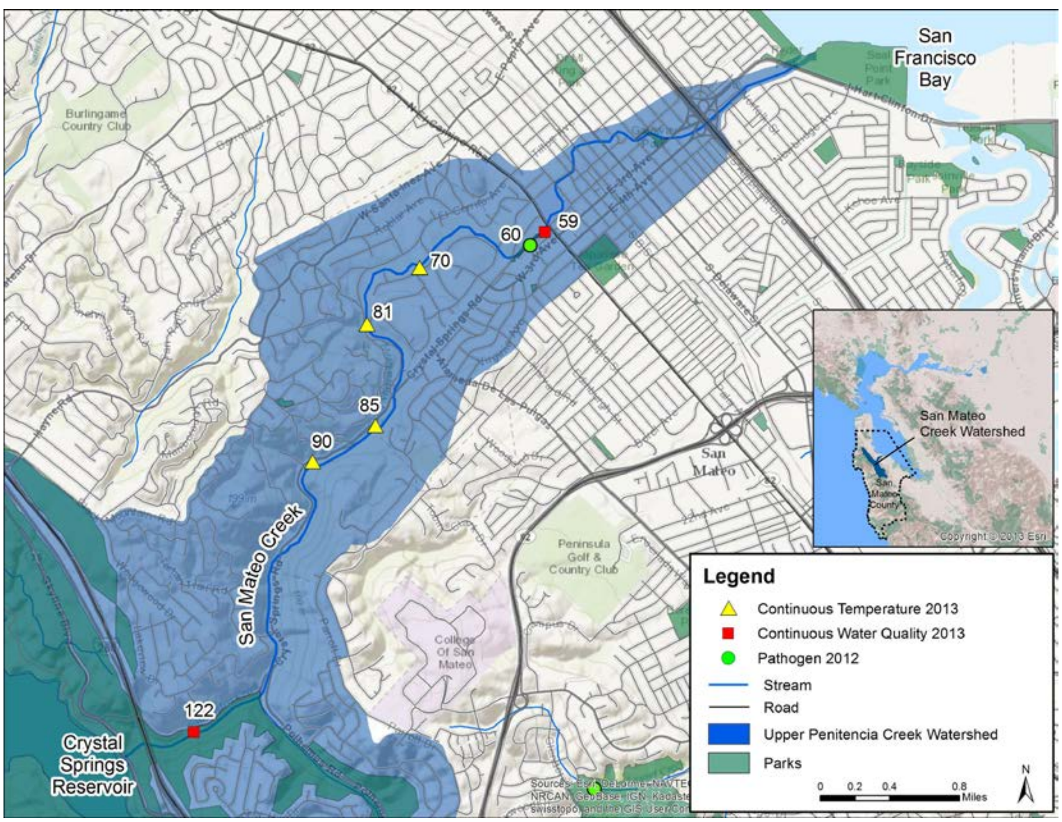


Figure 5.15. Continuous temperature stations in San Mateo Creek.

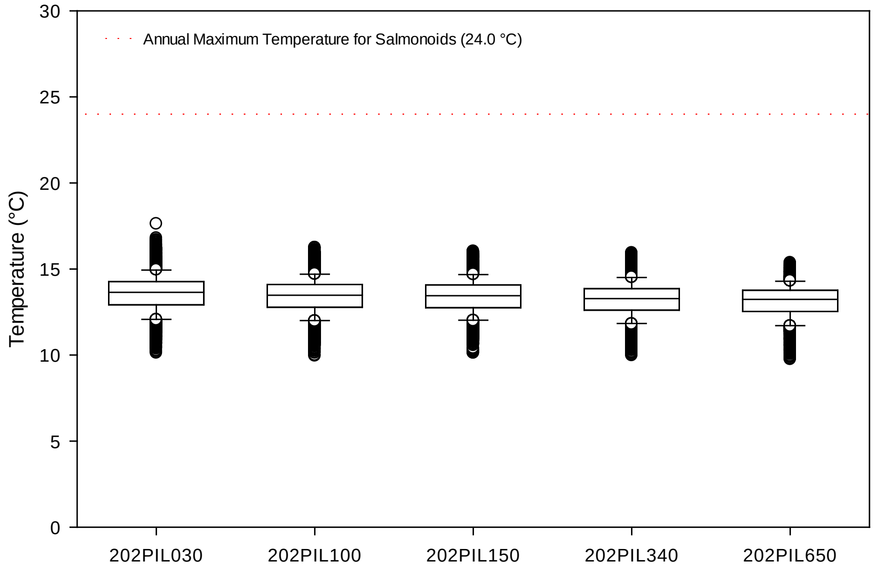


Figure 5.16. Box plots of water temperature data collected at five sites in Pilarcitos Creek, San Mateo County, from April through September 2012.

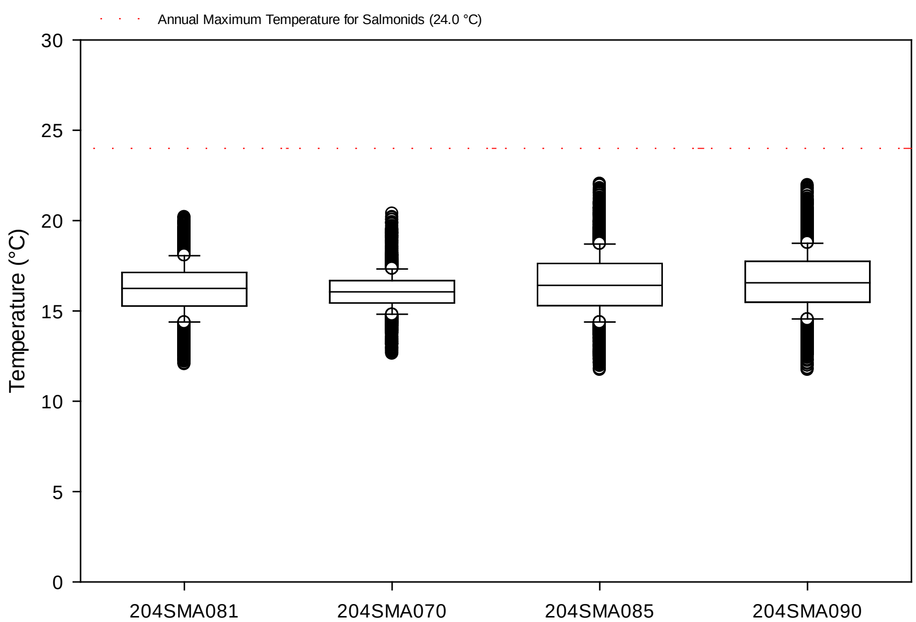


Figure 5.17 Box plots of water temperature data collected at four sites in San Mateo Creek, San Mateo County, from April through September 2013.

Box plots showing the distribution of water temperature data, calculated as the 7-day mean, for five sites in Pilarcitos Creek during WY2012 and at four sites in San Mateo Creek are shown in Figures 5.18 and 5.19, respectively. The chronic (maximum 7-day mean) temperature (MWAT) threshold (19.0 °C) is shown in both figures.

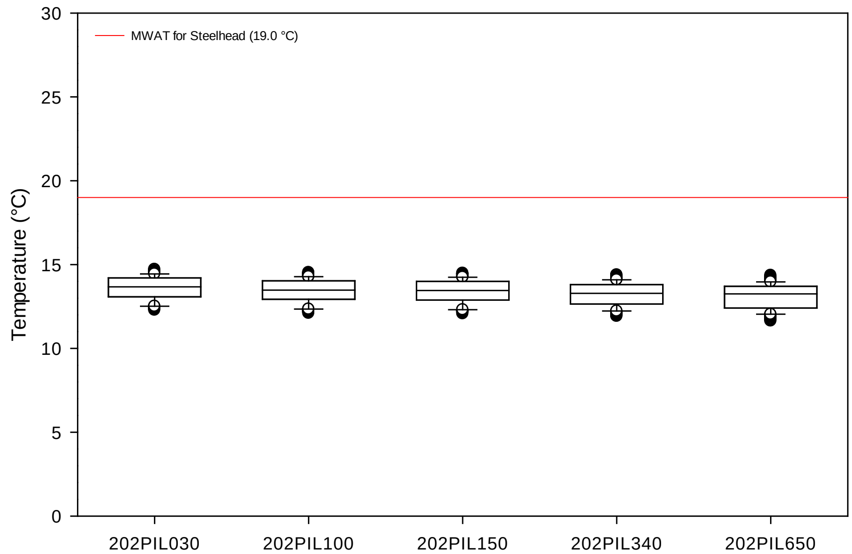


Figure 5.18 Box plots of water temperature data calculated as a rolling 7-day average, at five sites in Pilarcitos Creek, San Mateo County, from April through September 2012.

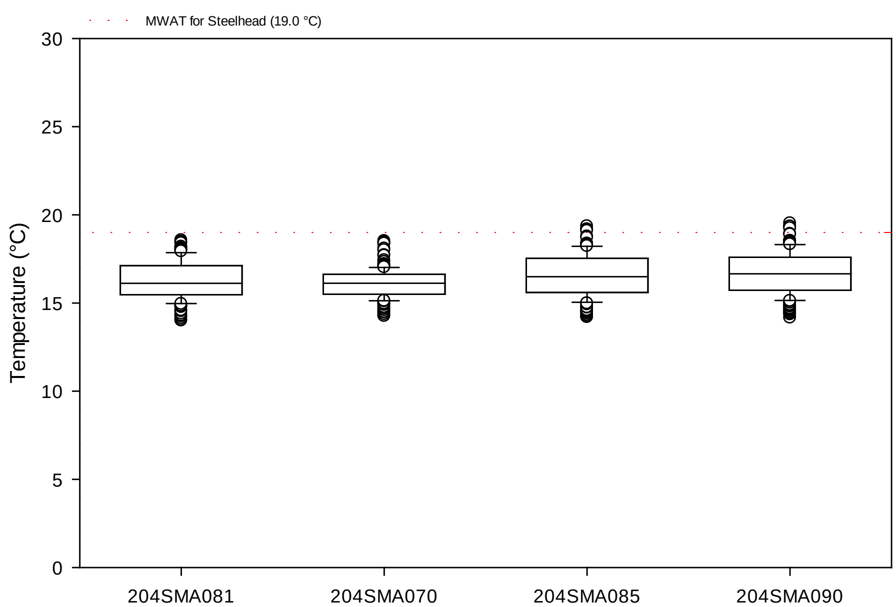


Figure 5.19 Box plots of water temperature data calculated as a rolling 7-day average, at four sites in San Mateo Creek, San Mateo County, from April through September 2013.

Trigger analysis of temperature data using the MWAT threshold is shown in Table 5.19. A trigger is defined when the MWAT exceeds the threshold for more than 20% of records at a single site. Trigger analysis of temperature data using the MWAT threshold is shown in Table 5.23. No triggers occurred at any of the sites monitored during WY2012 or WY2013.

Table 5.23. Percent of water temperature data measured between April – September 2012 at five sites in Pilarcitos and four sites in San Mateo Creek that exceeded MWAT maximum threshold value (19 °C). NR indicates data was not collected at the site for that year.

| Site ID | Creek | Site Name | Percentage results MWAT > 19º | |
|---|---|---|---|---|
| | | | 2012 | 2013 |
| 202PIL030 | Pilarcitos Creek | Treatment Plant | 0% | NR |
| 202PIL100 | | Highway 1 | 0% | NR |
| 202PIL150 | | Main Street | 0% | NR |
| 202PIL340 | | Madonna Ranch | 0% | NR |
| 202PIL650 | | Christmas Tree Farm | 0% | NR |
| 204SMA070 | San Mateo Creek | South School | NR | 0% |
| 204SMA081 | | Sierra | NR | 0% |
| 204SMA085 | | Buckeye | NR | 3% |
| 204SMA090 | | Crystal Springs Terrace | NR | 3% |

The Basin Plan (SFRWQCB 2013) designates several Beneficial Uses for both Pilarcitos Creek and San Mateo Creek that are associated with aquatic life uses, including COLD, WARM, MIGR, SPWN and RARE (Table 1.3). Both creeks support a small population of steelhead trout, with primary rearing and spawning habitat occurring downstream of large dam and upstream of urbanized reach.

An approximate 7.5-mile section of the Pilarcitos Creek mainstem extending from the mouth upstream to Stone Dam provides potential spawning and rearing habitat for steelhead (Leidy et al. 2005). The best spawning and rearing habitat occurs in the 2.7-mile reach below Stone Dam (Entrix 2006). Low stream flow, resulting from water diversions, abundant fine sediment impacts to spawning and rearing habitat, and limited food resources were identified as potential factors limiting steelhead production in Pilarcitos Creek (PWA 2008). Water quality, including temperature and dissolved oxygen, were not identified as factors limiting steelhead production. The water temperature data measured in Pilarcitos Creek by SMCWPPP in 2012 are well above thresholds needed to support juvenile steelhead life stages, which is consistent with the PWA (2008) assessment.

There are very limited reports available on the current status of the steelhead populations in San Mateo Creek. Small numbers of steelhead have been documented in the area below Crystal Springs Reservoir (Leidy et al. 2005). In 1993, steelhead were documented at four locations in San Mateo Creek between DeAnza Historical Park and Polhemus Creek confluence. Water temperature measured in San Mateo Creek by SMCWPPP in WY2013 is well above thresholds needed to support juvenile steelhead life stages.

## 5.5 General Water Quality

Summary statistics for general water quality measurements collected during two sampling events at two sites in Pilarcitos Creek in WY2012 and two sites in San Mateo Creek in WY2013 are listed in Table 5.24. Sample Event 1 occurred May-June and Event 2 occurred during August/September timeframe. Plots of the data collected in Pilarcitos Creek during Event 1 are shown in Figure 5.20 and during Event 2 in Figure 5.21. Plots of the data collected in San Mateo Creek during Event 1 are shown in Figure 5.22 and during Event 2 in Figure 5.23.

### 5.5.1 Temperature

Box plots showing the distribution of water temperature data collected at two sites in Pilarcitos Creek in WY2012 and two sites in San Mateo Creek in WY2013 are shown in Figure 5.24. The chronic (maximum 7-day mean) temperature (MWAT) threshold (19.0 °C) is shown in the figure. Trigger analysis of temperature data using the MWAT threshold is shown in Table 5.25.

Table 5.24. Descriptive statistics for continuous water temperature, dissolved oxygen, conductivity, and pH data measured at two sites in Pilarcitos Creek during WY2012 and two sites in San Mateo Creek during WY2013. Data was collected every 15 minutes over a two week time period during May/June (event 1) and August/September (event 2).

| Parameter | Data Type | 205PIL030 | | 205PIL340 | | 204SMA059 | | 204SMA122 | |
|---|---|---|---|---|---|---|---|---|---|
| | | May/June 2012 | Aug 2012 | May/June 2012 | Aug 2012 | June 2013 | Sept 2013 | May/June 2013 | Sept 2013 |
| Temp (° C) | Min | 9.4 | 11.2 | 10.1 | 12.6 | 14.0 | 13.1 | 15.7 | 12.7 |
| | Median | 11.6 | 12.1 | 12.7 | 13.9 | 15.3 | 15.8 | 17.8 | 16.0 |
| | Mean | 11.6 | 12.2 | 12.8 | 14.0 | 15.3 | 15.7 | 18.0 | 15.9 |
| | Max | 13.8 | 14.1 | 15.2 | 15.8 | 16.9 | 18.5 | 21.3 | 19.1 |
| | Max 7-day Mean | 11.8 | 12.5 | 12.9 | 14.4 | 15.4 | 16.4 | 18.37 | 17.5 |
| Dissolved Oxygen (mg/l) | Min | 7.4 | 9.6 | 9.4 | 9.6 | 2.1 | 5.2 | 7.9 | 10.7 |
| | Median | 9.6 | 10.2 | 10.1 | 10.2 | 7.5 | 7.5 | 8.5 | 16.8 |
| | Mean | 9.3 | 10.2 | 10.1 | 10.2 | 7.0 | 7.4 | 8.5 | 17.0 |
| | Max | 10.7 | 10.7 | 10.8 | 10.5 | 9.0 | 8.9 | 8.9 | 18.9 |
| | 7-day Avg. Min | 7.9 | 9.7 | 9.6 | 9.8 | 3.6 | 6.0 | 8.1 | 7.6 |
| pH | Min | 7.6 | 7.9 | 7.8 | 7.9 | 7.3 | 7.3 | 7.6 | 7.0 |
| | Median | 7.8 | 8.0 | 7.9 | 8.0 | 7.7 | 7.7 | 7.7 | 7.2 |
| | Mean | 7.8 | 8.0 | 7.9 | 8.0 | 7.7 | 7.7 | 7.7 | 7.3 |
| | Max | 7.9 | 8.1 | 8.0 | 8.1 | 8.1 | 7.8 | 7.8 | 7.6 |
| Specific Conductance (uS/cm) | Min | 385 | 417 | 340 | 351 | 371 | 253 | 190 | 178 |
| | Median | 486 | 447 | 388 | 381 | 392 | 372 | 193 | 203 |
| | Mean | 463 | 448 | 388 | 380 | 392 | 368 | 193 | 207 |
| | Max | 566 | 480 | 432 | 403 | 456 | 427 | 198 | 254 |
| Total number data points (n) | | 1626 | 1239 | 1632 | 1239 | 1253 | 1159 | 1335 | 1150 |

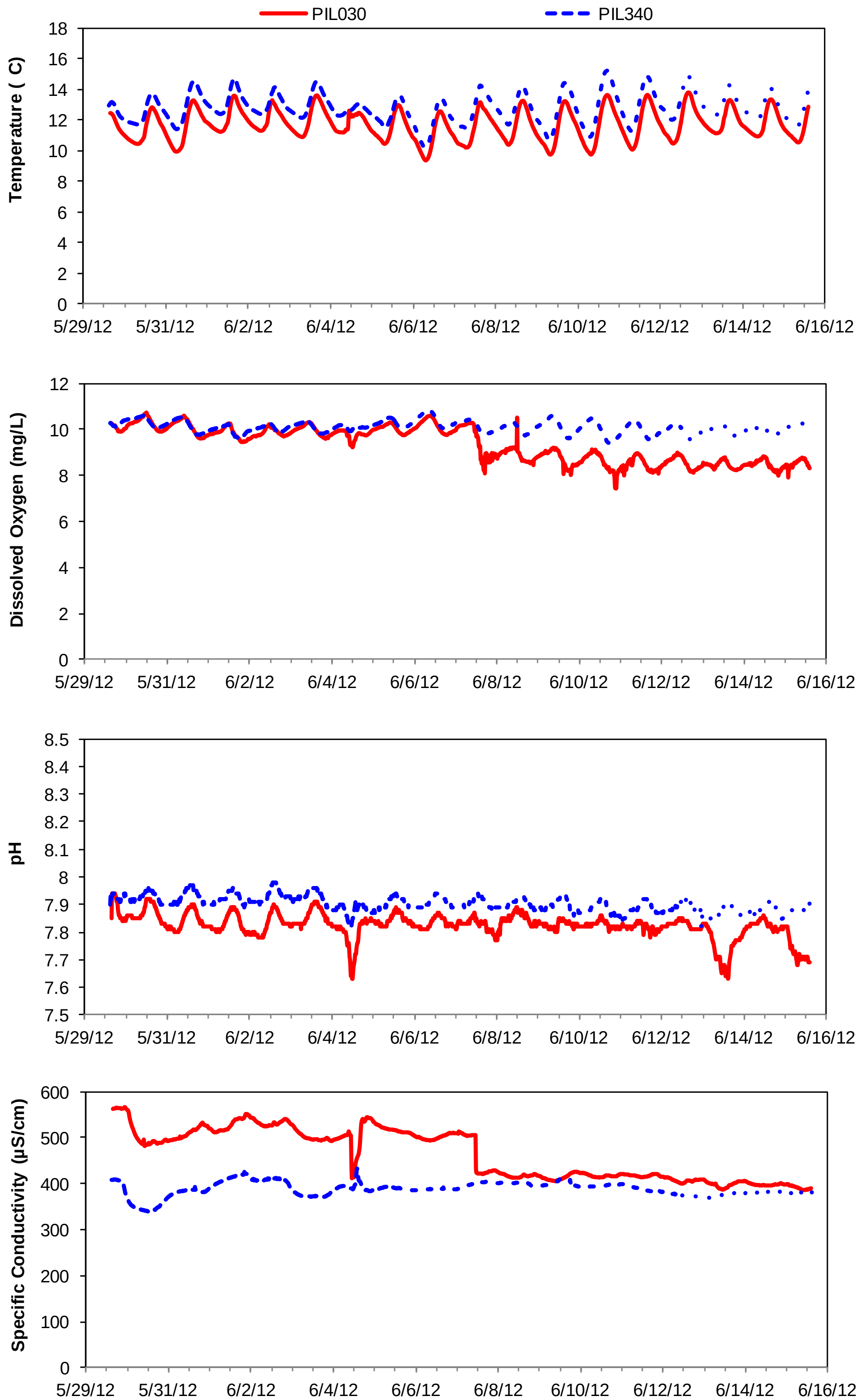


Figure 5.20 Continuous water quality data (temperature, dissolved oxygen, pH and specific conductance) collected at two sites in Pilarcitos Creek during May 29-June 15, 2012 (Event 1).

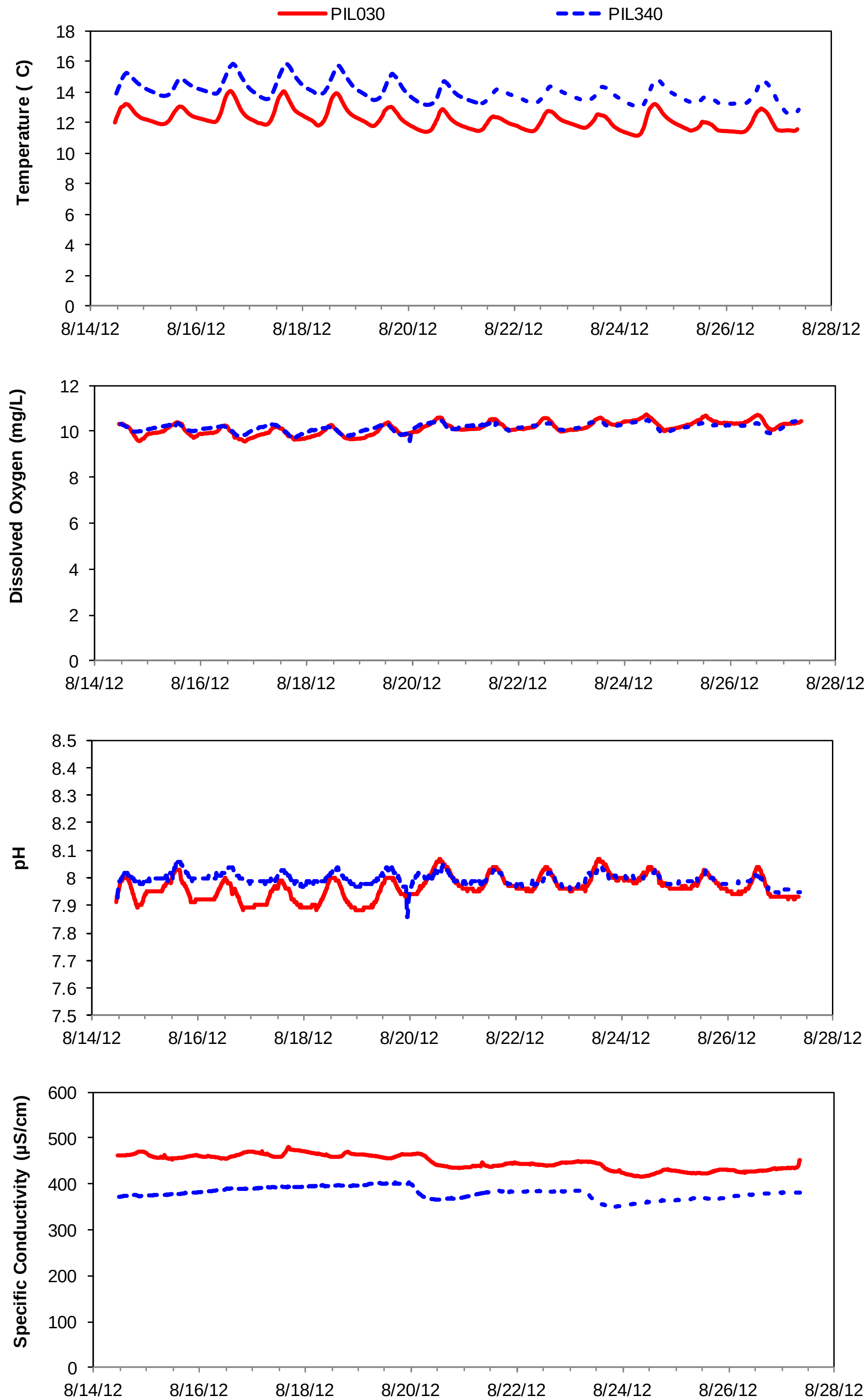


Figure 5.21 Continuous water quality data (temperature, dissolved oxygen, pH and specific conductance) collected at two sites in Pilarcitos Creek during August 14th-28th, 2012 (Event 2).

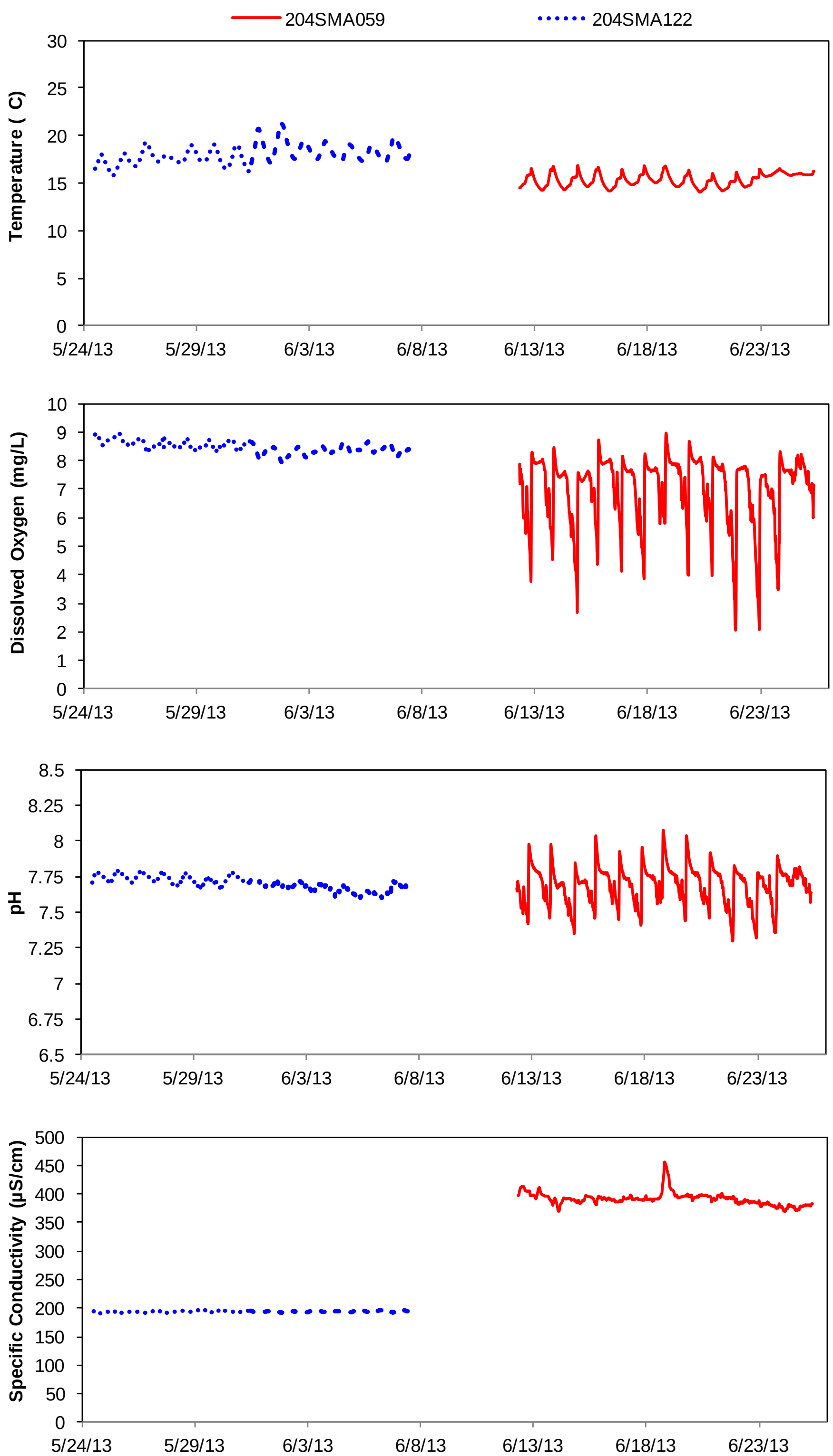


Figure 5.22 Continuous water quality data (temperature, dissolved oxygen, pH and specific conductance) collected at two sites in San Mateo Creek during May 24-June 7, 2013 (site 205SMA122) and June 12-25, 2013 (site 205SMA059) (Event 1).

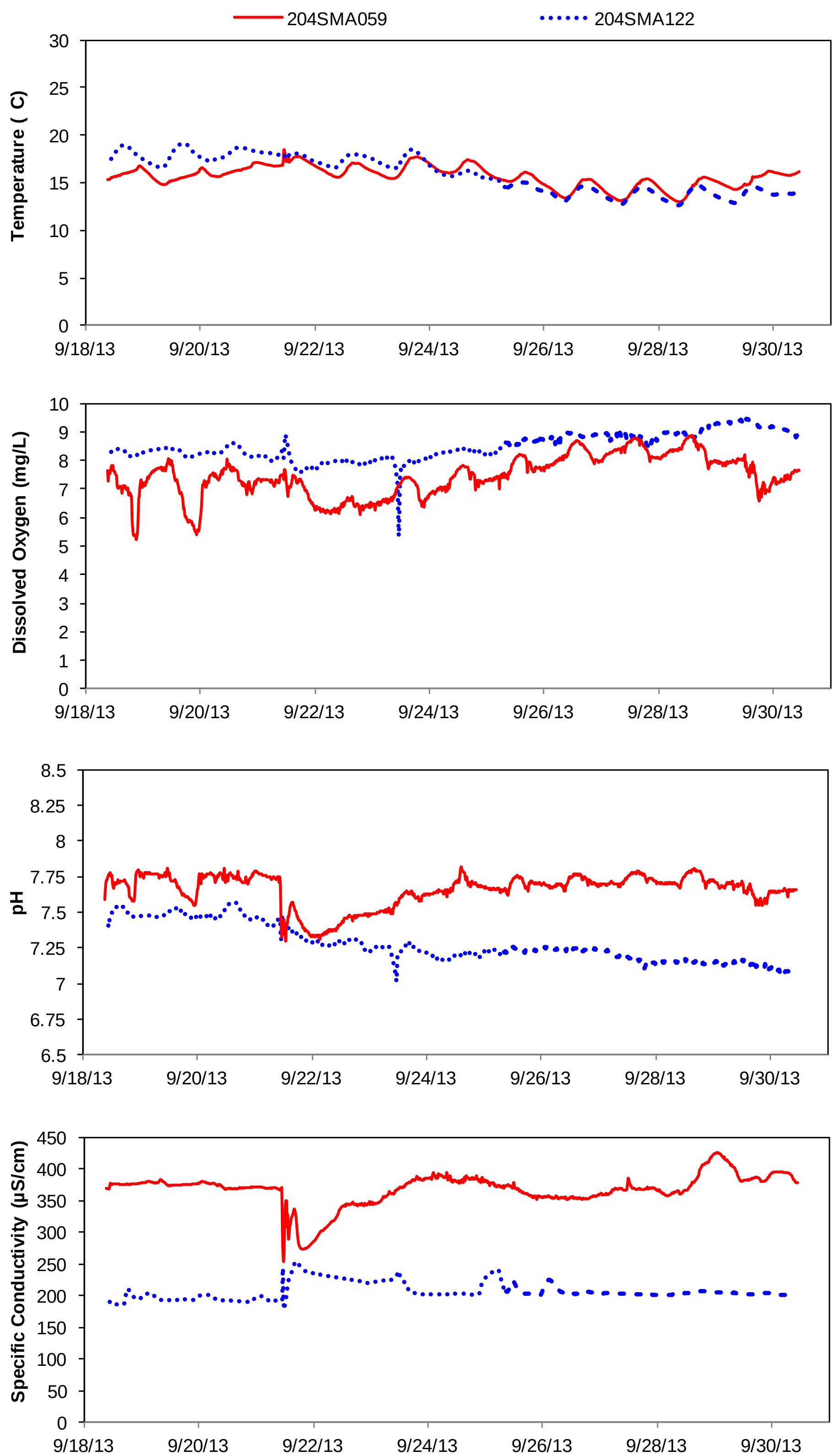


Figure 5.23 Continuous water quality data (temperature, dissolved oxygen, pH and specific conductance) collected at two sites in San Mateo Creek during September 18-30th, 2013 (Event 2).

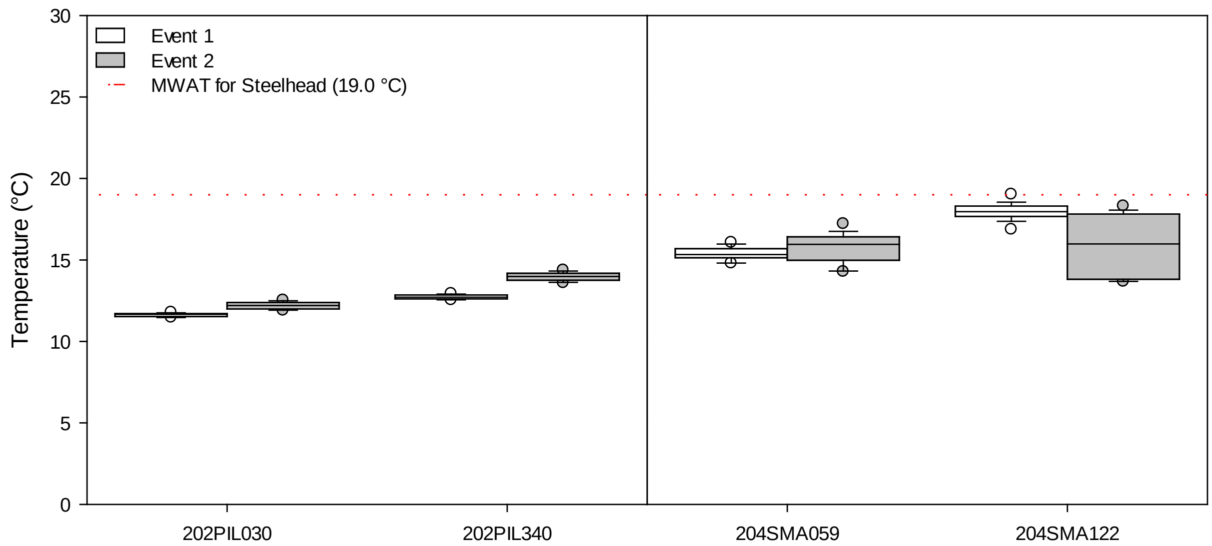


Figure 5.24 Box plots of water temperature data, calculated as a rolling 7-day average, collected during two sampling events at sites in Pilarcitos Creek and San Mateo Creek.

Table 5.25. Percent of temperature data measured during two events at two sites in Pilarcitos Creek and San Mateo Creek that exceed trigger values identified in Table 3.2.

| Site ID | Creek Name | Site | Monitoring Event | *Percent results MWAT > 19 °C* |
|---|---|---|---|---|
| 202PIL030 | Pilarcitos Creek | Treatment Plant | May 2012 | 0% |
| | | | Aug 2012 | 0% |
| 202PIL340 | | Madonna Ranch | May 2012 | 0% |
| | | | Aug 2012 | 0% |
| 204SMA059 | San Mateo Creek | DeAnza Park | June 2013 | 0% |
| | | | Sept 2013 | 0% |
| 204SMA122 | | Below Reservoir | June 2013 | 7% |
| | | | Sept 2013 | 0% |

The MWAT threshold was exceeded for 7% of the measurements made at site 204SMA122 during event 1 in 2013 and 0% of the measurements made at all other sites for both years. The temperature results suggest temperature does not affect steelhead spawning and rearing life stages in either creek, consistent with temperature results discussed in Section 5.5.1.

### 5.5.2 Dissolved Oxygen

Figure 5.25 compare DO levels measured during the two sampling events at the Pilarcitos Creek and San Mateo Creek sites to the SF Bay Basin Plan WQOs for WARM (5.0 mg/L) and COLD (7.0 mg/L) beneficial uses. The DO measurements taken at both sites in Pilarcitos Creek in 2012 were all above the WQOs for DO. The WQO for WARM was exceeded for 8% of the measurements taken at site 204SMA089 during Event 1. The WQO for COLD was exceeded 24% - 36% of measurements taken during Event 2 and Event 1, respectively, at same location (Table 4.6).

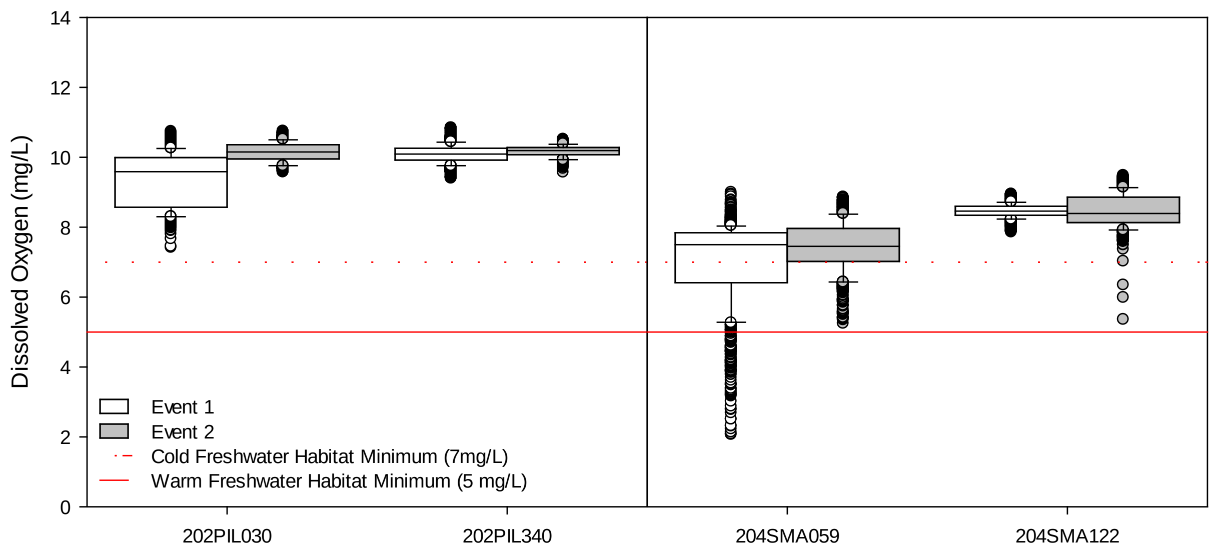


Figure 5.25. Box plots of dissolved oxygen data collected using sondes during two sampling events at sites in Pilarcitos Creek and San Mateo Creek compared to Basin Plan Water Quality Objectives.

Table 5.26. Percent of water dissolved oxygen data measured during two events at two sites in Pilarcitos Creek and San Mateo Creek that exceed trigger values identified in Table 3.2.

| Site ID | Creek Name | Site | Monitoring Event | *Percent Results DO < 5.0 mg/L* | *Percent Results DO < 7.0 mg/L* |
|---|---|---|---|---|---|
| 202PIL030 | Pilarcitos Creek | Treatment Plant | May 2012 | 0% | 0% |
| | | | Aug 2012 | 0% | 0% |
| 202PIL340 | | Madonna Ranch | May 2012 | 0% | 0% |
| | | | Aug 2012 | 0% | 0% |
| 204SMA059 | San Mateo Creek | DeAnza Park | June 2013 | 8% | 36% |
| | | | Sept 2013 | 0% | 24% |
| 204SMA122 | | Below Reservoir | June 2013 | 0% | 0% |
| | | | Sept 2013 | 0% | 0% |

A daily pattern of fluctuating DO concentrations can be observed during Event 1 at the DeAnza Park (site 204SMA059) (Figure 5.22). The observed DO pattern is consistent with polymictic pool behavior in which the stream pool becomes thermally stratified during the day (possibly as a result of low streamflow, high air temperatures, and cold groundwater seepage) followed by mixing at night as air temperatures cool. This pattern is also observed to some extent during Event 2 deployment, until a storm event that occurred on September 22 appeared to reduce the diurnal variability, presumed due to the absence of the thermal stratification (Figure 5.23).

Juvenile steelhead rearing and spawning habitat is primarily within a two mile reach of San Mateo Creek below the Crystal Springs Reservoir (Brinkerhoff, SFPUC, personal communication, 2013). The water quality data collected by SMCWPPP in 2013 indicate dissolved oxygen levels would not impact juvenile steelhead life stages. It is unclear to what extent DO oxygen concentrations observed at the DeAnza Park site may be impacting native fishes. The low DO conditions at DeAnza Park may also be the result of low summer baseflows from the Crystal Springs Dam, which have relied primarily upon ground seepage during SFPUC's replacement of the release valve. Increased summer discharges from Crystal Springs reservoir are anticipated in the future as a result of the dam improvements that are currently being constructed by the San Francisco Public Utilities Commission (SFPUC). SMCWPPP is in the process of developing a work plan to further investigate the extent, duration, and cause of low DO concentrations in San Mateo Creek.

### 5.5.3 pH

Figure 5.26 compare pH levels measured during the two sampling events at the Pilarcitos Creek and San Mateo Creek sites to the SF Bay Basin Plan WQOs for pH (< 6.5 and/or > 8.5). The pH measurements never exceeded the WQOs at any of the sampling locations.

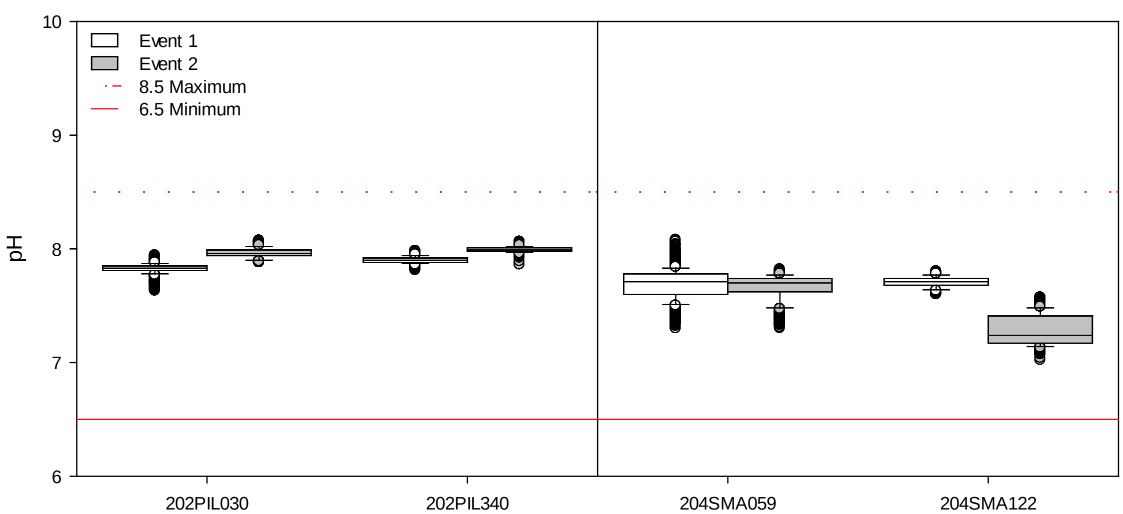


Figure 5.26 Box plots of pH data collected using sondes during two sampling events at sites in Pilarcitos Creek and San Mateo Creek compared to associated SF Bay Basin Plan Water Quality Objectives.

### 5.5.4 Specific Conductivity

Box plots showing the distribution of specific conductivity measurements taken during the two sampling events in Pilarcitos Creek and San Mateo Creek are shown in Figure 5.27. There are no water quality objectives or thresholds for this parameter, so an evaluation of trigger exceedance was not conducted.

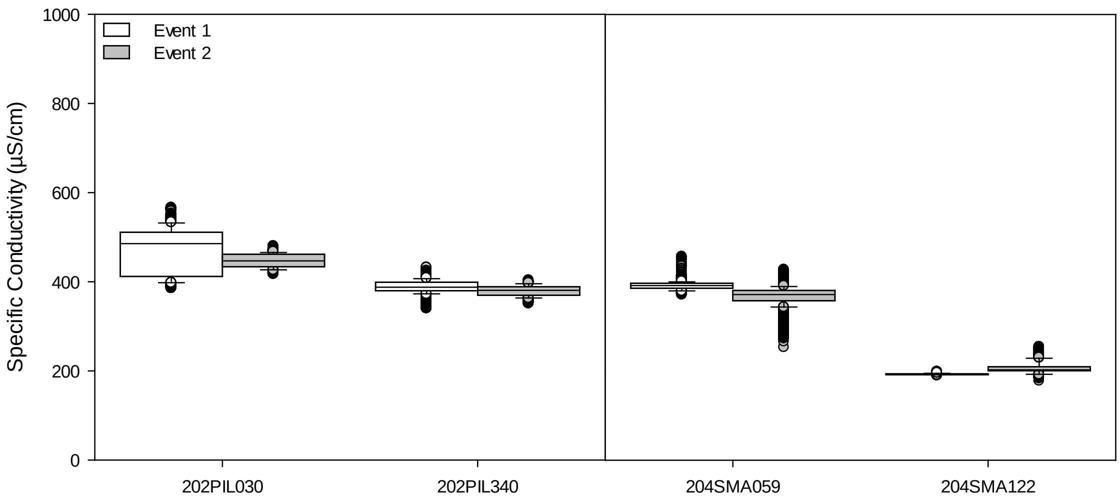


Figure 5.27. Box plots of specific conductivity measurements collected using sondes during two sampling events at sites in Pilarcitos Creek and San Mateo Creek.

## 5.6 Pathogen Indicators

Pathogen indicator densities measured in water samples in Water Years 2012 and 2013 are listed in Table 5.27. All creeks monitored for pathogen indicators are designated for both contact (REC-1) and non-contact (REC-2) water recreation beneficial uses, although none of the stations could be considered "bathing beaches." The WY2012 stations were sited at city parks or trails throughout the County that were considered to exhibit high potential for public access. The potential for public access and exposure appeared to be very low in the remaining non-sampled areas of these five creeks. The WY2013 stations were not necessarily sited at parks or trails and were instead selected to coincide with stations along San Pedro Creek which have been monitored by the SFRWQCB as part of their Bacterial TMDL research (Figure 5.28). San Pedro Creek is designated for contact (REC-1) and non-contact (REC-2) water recreation beneficial uses.

Table 5.27. Fecal coliform and E. coli levels measured in San Mateo County during Water Years 2012 and 2013.

| Site ID | Creek Name | Site Name | *Fecal Coliform (MPN/100ml)* | *E. Coli (MPN/100ml)* | Sample Date |
|---|---|---|---|---|---|
| | | *Trigger Threshold* | *400* | *410 (235[1])* | |
| 204LAU230 | Laurel Creek | Laurelwood Park | 400 | 400 | Jul 17, 2012 |
| 204BEL160 | Belmont Creek | Twin Pines Park | 500 | 500 | Jul 17, 2012 |
| 204SMA060 | San Mateo Creek | De Anza Historical Park | 1,300 | 1,300 | Jul 17, 2012 |
| 204AOA250 | Arroyo Ojo de Aqua | Stulsaft Park | 1,500 | 5,000 | Jul 17, 2012 |
| 202PIL015 | Pilarcitos Creek | Half Moon Bay Coastal Trail | 1,700 | 1,700 | Jul 17, 2012 |
| 202SPE010 | San Pedro Creek | Below Shamrock Ranch | 900 | 900 | Jul 22, 2013 |
| 202SPE018 | San Pedro Creek | Above Shamrock Ranch | 700 | 700 | Jul 22, 2013 |
| 202SPE030 | San Pedro Creek | Alma Heights School | 300 | 300 | Jul 22, 2013 |
| 202SPE045 | San Pedro Creek | Capistrano Drive | 2,800 | 2,800 | Jul 22, 2013 |
| 202SPE060 | San Pedro Creek | North Fork | 1,300 | 1,300 | Jul 22, 2013 |

Notes:

1. The lower E. coli trigger threshold of 235 MPN/100ml from the San Pedro Creek Bacteria TMDL is listed here for reference but not applied to trigger evaluation because the TMDL Implementation and Bacteria Monitoring Plan is still in development.

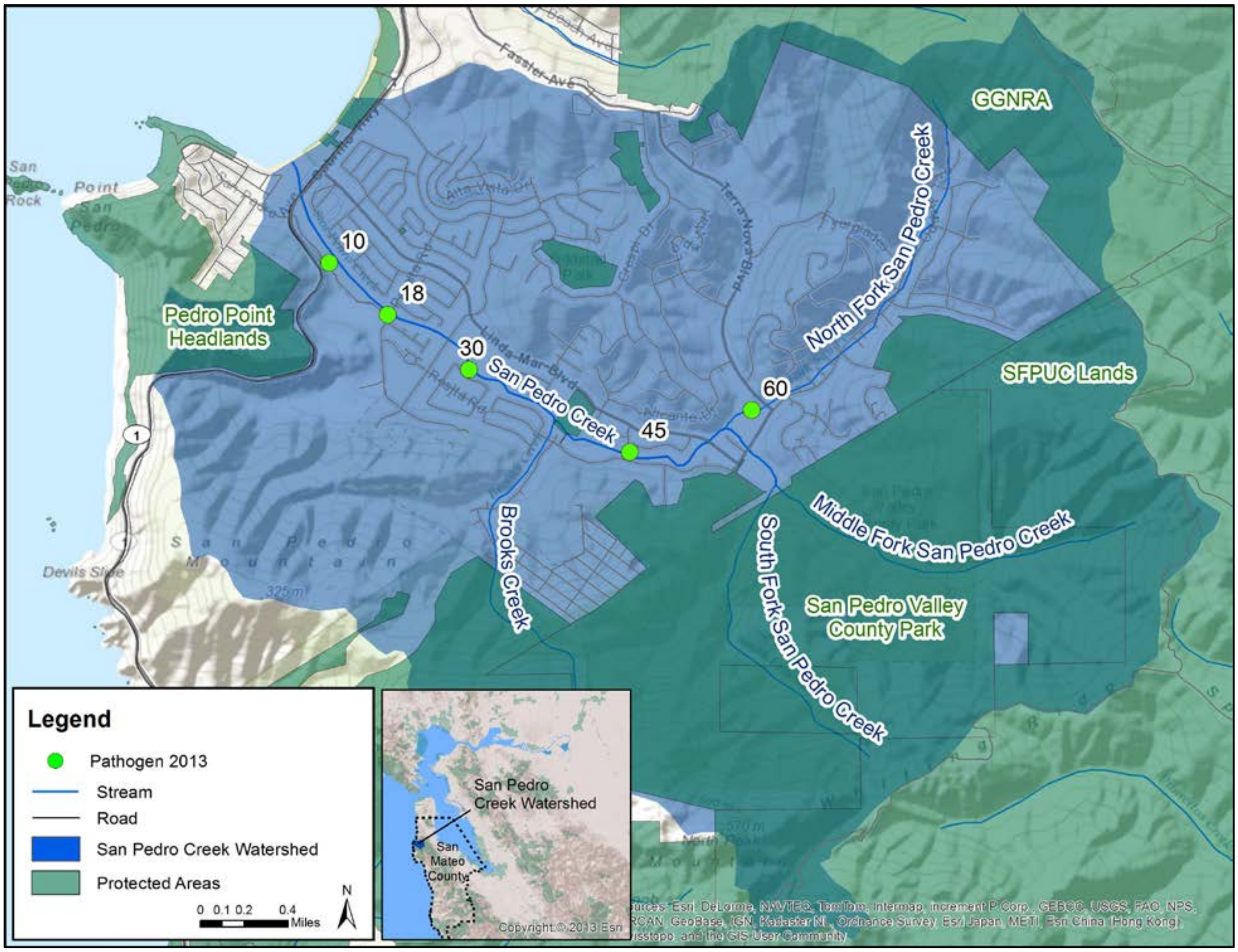


Figure 5.28. Pathogen indicator sampling stations in San Pedro Creek, WY2013.

In both water years, four out of five stations exceed the Basin Plan fecal coliform WQO. Five stations in WY2012 and four stations in WY2013 exceed the 2012 EPA *E. coli* criterion for recreational waters. The highest densities of both pathogen indicators (2,800 MPN/100ml) were measured in San Pedro Creek at the Capistrano Drive crossing in WY2013.

Comparison of fecal indicator results from local creeks to existing WQOs for REC-1 may not be appropriate and such comparisons should be made only with several caveats:

- The Standard Methods MPN (Most Probably Number) 95% Confidence Level range varies from approximately 1/3 to 4 times the estimated reported densities indicating a relatively high level of uncertainty regarding actual values.
- The correlation between the presence of bacterial indicator organisms and pathogens of public health concern is highly uncertain.
- The method used to derive these criteria makes their application to data from local watersheds questionable. The criteria are based upon epidemiological studies of people recreating at bathing beaches that received bacteriological contamination via treated human wastewater. Applying these criteria to data collected from creeks where ingestion of the water is highly unlikely relative to a bathing beach is highly questionable.

- Sources of fecal indicators in the watershed likely include non-human sources (e.g., wildlife and domestic animals); non-human fecal contamination may pose a lower risk to water contact recreators. Recent research indicates that the source of fecal contamination is critical to understanding the human health risk associated with its contamination of recreational waters, and that the amount of human health risk in recreational waters varies with various fecal sources (USEPA 2011).

- A Microbial Source Tracking study conducted in 2006 with funding from State Water Board Proposition 13 estimated the contribution percentage of human and animal sources of bacteria to the overall bacterial load of San Pedro Creek at seven stations during the wet and dry seasons. Avian sources dominated the load at all stations during both seasons with significant contributions from canine, human, and raccoon sources especially during the dry season. Horse sources were also significant during the wet season. (Ivanetich 2006)

# 6.0 Conclusions

The following conclusions from the MRP creek status monitoring conducted during Water Years 2012 and 2013 in San Mateo County are based on the management questions presented in Section 1.0:

1) ***Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?***

2) ***Are conditions in local receiving water supportive of or likely supportive of beneficial uses?***

The first management question is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in Table 4.4. A summary of trigger exceedances observed for each site is presented in Table 6.1. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of stressor source identification projects.

The second management question is addressed primarily through calculation of indices of biological integrity (IBI) using benthic macroinvertebrate data collected at probabilistic sites, and sites sampled prior to MRP implementation. Biological condition scores were compared to physical habitat and water quality data collected synoptically with bioassessments to evaluate whether any correlations exist that may explain the variation in IBI scores.

**Biological Condition**

- Under the level of MRP-required monitoring, the RMC probabilistic design requires at least four years of data to develop a statistically-robust characterization of biological conditions of the creeks within SMCWPPP. Therefore, the **overall biological condition assessment** that can be derived based on the Water Years 2012 and 2013 bioassessment data should be considered preliminary.

- SoCal B-IBI scores were calculated to assess biological condition at probabilistic sites. Ten sites (43%) scored as very poor or poor (scores of 0 to 39). All of these sites are located in urban areas, with half the sites characterized as highly modified channels. Ten sites (43%) were scored as very good or good (scores of 60 to 100) with a majority of these sites classified as non-urban.

- CSCI scores were calculated for MRP probabilistic sites as well as a large historical dataset (2002 to 2009) to evaluate the utility of this new tool. Overall, the CSCI scores correlated well with SoCal B-IBI scores. The CSCI scores showed greater variability within each condition category, suggesting it may be more responsive to stressors associated with physical habitat condition and water quality.

- The mean CSCI scores were higher for perennial sites compared to non-perennial sites (0.82 versus 0.57) and higher for non-urban sites compared to urban sites (1.0 versus 0.55).

- Total PHAB and CRAM scores were moderately correlated with biological condition scores. High CRAM score (79 out of 100) and very poor CSCI score (0.19) at site 202R00908 may indicate that water quality stressor(s) are impacting biological condition.

- Diatom IBI scores do not correlate well with CSCI or SoCal B-IBI scores. None of the physical habitat or water quality stressor variables correlated well with the Diatom IBI scores.

**Nutrients and Conventional Analytes**

- Nutrients (nitrogen and phosphorus), algal biomass indicators, and other conventional analytes were measured in samples collected concurrently with bioassessments which are conducted in the spring season. MRP Trigger thresholds for chloride, unionized ammonia, and nitrate were not exceeded.

- The parameters in this group of constituents that correlates well with SoCal B-IBI and CSCI scores include chloride, nitrate, and total Kjeldahl nitrogen.

**Water Toxicity**

- Water toxicity samples were collected from three sites during each year of the program at a frequency of twice per year. No water toxicity samples exceeded the MRP trigger thresholds.

**Sediment Toxicity and Chemistry/Sediment Triad Analysis**

- Sediment toxicity and chemistry samples were collected concurrently with the summer water toxicity samples. No MRP trigger thresholds were exceeded.

- Sediment toxicity was evaluated with bioassessment scores and sediment chemistry data (TEC and PEC quotients, and pyrethroid TU equivalents) as part of the Sediment Triad Analysis. One or more aspects of the Sediment Triad Analysis were exceeded at each site suggesting that all four sites should be considered for future evaluation for stressor source identification projects.

**Spatial and Temporal Variability of Water Quality Conditions**

- There was minimal spatial variability in water temperature across the five sites in Pilarcitos Creek and across the four sites in San Mateo Creek.

- Dissolved oxygen concentrations at the DeAnza Park site (204SMA059) in San Mateo Creek were consistently lower compared to levels measured at the site below the dam. At the DeAnza site, DO levels had diurnal fluctuations that appear to be driven by stratification and mixing caused by changes in air temperature.

**Potential Impacts to Aquatic Life**

- There were no exceedences of the Mean Weekly Average Temperature (MWAT) threshold at the two sites in Pilarcitos Creek or two sites in San Mateo Creek. These results suggest that water temperature is not a limiting factor for the resident steelhead population.

- Dissolved oxygen concentrations at both sites monitored in Pilarcitos Creek did not exceed WARM or COLD Water Quality Objectives. The WQO for COLD was exceeded at the DeAnza Park site (204SMA059) for 24% - 36% of the measurements made during the summer and spring sampling event, respectively. In WY 2014, SMCWPPP will conduct further investigation on the spatial and temporal extent of reduced dissolved oxygen concentrations at the DeAnza Park site.

- Values for pH were within Water Quality Objectives at both sites in Pilarcitos Creek and San Mateo Creek.

**Potential Impacts to Water Contact Recreation**

- Pathogen indicator densities were measured at five sites spread throughout San Mateo County in WY2012. In WY2013, pathogen indicator sites were focused in San Pedro Creek where a bacteria TMDL was recently adopted. Threshold triggers for fecal coliform and/or *E. coli* were exceeded at all sites in WY2012 and at four sites in WY2013.

- It is important to recognize that pathogen indicator thresholds are based on human recreation at beaches receiving bacteriological contamination from human wastewater, and may not be applicable to conditions found in urban creeks. As a result, the comparison of pathogen indicator results to water quality objectives and criteria for full body contact recreation, may not be appropriate and should be interpreted cautiously.

Table 6.1. Summary of SMCWPPP MRP Trigger Threshold Exceedance Analysis, Water Years 2012 and 2013. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger.

| Station Number | Creek Name | Bioassessment | Nutrients | Chlorine | Water Toxicity | Sediment Toxicity | Sediment Chemistry | Temperature | Continuous WQ | Pathogen Indicators | Water Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 204BEL160 | Belmont Creek | | | | | | | | | Yes | 2012 |
| 204R00520 | Belmont Creek | Yes | No | Yes | No | No | Yes | | | | 2013 |
| 204R00807 | Colma Creek | Yes | No | No | | | | | | | 2013 |
| 204R00436 | Easton Creek | Yes | No | No | | | | | | | 2013 |
| 204R00884 | Easton Creek | Yes | No | No | | | | | | | 2013 |
| 204LAU230 | Laurel Creek | | | | | | | | | Yes | 2012 |
| 204R00232 | Arroyo Ojo De Aqua | Yes | No | No | | | | | | | 2012 |
| 204AOA250 | Arroyo Ojo de Aqua | | | | | | | | | Yes | 2012 |
| 204R00680 | Redwood Creek | Yes | No | No | No | No | Yes | | | | 2013 |
| 204R00244 | Trib to Arroyo Ojo De Aqua | Yes | No | Yes | | | | | | | 2012 |
| 202R00984 | Bear Gulch Creek | No | No | No | | | | | | | 2013 |
| 205R00872 | Bear Gulch Creek | No | No | No | | | | | | | 2013 |
| 205R00088 | Corte Madera Creek | No | No | No | No | No | Yes | | | | 2012 |
| 205R00168 | Corte Madera Creek | No | No | No | | | | | | | 2012 |
| 204R00200 | Polhemus Creek | Yes | No | No | | | | | | | 2012 |
| 204SMA059 | San Mateo Creek | | | | | | | | Yes | | 2013 |
| 204SMA070 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA081 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA085 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA090 | San Mateo Creek | | | | | | | No | | | 2013 |
| 204SMA122 | San Mateo Creek | | | | | | | | No | | 2013 |
| 204SMA060 | San Mateo Creek | | | | | | | | | Yes | 2012 |
| 204R00180 | Sanchez Creek | Yes | No | No | | | | | | | 2012 |
| 202R00166 | Little Butano Creek | No | No | No | | | | | | | 2012 |
| 202R00038 | Little Butano Creek | No | No | No | | | | | | | 2012 |
| 202R00908 | Calera Creek | Yes | No | Yes | | | | | | | 2013 |
| 202R00284 | Denniston Creek | No | No | No | | | | | | | 2012 |
| 202R00087 | Milagra Creek | No | No | No | No | No | Yes | | | | 2012 |
| 202PIL030 | Pilarcitos Creek | | | | | | | No | No | | 2012 |
| 202PIL100 | Pilarcitos Creek | | | | | | | No | | | 2012 |
| 202PIL150 | Pilarcitos Creek | | | | | | | No | | | 2012 |
| 202PIL340 | Pilarcitos Creek | | | | | | | No | No | | 2012 |

| Station Number | Creek Name | Bioassessment | Nutrients | Chlorine | Water Toxicity | Sediment Toxicity | Sediment Chemistry | Temperature | Continuous WQ | Pathogen Indicators | Water Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 202PIL650 | Pilarcitos Creek | | | | | | | No | | | 2012 |
| 202R00072 | Pilarcitos Creek | No | No | No | | | | | | | 2012 |
| 202PIL015 | Pilarcitos Creek | | | | | | | | | Yes | 2012 |
| 202R00104 | La Honda Creek | No | No | | | | | | | | 2012 |
| 202R00248 | San Gregorio Creek | No | No | No | | | | | | | 2013 |
| 202R00280 | Tributary to Alpine Creek | No | No | No | | | | | | | 2013 |
| 202R00024 | Woodhams Creek | No | No | No | | | | | | | 2012 |
| 202SPE010 | San Pedro Creek | | | | | | | | | Yes | 2013 |
| 202SPE018 | San Pedro Creek | | | | | | | | | Yes | 2013 |
| 202SPE030 | San Pedro Creek | | | | | | | | | No | 2013 |
| 202SPE045 | San Pedro Creek | | | | | | | | | Yes | 2013 |
| 202SPE060 | San Pedro Creek | | | | | | | | | Yes | 2013 |

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# ATTACHMENTS

# Attachment A
# Site Evaluation Details

| Appendix A. SMCWPPP Site Evaluation Details. | | | | | |
|---|---|---|---|---|---|
| **Station Code** | **Stratum** | **Agency Code** | **Year Evaluated** | **Target Status Code** | **Target Status Detail** |
| 202R00012 | SM_R2_Nonurb | SWAMP | 2012 | NT | NT_NLSF |
| 202R00024 | SM_R2_Nonurb | SMCWPPP | 2012 | T | Target |
| 202R00028 | SM_R2_Urb | SMCWPPP | 2012 | TNS | TNS_IA |
| 202R00038 | SM_R2_Nonurb | SWAMP | 2012 | T | Target |
| 202R00054 | SM_R2_Nonurb | SWAMP | 2012 | TNS | TNS_PD |
| 202R00056 | SM_R2_Nonurb | SWAMP | 2012 | TNS | TNS_PD |
| 202R00072 | SM_R2_Nonurb | SMCWPPP | 2012 | T | Target |
| 202R00076 | SM_R2_Nonurb | SMCWPPP | 2012 | TNS | TNS_PD |
| 202R00087 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 202R00102 | SM_R2_Nonurb | SWAMP | 2012 | NT | NT_NLSF |
| 202R00104 | SM_R2_Nonurb | SWAMP | 2012 | T | Target |
| 202R00120 | SM_R2_Nonurb | SMCWPPP | 2013 | TNS | TNS_PD |
| 202R00136 | SM_R2_Nonurb | SMCWPPP | 2013 | NT | NT_NLSF |
| 202R00140 | SM_R2_Urb | SMCWPPP | 2012 | TNS | TNS_IA |
| 202R00150 | SM_R2_Nonurb | SWAMP | 2013 | T | Target |
| 202R00152 | SM_R2_Nonurb | SWAMP | 2013 | TNS | TNS_PD |
| 202R00166 | SM_R2_Nonurb | SWAMP | 2012 | T | Target |
| 202R00184 | SM_R2_Nonurb | SMCWPPP | 2013 | TNS | TNS_IA |
| 202R00204 | SM_R2_Urb | SMCWPPP | 2012 | TNS | TNS_IA |
| 202R00214 | SM_R2_Nonurb | SWAMP | 2013 | T | Target |
| 202R00216 | SM_R2_Nonurb | SMCWPPP | 2013 | TNS | TNS_PD |
| 202R00230 | SM_R2_Nonurb | SMCWPPP | 2013 | TNS | TNS_IA |
| 202R00243 | SM_R2_Nonurb | SMCWPPP | 2013 | NT | NT_NLSF |
| 202R00248 | SM_R2_Nonurb | SMCWPPP | 2013 | T | Target |
| 202R00250 | SM_R2_Nonurb | SMCWPPP | 2013 | TNS | TNS_PD |
| 202R00268 | SM_R2_Nonurb | SWAMP | 2013 | T | Target |
| 202R00280 | SM_R2_Nonurb | SMCWPPP | 2013 | T | Target |
| 202R00284 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 202R00588 | SM_R2_Urb | SMCWPPP | 2012 | NT | NT_P |
| 202R00652 | SM_R2_Urb | SMCWPPP | 2013 | TNS | TNS_IA |
| 202R00716 | SM_R2_Urb | SMCWPPP | 2013 | TNS | TNS_IA |
| 202R00908 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |
| 204R00008 | SM_R2_Urb | SMCWPPP | 2012 | TNS | TNS_PD |
| 204R00040 | SM_R2_Urb | SMCWPPP | 2012 | NT | NT_NLSF |
| 204R00180 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 204R00200 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 204R00232 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 204R00244 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 204R00264 | SM_R2_Urb | SMCWPPP | 2012 | NT | NT_NC |

| Appendix A. SMCWPPP Site Evaluation Details. | | | | | |
|---|---|---|---|---|---|
| **Station Code** | **Stratum** | **Agency Code** | **Year Evaluated** | **Target Status Code** | **Target Status Detail** |
| 204R00424 | SM_R2_Urb | SMCWPPP | 2012 | NT | NT_NLSF |
| 204R00436 | SM_R2_Urb | SCVURPPP | 2013 | T | Target |
| 204R00500 | SM_R2_Urb | SMCWPPP | 2012 | NT | NT_P |
| 204R00520 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |
| 204R00680 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |
| 204R00692 | SM_R2_Urb | SMCWPPP | 2013 | NT | NT_NLSF |
| 204R00712 | SM_R2_Urb | SMCWPPP | 2012 | NT | NT_T |
| 204R00807 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |
| 204R00884 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |
| 204R00936 | SM_R2_Urb | SMCWPPP | 2013 | NT | NT_NLSF |
| 204R00948 | SM_R2_Urb | SMCWPPP | 2013 | NT | NT_AGDITCH |
| 205R00088 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 205R00168 | SM_R2_Urb | SMCWPPP | 2012 | T | Target |
| 205R00296 | SM_R2_Nonurb | SWAMP | 2013 | T | Target |
| 205R00307 | SM_R2_Urb | SMCWPPP | 2012 | TNS | TNS_PD |
| 205R00616 | SM_R2_Urb | SMCWPPP | 2013 | TNS | TNS_PD |
| 205R00728 | SM_R2_Urb | SMCWPPP | 2013 | NT | NT_NLSF |
| 205R00792 | SM_R2_Urb | SMCWPPP | 2013 | NT | NT_NLSF |
| 205R00808 | SM_R2_Urb | SMCWPPP | 2013 | TNS | TNS_PD |
| 205R00872 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |
| 205R00984 | SM_R2_Urb | SMCWPPP | 2013 | T | Target |

| Code | Description |
|---|---|
| ***TNS: target not sampleable*** | |
| TNS_PD | Access permanently denied OR no owner response, so access effectively denied |
| TNS_NR | No response from owners |
| TNS_TD | Access temporarily denied or temporarily inaccessible for other reasons |
| TNS_TNW | Temporarily no water due to water management activities |
| TNS_IA | Terrain is steep and unsafe for crews, and/or channel is too choked with vegetation to sample |
| TNS_DIST | Physically inaccessible - cannot hike round trip and sample in one day, and/or no good roads to access. |
| ***NT: non-target*** | |
| NT_W | Wetland |
| NT_NLSF | No/low spring flow |
| NT_H | Human hazards; unsafe for field crews |
| NT_NW | Non-wadable |
| NT_NC | Not a stream channel |
| NT_AGDITCH | Agricultural ditch; not natural, historic receiving water |
| NT_P | Pipeline |
| NT_T | Tidally influenced |

| Appendix A. SMCWPPP Site Evaluation Details. | | | | | |
|---|---|---|---|---|---|
| **Station Code** | **Stratum** | **Agency Code** | **Year Evaluated** | **Target Status Code** | **Target Status Detail** |
| NT_RI | Reservoir or impoundment | | | | |

# Attachment B
# QA/QC Details

## Water and Sediment Chemistry Field Duplicates

Included in this attachment are the results of water and chemistry field duplicate samples taken by SMCWPPP in 2012 and 2013. The following tables are included:

- Table B-1. 2012 Water Chemistry Field Duplicate Site 205R00232
- Table B-2. 2013 Water Chemistry Field Duplicate Site 205R00248
- Table B-3. 2012 Sediment Chemistry - Field Duplicate Results and QA Results
- Table B-4. 2013 Sediment Chemistry - Field Duplicate Results and QA Results
- Table B-5. 2012 Pathogen Sample and Field Duplicate Results
- Table B-6. 2013 Pathogen Sample and Field Duplicate Results

In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable.

Table B-1. 2012 Water Chemistry Field Duplicate Site 204R00232

| Sample Date | Sample ID | Analyte Name | Fraction Name | Unit Name | Result | DUP Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|---|---|
| 12/Jun/2012 | 204R00232-W | Alkalinity as CaCO3 | Total | mg/L | 470 | 467 | 0.32% | No |
| 12/Jun/2012 | 204R00232-W | Ammonia as N | Total | mg/L | ND | ND | N/A | N/A |
| 12/Jun/2012 | 204R00232-W | Ash Free Dry Mass | Fixed | $g/m^2$ | 103 | 125 | 19% | No |
| 12/Jun/2012 | 204R00232-W | Bicarbonate | None | mg/L | 438 | 434 | 0.46% | No |
| 12/Jun/2012 | 204R00232-W | Carbonate | None | mg/L | 31 | 33 | 3.13% | No |
| 12/Jun/2012 | 204R00232-W | Chloride | None | mg/L | 30 | 30 | 0.00% | No |
| 12/Jun/2012 | 204R00232-W | Chlorophyll a | Particulate | $mg/m^2$ | ND | ND | N/A | N/A |
| 12/Jun/2012 | 204R00232-W | Dissolved Organic Carbon | None | mg/L | 2.8 | 2.8 | 0.00% | No |
| 12/Jun/2012 | 204R00232-W | Hydroxide | None | mg/L | ND | ND | N/A | N/A |
| 12/Jun/2012 | 204R00232-W | Nitrate as N | None | mg/L | 1.5 | 1.5 | 0.00% | No |
| 12/Jun/2012 | 204R00232-W | Nitrite as N | None | mg/L | ND | ND | N/A | N/A |
| 12/Jun/2012 | 204R00232-W | Nitrogen, Total Kjeldahl | None | mg/L | 0.46 | 0.36 | 12.20% | No |
| 12/Jun/2012 | 204R00232-W | Ortho Phosphate as P | Dissolved | mg/L | 0.1 | 0.1 | 0.00% | No |
| 12/Jun/2012 | 204R00232-W | Phosphorus as P | Total | mg/L | 0.11 | 0.11 | 0.00% | No |
| 12/Jun/2012 | 204R00232-W | Silica as SiO2 | Total | mg/L | 68.3 | 68.4 | 0.07% | No |
| 12/Jun/2012 | 204R00232-W | Suspended Sediment Concentration | None | mg/L | ND | ND | N/A | N/A |

Table B-2. 2013 Water Chemistry Field Duplicate Site 202R00248

| Sample Date | SampleID | Analyte Name | Fraction Name | Unit Name | Result | DUP Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|---|---|
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Alkalinity as CaCO3 | Total | mg/L | 235 | 234 | 0% | No |
| 27/May/2013 | 202R00248-W-01<br>202R00248-W-51 | Ammonia as N | Total | mg/L | ND | ND | N/A | N/A |
| 27/May/2013 | 202R00248-W-08<br>202R00248-W-58 | Ash Free Dry Mass | Fixed | $g/m^2$ | 228 | 113 | 67% | Yes |
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Bicarbonate | Total | mg/L | 235 | 234 | 0% | No |
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Carbonate | Total | mg/L | ND | ND | N/A | N/A |
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Chloride | Dissolved | mg/L | 56 | 59 | 5% | No |
| 27/May/2013 | 202R00248-W-07<br>202R00248-W-57 | Chlorophyll a | Particulate | $mg/m^2$ | 36 | 26 | 32% | Yes |
| 27/May/2013 | 202R00248-W-06<br>202R00248-W-56 | Dissolved Organic Carbon | Dissolved | mg/L | 3.1 | 3.4 | 9% | No |
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Hydroxide | Total | mg/L | ND | ND | N/A | N/A |
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Nitrate as N | Dissolved | mg/L | ND | ND | N/A | N/A |
| 27/May/2013 | 202R00248-W-02<br>202R00248-W-52 | Nitrite as N | Total | mg/L | ND | ND | N/A | N/A |
| 27/May/2013 | 202R00248-W-01<br>202R00248-W-51 | Nitrogen, Total Kjeldahl | None | mg/L | ND | ND | N/A | N/A |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 27/May/2013 | 202R00248-W-05<br>202R00248-W-55 | Ortho Phosphate as P | Dissolved | mg/L | 0.15 | 0.15 | 0% | No |
| 27/May/2013 | 202R00248-W-01<br>202R00248-W-51 | Phosphorus as P | Total | mg/L | 0.16 | 0.16 | 0% | No |
| 27/May/2013 | 202R00248-W-04<br>202R00248-W-54 | Silica as SiO2 | Total | mg/L | 27 | 27 | 0% | No |
| 27/May/2013 | 202R00248-W-03<br>202R00248-W-53 | Suspended Sediment Concentration | Particulate | mg/L | ND | ND | N/A | N/A |

Table B-3. 2012 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| SM 2540 B | % Solids | % | 52 | 55 | 6% | No |
| SM 2540 B | % Solids | % | 50 | 54 | 8% | No |
| EPA 8270C | Acenaphthene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Acenaphthylene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Anthracene | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Arsenic | mg/Kg dw | 2 | 1.9 | 5% | No |
| EPA 8270C | Benz(a)anthracene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Benzo(a)pyrene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Benzo(b)fluoranthene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Benzo(e)pyrene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Benzo(g,h,i)perylene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Benzo(k)fluoranthene | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Bifenthrin | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Biphenyl | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Cadmium | mg/Kg dw | 0.09 | 0.09 | 0% | No |
| EPA 8081A | Chlordane, cis- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Chlordane, trans- | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Chromium | mg/Kg dw | 67 | 64 | 5% | No |
| EPA 8270C | Chrysene | ng/g dw | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Clay | % | 21.07 | 20.83 | 1% | No |
| Plumb, 1981, GS | Clay | % | 6.01 | 4.91 | 20% | No |
| EPA 6020 | Copper | mg/Kg dw | 20 | 20 | 0% | No |
| GCMS-NCI-SIM | Cyfluthrin, total | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Cyhalothrin, lambda, total | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Cypermethrin, total | ng/g dw | ND | ND | N/A | N/A |

Table B-3. 2012 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| EPA 8081A | DDD(o,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDD(p,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDE(o,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDE(p,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDT(o,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDT(p,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Decachlorobiphenyl(Surrogate) | % recovery | 33 | 38 | 14% | No |
| GCMS-NCI-SIM | Decachlorobiphenyl(Surrogate) | % recovery | 94 | 76 | 21% | No |
| GCMS-NCI-SIM | Deltamethrin/Tralomethrin | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Dibenz(a,h)anthracene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Dibenzothiophene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Dieldrin | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Dimethylnaphthalene, 2,6- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Endrin | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Esfenvalerate/Fenvalerate, total | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Esfenvalerate-d6;#1(Surrogate) | % recovery | 101 | 96 | 5% | No |
| GCMS-NCI-SIM | Esfenvalerate-d6;#2(Surrogate) | % recovery | 95 | 95 | 0% | No |
| EPA 8270C | Fluoranthene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Fluorene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Fluorobiphenyl, 2-(Surrogate) | % recovery | 84 | 89 | 6% | No |
| Plumb, 1981, GS | Granule | % | 0.64 | 0.38 | 51% | Yes |
| EPA 8081A | HCH, gamma | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Heptachlor epoxide | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Indeno(1,2,3-c,d)pyrene | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Lead | mg/Kg dw | 9.3 | 8.7 | 7% | No |

Table B-3. 2012 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| EPA 7471A | Mercury | mg/Kg dw | 0.065 | 0.058 | 11% | No |
| EPA 8270C | Methylnaphthalene, 1- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Methylnaphthalene, 2- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Methylphenanthrene, 1- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Naphthalene | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Nickel | mg/Kg dw | 150 | 140 | 7% | No |
| EPA 8270C | Nitrobenzene-d5(Surrogate) | % recovery | 80 | 85 | 6% | No |
| Plumb, 1981, GS | Pebble | % | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Pebble | % | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Pebble | % | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Pebble | % | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Permethrin, cis- | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Permethrin, Total | ng/g dw | ND | ND | N/A | N/A |
| GCMS-NCI-SIM | Permethrin, trans- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Perylene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Phenanthrene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Pyrene | ng/g dw | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Sand | % | 15.94 | 15.41 | 3% | No |
| Plumb, 1981, GS | Sand | % | 12.2 | 12.7 | 4% | No |
| Plumb, 1981, GS | Sand | % | 14.52 | 17.59 | 19% | No |
| Plumb, 1981, GS | Sand | % | 2.92 | 3.27 | 11% | No |
| Plumb, 1981, GS | Sand | % | 0.9 | 1.66 | 59% | Yes |
| Plumb, 1981, GS | Silt | % | 4.49 | 4.43 | 1% | No |
| Plumb, 1981, GS | Silt | % | 3.31 | 3.46 | 4% | No |
| Plumb, 1981, GS | Silt | % | 6.25 | 5.76 | 8% | No |

Table B-3. 2012 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| Plumb, 1981, GS | Silt | % | 12.39 | 9.98 | 22% | No |
| EPA 8270C | Terphenyl-d14(Surrogate) | % recovery | 124 | 134 | 8% | No |
| EPA 8081A | Tetrachloro-m-xylene(Surrogate) | % recovery | 50 | 48 | 4% | No |
| EPA 9060 | Total Organic Carbon | % dw | 1.4 | 1.5 | 7% | No |
| EPA 6020 | Zinc | mg/Kg dw | 47 | 44 | 7% | No |

Note: Highlighted rows - exceeds MQO (>25%).

Table B-4. 2013 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| EPA 8270C | Acenaphthene | ng/g dw | 48 | 26 | 59% | Yes |
| EPA 8270C | Acenaphthylene | ng/g dw | J7.1 | ND | N/A | N/A |
| EPA 8270C | Anthracene | ng/g dw | 220 | 98 | 77% | Yes |
| EPA 6020 | Arsenic | mg/Kg dw | 2.5 | 2.4 | 4% | No |
| EPA 8270C | Benz(a)anthracene | ng/g dw | 700 | 360 | 64% | Yes |
| EPA 8270C | Benzo(a)pyrene | ng/g dw | 230 | 220 | 4% | No |
| EPA 8270C | Benzo(b)fluoranthene | ng/g dw | 430 | 440 | 2% | No |
| EPA 8270C | Benzo(e)pyrene | ng/g dw | 170 | 180 | 6% | No |
| EPA 8270C | Benzo(g,h,i)perylene | ng/g dw | 230 | 190 | 19% | No |
| EPA 8270C | Benzo(k)fluoranthene | ng/g dw | 170 | 190 | 11% | No |
| EPA 8270M_NCI | Bifenthrin | ng/g dw | 1 | 0.92 | 8% | No |
| EPA 8270C | Biphenyl | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Cadmium | mg/Kg dw | 0.54 | 0.48 | 12% | No |
| EPA 8081A | chlordane, cis- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | chlordane, trans- | ng/g dw | ND | ND | N/A | N/A |
| EPA 6020 | Chromium | mg/Kg dw | 24 | 21 | 13% | No |
| EPA 8270C | Chrysene | ng/g dw | 870 | 640 | 30% | Yes |
| Plumb, 1981, GS | Clay - Coarse 0.00195 to <0.0039 mm | % | 1.4 | 1.5 | 7% | No |
| Plumb, 1981, GS | Clay - Medium 0.00098 to <0.00195 mm | % | 3.78 | 3.36 | 12% | No |
| EPA 6020 | Copper | mg/Kg dw | 24 | 22 | -9% | No |
| EPA 8270M_NCI | Cyfluthrin, total | ng/g dw | 0.31 | ND | N/A | N/A |
| EPA 8270M_NCI | Cyhalothrin, lambda, total | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270M_NCI | Cypermethrin, total | ng/g dw | J0.23 | ND | N/A | N/A |
| EPA 8081A | DDD(o,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDD(p,p') | ng/g dw | 3.4 | 2.3 | 39% | Yes |

Table B-4. 2013 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| EPA 8081A | DDE(o,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | DDE(p,p') | ng/g dw | 2.7 | 1.8 | 40% | Yes |
| EPA 8081A | DDT(o,p') | ng/g dw | 4.7 | ND | N/A | N/A |
| EPA 8081A | DDT(p,p') | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Decachlorobiphenyl(Surrogate) | % recovery | 9.2 | 7 | 27% | Yes |
| EPA 8270M_NCI | Deltamethrin/Tralomethrin | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Dibenz(a,h)anthracene | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Dibenzothiophene | ng/g dw | 44 | 32 | 32% | Yes |
| EPA 8081A | Dieldrin | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Dimethylnaphthalene, 2,6- | ng/g dw | 68 | ND | N/A | N/A |
| EPA 8081A | Endrin | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270M_NCI | Esfenvalerate-d6-1(Surrogate) | % recovery | 109 | 121 | 10% | No |
| EPA 8270M_NCI | Esfenvalerate-d6-2(Surrogate) | % recovery | 113 | 129 | 13% | No |
| EPA 8270M_NCI | Esfenvalerate/Fenvalerate, total | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Fluoranthene | ng/g dw | 2100 | 1300 | 47% | Yes |
| EPA 8270C | Fluorene | ng/g dw | 67 | 39 | 53% | Yes |
| EPA 8270C | Fluorobiphenyl, 2-(Surrogate) | % recovery | 61 | 49 | 22% | No |
| Plumb, 1981, GS | Granule - 2.0 to <4.0 mm | % | 5.52 | 3.98 | 32% | Yes |
| EPA 8081A | HCH, gamma- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8081A | Heptachlor epoxide | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Indeno(1,2,3-c,d)pyrene | ng/g dw | 220 | 180 | 20% | No |
| EPA 6020 | Lead | mg/Kg dw | 51 | 42 | 19% | No |
| EPA 7471A | Mercury | mg/Kg dw | 0.12 | 0.078 | 42% | Yes |
| EPA 8270C | Methylnaphthalene, 1- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Methylnaphthalene, 2- | ng/g dw | ND | ND | N/A | N/A |

Table B-4. 2013 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| EPA 8270C | Methylphenanthrene, 1- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Naphthalene | ng/g dw | 14 | J9.3 | N/A | N/A |
| EPA 6020 | Nickel | mg/Kg dw | 26 | 25 | 4% | No |
| EPA 8270C | Nitrobenzene-d5(Surrogate) | % recovery | 76 | 62 | 20% | No |
| Plumb, 1981, GS | Pebble - Large 16 to <32 mm | % | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Pebble - V. Large 32 to <64 mm | % | ND | ND | N/A | N/A |
| Plumb, 1981, GS | Pebble - Small 4 to <8 mm | % | 1.87 | 2.13 | 13% | No |
| Plumb, 1981, GS | Pebble - Medium 8 to <16 mm | % | 3.06 | 7.77 | 87% | Yes |
| EPA 8270M_NCI | Permethrin, cis- | ng/g dw | 2.5 | 2.8 | 11% | No |
| EPA 8270M_NCI | Permethrin, trans- | ng/g dw | ND | ND | N/A | N/A |
| EPA 8270C | Perylene | ng/g dw | 54 | 52 | 4% | No |
| EPA 8270C | Phenanthrene | ng/g dw | 1100 | 580 | 62% | Yes |
| EPA 8270C | Pyrene | ng/g dw | 1900 | 1200 | 45% | Yes |
| Plumb, 1981, GS | Sand - V. Coarse 1.0 to <2.0 mm | % | 4.51 | 4.46 | 1% | No |
| Plumb, 1981, GS | Sand - Fine 0.125 to <0.25 mm | % | 21.17 | 20.58 | 3% | No |
| Plumb, 1981, GS | Sand - Medium 0.25 to <0.5 mm | % | 16.99 | 16.27 | 4% | No |
| Plumb, 1981, GS | Sand - Coarse 0.5 to <1.0 mm | % | 6.36 | 6.02 | 5% | No |
| Plumb, 1981, GS | Sand - V. Fine 0.0625 to <0.125 mm | % | 16.25 | 15.32 | 6% | No |
| Plumb, 1981, GS | Silt - Medium 0.0156 to <0.031 mm | % | 3.89 | 3.33 | 16% | No |
| Plumb, 1981, GS | Silt - Coarse 0.031 to <0.0625 mm | % | 12.36 | 12.7 | 3% | No |
| Plumb, 1981, GS | Silt - V. Fine 0.0039 to <0.0078 mm | % | 1.53 | 1.1 | 33% | Yes |
| Plumb, 1981, GS | Silt - Fine 0.0078 to <0.0156 mm | % | 1.31 | 1.47 | 12% | No |
| EPA 8270C | Terphenyl-d14(Surrogate) | % recovery | 118 | 106 | 11% | No |
| EPA 8081A | Tetrachloro-m-xylene(Surrogate) | % recovery | 73 | 80 | 9% | No |
| EPA 9060 | Total Organic Carbon | % dw | 1.4 | 1.7 | 19% | No |

Table B-4. 2013 Sediment Chemistry - Field Duplicate Results and QA Results

| Method Name | Analyte Name | Unit | Sample Result | Field Duplicate Result | RPD | Exceeds MQO (>25%) |
|---|---|---|---|---|---|---|
| EPA 6020 | Zinc | mg/Kg dw | 160 | 150 | 6% | No |

Table B-5. 2012 Pathogen Sample and Field Duplicate Results

| Parameter | Unit | Sample Result | Field Duplicate Result | 95% Confidence Interval | Exceeds MQO |
|---|---|---|---|---|---|
| E. Coli | MPN/100mL | 220 | 170 | 70-440 | No |
| Fecal Coliform | MPN/100mL | 80 | 70 | 22-220 | No |
| Total Coliform | MPN/100mL | 80 | 70 | 22-220 | No |

Table B-6. 2013 Pathogen Sample and Field Duplicate Results

| Parameter | Unit | Sample Result | Field Duplicate Result | 95% Confidence Interval | Exceeds MQO |
|---|---|---|---|---|---|
| E. Coli | MPN/100mL | 900 | 900 | 220-2600 | No |
| Fecal Coliform | MPN/100mL | 900 | 900 | 220-2600 | No |

# Attachment C
# SoCal B-IBI and CSCI Scores for Historical Dataset

Attachment C. Biological condition, represented by SoCal B-IBI, NoCal B-IBI, and CSCI scores, for 90 sampling events conducted in San Mateo County between 2002 and 2013.

| Station Code | Sample Date | Project | Creek | NoCal IBI | SoCal IBI Score | CSCI Score |
|---|---|---|---|---|---|---|
| 202BUT020 | 4/9/2002 | Water Board | Butano Creek | 52 | 66 | 0.89 |
| 202BUT030 | 4/9/2002 | Water Board | Butano Creek | 64 | 82 | 0.95 |
| 202BUT040 | 4/9/2002 | Water Board | Butano Creek | 75 | 96 | 1.11 |
| 202BUT050 | 4/9/2002 | Water Board | Little Butano Creek | 78 | 87 | 1.04 |
| 202PES050 | 4/9/2002 | Water Board | Pescadero Creek | 40 | 63 | 0.75 |
| 202PES060 | 4/10/2002 | Water Board | Pescadero Creek | 55 | 64 | 0.96 |
| 202PES070 | 4/10/2002 | Water Board | Pescadero Creek | 49 | 66 | 0.92 |
| 202PES080 | 4/10/2002 | Water Board | Pescadero Creek | 39 | 52 | 0.70 |
| 202PES095 | 4/10/2002 | Water Board | Pescadero Creek | 60 | 77 | 1.10 |
| 202PES100 | 4/10/2002 | Water Board | Pescadero Creek | 66 | 77 | 1.10 |
| 202PES120 | 4/10/2002 | Water Board | Pescadero Creek | 60 | 90 | 1.09 |
| 202PES140 | 4/9/2002 | Water Board | Pescadero Creek | 66 | 87 | 1.04 |
| 202PES150 | 4/10/2002 | Water Board | Jones Gulch | 65 | 80 | 0.84 |
| 202PES160 | 4/10/2002 | Water Board | Pescadero Creek | 74 | 92 | 1.06 |
| 202PES170 | 4/10/2002 | Water Board | Tareater Creek | 75 | 87 | 1.00 |
| 202PES180 | 4/10/2002 | Water Board | Peters Creek | 76 | 100 | 1.17 |
| 202PES190 | 4/10/2002 | Water Board | Pescadero Creek | 79 | 93 | 1.10 |
| 202PES200 | 4/9/2002 | Water Board | Slate Creek | 85 | 92 | 1.18 |
| 202PES210 | 4/9/2002 | Water Board | Oil Creek | 78 | 92 | 1.06 |
| 202PES230 | 4/9/2002 | Water Board | Waterman Creek | 69 | 96 | 0.89 |
| 202PES240 | 4/9/2002 | Water Board | Pescadero Creek | 86 | 97 | 1.10 |
| 202R00024 | 6/6/2012 | RMC | Woodhams Creek | 61 | 83 | 0.87 |
| 202R00038 | 6/26/2012 | RMC | Little Butano Creek | 76 | 92 | 0.93 |
| 202R00072 | 5/29/2012 | RMC | Pillarcitos Creek | 60 | 73 | 1.02 |
| 202R00087 | 5/30/2012 | RMC | Milagra | 42 | 57 | 0.63 |
| 202R00104 | 6/13/2012 | RMC | La Honda Creek | 41 | 57 | 0.71 |
| 202R00166 | 6/25/2012 | RMC | Little Butano Creek | 79 | 93 | 1.07 |
| 202R00248 | 5/23/2013 | RMC | San Gregorio Creek | 59 | 82 | 1.06 |
| 202R00280 | 5/22/2013 | RMC | Tributary to Alpine Creek | 52 | 67 | 0.91 |
| 202R00284 | 6/15/2012 | RMC | Denniston Creek | 52 | 62 | 0.77 |
| 202R00908 | 5/21/2013 | RMC | Calera | 15 | 14 | 0.19 |
| 202SGR010 | 4/11/2002 | Water Board | San Gregorio Creek | 71 | 80 | 1.08 |
| 202SGR030 | 4/11/2002 | Water Board | El Corte de Madera | 59 | 89 | 0.99 |
| 202SGR040 | 4/11/2002 | Water Board | San Gregorio Creek | 75 | 84 | 1.13 |
| 202SGR060 | 4/11/2002 | Water Board | Harrington Creek | 68 | 87 | 1.05 |
| 202SGR075 | 4/11/2002 | Water Board | San Gregorio Creek | 74 | 84 | 1.14 |
| 202SGR080 | 4/11/2002 | Water Board | La Honda Creek | 61 | 79 | 1.04 |
| 202SGR090 | 4/11/2002 | Water Board | Alpine Creek | 71 | 90 | 1.08 |

| Station Code | Sample Date | Project | Creek | NoCal IBI | SoCal IBI Score | CSCI Score |
|---|---|---|---|---|---|---|
| 202SGR110 | 4/11/2002 | Water Board | La Honda Creek | 78 | 94 | 1.12 |
| 202SGR120 | 4/11/2002 | Water Board | La Honda Creek | 58 | 70 | 1.04 |
| 202SGR130 | 4/11/2002 | Water Board | Mindego Creek | 80 | 93 | 1.08 |
| 202SGR150 | 4/11/2002 | Water Board | Alpine Creek | 86 | 92 | 1.06 |
| 202SPE020 | 5/15/2002 | SMCWPPP | San Pedro Creek | 16 | 27 | 0.43 |
| 202SPE020 | 5/4/2003 | SMCWPPP | San Pedro Creek | 21 | 34 | 0.52 |
| 202SPE040 | 5/15/2002 | SMCWPPP | San Pedro Creek | 28 | 27 | 0.67 |
| 202SPE040 | 4/27/2003 | SMCWPPP | San Pedro Creek | 26 | 30 | 0.59 |
| 202SPE050 | 5/11/2002 | SMCWPPP | San Pedro Creek | 24 | 40 | 0.63 |
| 202SPE050 | 4/27/2003 | SMCWPPP | San Pedro Creek | 29 | 32 | 0.64 |
| 202SPE060 | 5/11/2002 | SMCWPPP | San Pedro Creek NF | 22 | 13 | 0.42 |
| 202SPE060 | 4/27/2003 | SMCWPPP | San Pedro Creek NF | 21 | 10 | 0.29 |
| 202SPE070 | 5/11/2002 | SMCWPPP | San Pedro Creek SF/MF | 51 | 74 | 0.92 |
| 202SPE070 | 4/27/2003 | SMCWPPP | San Pedro Creek SF/MF | 71 | 90 | 1.03 |
| 202SPE080 | 5/4/2003 | SMCWPPP | San Pedro Creek SF/MF | 69 | 86 | 1.04 |
| 202SPE090 | 5/11/2002 | SMCWPPP | San Pedro Creek SF/MF | 69 | 84 | 1.01 |
| 202SPE090 | 5/4/2003 | SMCWPPP | San Pedro Creek SF/MF | 66 | 76 | 0.88 |
| 202SPE090 | 3/20/2009 | SMCWPPP | San Pedro Creek SF/MF | 65 | 82 | 0.94 |
| 204COR010 | 4/25/2005 | SMCWPPP | Cordilleras Creek | 14 | 21 | 0.31 |
| 204COR020 | 4/25/2005 | SMCWPPP | Cordilleras Creek | 14 | 17 | 0.32 |
| 204COR040 | 4/25/2005 | SMCWPPP | Cordilleras Creek | 25 | 21 | 0.51 |
| 204COR050 | 4/26/2005 | SMCWPPP | Cordilleras Creek | 20 | 23 | 0.53 |
| 204COR060 | 4/26/2005 | SMCWPPP | Cordilleras Creek | 14 | 13 | 0.40 |
| 204COR070 | 4/26/2005 | SMCWPPP | Cordilleras Creek | 21 | 27 | 0.46 |
| 204R00180 | 5/30/2012 | RMC | Sanchez Creek | 20 | 14 | 0.50 |
| 204R00200 | 5/31/2012 | RMC | Polhemus Creek | 24 | 19 | 0.54 |
| 204R00232 | 6/12/2012 | RMC | Arroyo Ojo de Aqua | 28 | 17 | 0.50 |
| 204R00244 | 6/12/2012 | RMC | Trib to Arroyo Ojo de Aqua | 6 | 9 | 0.54 |
| 204R00436 | 5/20/2013 | RMC | Easton Creek | 11 | 9 | 0.32 |
| 204R00520 | 5/28/2013 | RMC | Belmont Creek | 22 | 29 | 0.55 |
| 204R00680 | 5/28/2013 | RMC | Redwood Creek | 25 | 29 | 0.52 |
| 204R00807 | 5/21/2013 | RMC | Colma Creek | 8 | 1 | 0.22 |
| 204R00884 | 5/20/2013 | RMC | Easton Creek | 15 | 19 | 0.43 |
| 204SMA020 | 4/1/2003 | Water Board | San Mateo Creek | 9 | 14 | 0.24 |
| 204SMA020 | 4/14/2004 | SMCWPPP | San Mateo Creek | 8 | 0 | 0.31 |
| 204SMA060 | 4/1/2003 | Water Board | San Mateo Creek | 10 | 7 | 0.21 |
| 204SMA060 | 4/14/2004 | SMCWPPP | San Mateo Creek | 9 | 1 | 0.32 |
| 204SMA080 | 4/1/2003 | Water Board | San Mateo Creek | 11 | 9 | 0.26 |
| 204SMA080 | 4/13/2004 | SMCWPPP | San Mateo Creek | 20 | 16 | 0.35 |
| 204SMA110 | 4/1/2003 | Water Board | San Mateo Creek | 6 | 10 | 0.31 |

| Station Code | Sample Date | Project | Creek | NoCal IBI | SoCal IBI Score | CSCI Score |
|---|---|---|---|---|---|---|
| 204SMA110 | 4/13/2004 | SMCWPPP | San Mateo Creek | 21 | 10 | 0.42 |
| 204SMA120 | 4/1/2003 | Water Board | Polhemus Creek | 12 | 20 | 0.26 |
| 204SMA160 | 4/2/2003 | Water Board | San Mateo Creek | 68 | 86 | 0.86 |
| 204SMA160 | 4/15/2004 | SMCWPPP | San Mateo Creek | 64 | 77 | 0.77 |
| 204SMA160 | 3/20/2009 | Water Board | San Mateo Creek | 69 | 80 | 0.90 |
| 204SMA180 | 4/2/2003 | Water Board | San Mateo Creek | 54 | 76 | 0.69 |
| 204SMA180 | 4/15/2004 | SMCWPPP | San Mateo Creek | 66 | 76 | 0.90 |
| 204SMA180 | 3/20/2009 | Water Board | San Mateo Creek | 61 | 74 | 0.86 |
| 205R00088 | 6/4/2012 | RMC | Corte Madera | 64 | 79 | 1.19 |
| 205R00168 | 6/4/2012 | RMC | Corte Madera Creek | 64 | 82 | 1.00 |
| 205R00872 | 5/27/2013 | RMC | Bear Gulch Creek | 28 | 43 | 0.77 |
| 205R00984 | 5/27/2013 | RMC | Bear Gulch Creek | 49 | 66 | 0.93 |

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

# Appendix B

## SMCWPPP Geomorphic Study

# Geomorphic Study in San Pedro Creek

Submitted in Compliance with
NPDES Permit No. CAS612008, Provision C.8.d.iiii

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

*Prepared for:*

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)

*Prepared by:*

EOA, Inc.
1410 Jackson St.
Oakland, CA 94612

EOA inc.

## December 12, 2013

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# 1.0 INTRODUCTION

This *Geomorphic Study* conducted on behalf of the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) addresses the requirements of Provision C.8.d.iii of the Municipal Regional Permit (MRP) (SFRWQCB 2009).

MRP Provision C.8.d.iii requires Permittees to conduct a geomorphic monitoring project intended to answer the question: How and where can our creeks be restored or protected to cost-effectively reduce the impacts of pollutants, increased flow rates, and increased flow durations of urban runoff?

The provision requires that Permittees select a waterbody/reach, preferably one that contains significant fish and wildlife resources, and conduct one of the following projects:

*(1) Gather geomorphic data to support the efforts of a local watershed partnership to improve creek conditions; or*

*(2) Inventory locations for potential retrofit projects in which decentralized, landscape-based stormwater retention units can be installed; or*

*(3) Conduct a geomorphic study which will help in development of regional curves which help estimate equilibrium channel conditions for different-sized drainages. Select a waterbody/reach that is not undergoing changing land use. Collect and report the following data*

- *Formally surveyed channel dimensions (profile), planform, and cross-sections. Cross-sections shall include the topmost floodplain terraces and be marked by a permanent, protruding (not flush with the ground) monument.*
- *Contributing drainage area.*
- *Best available information on bankfull discharges and width and depth of channel formed by bankfull discharges.*
- *Best available information on average annual rainfall in the study area*

SMCWPPP has elected to complete option three. Bankfull geometries were measured by EOA, Inc. (EOA) in the Middle Fork of San Pedro Creek on November 22, 2013 and are presented here in relation to regional curves developed for various regions of the San Francisco Bay Area.

# 2.0 BACKGROUND

Bankfull is the water level, or stage, at which a channel is at the top of its banks and any further rise would result in water moving onto the flood plain. Dunne and Leopold (1978) defined bankfull stage as corresponding "*to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels*." Although extreme flow events often result in significant in-stream erosion, it is the more frequent flow events that transport the greatest quantity of sediment over time, forming the dimensions (or geometry) of natural channels. Hence, bankfull discharge typically has a recurrence interval of one to two years. Bankfull discharge is primarily a function of watershed area and mean annual precipitation. Bankfull dimensions however, respond to local rainfall patterns, geology, and local vegetation communities. Therefore, the relationship between watershed area and bankfull geometry differs with location.

Regional curves, otherwise known as bankfull hydraulic geometry relationships (Dunne and Leopold 1978), are statistical models (one-variable, ordinary least-squares regressions) that relate drainage area to bankfull discharge, bankfull cross-sectional area, bankfull width, and bankfull mean depth in settings that are expected to have similar runoff characteristics. Equations describing the regional curves can be used to estimate the discharge and dimensions of the bankfull channel when the drainage area of a watershed is known and are helpful for confirming field identification of the bankfull channel. Therefore, regional hydraulic curves are useful for a number of applications, including geomorphic assessment, regulatory activities, flood recovery, fluvial conflict management, and stream corridor protection and restoration design. Stream-restoration projects utilizing natural stream designs frequently are based on the bankfull- channel characteristics of stream reaches that can accommodate streamflow and sediment transport without excessive erosion or deposition and lie within a watershed that has similar runoff characteristics.

In 1978, Dunne and Leopold published a regional curve for the San Francisco Bay Region. This curve is generally appropriate for areas with at least 30 inches of mean annual precipitation. Riley (2003) modified the Dunne and Leopold curve for areas of the East Bay which experience lower rainfall and therefore have smaller channel dimensions for comparable drainage areas. Balance Hydrologics (Senter et al., 2012) recently developed the new "Inland South Bay and Monterey Bay" regional curve by compiling bankfull geometries from several creeks in the vicinity of Santa Clara County. The curve has a similar slope as the others developed for the San Francisco Bay Region but is characterized by even smaller bankfull dimensions that are the result of lower rainfall. Balance Hydrologics (Balance) subsequently presented an updated and improved Inland curve at the 2013 State of the Estuary Conference (Hecht et al., 2013). In contrast, Collins and Leventhal (2013)) developed a regional curve for the wetter regions of Marin and Sonoma Counties, and Howell (2009) published a curve for the Santa Cruz Mountains which have high rainfall and are characterized by redwood forests. These regional curves are shown in Figure 1. Supporting data are listed in Table 1.

# 3.0 GEOMORPHIC STUDY

SMCWPPP identified San Pedro Creek as a potential reference reach meeting the MRP Provision C.8.c.iii requirement that the selected waterbody/reach contain significant fish and wildlife resources and is not undergoing changing land use. The upper reaches of San Pedro Creek are perennial and protected from development within San Mateo County's San Pedro Valley Park which encompasses the Middle and South Forks. San Pedro Creek also supports steelhead trout populations (*Oncorhynchus mykiss*) which are expected to increase as a result of ongoing fish barrier removal projects. The Middle Fork is drains steep hillsides that are underlain primarily by sandstone formations in the north and the Franciscan Complex in the south (SMCWPPP 2001). Vegetation communities include native coastal shrub and chaparral on the hillsides and historically-farmed grasslands on the relatively flat and narrow valley floor. The riparian corridor is characterized by a dense canopy of mostly native species.

On November 8, 2013 staff from EOA (Bonnie de Berry), Balance (Barry Hecht), and the San Francisco State University (SFSU) Geography Department (Jerry Davis) conducted a stream survey of the Middle Fork of San Pedro Creek to confirm that it meets other channel reference reach selection criteria (i.e., is not undergoing active erosion and bankfull is easily recognizable). The reach located approximately 800 feet upstream of the Weller Ranch Road crossing met these criteria. Indicators of bankfull included geomorphic features such as deposits of finer sediment and breaks in bank slopes; absence of active erosion or bank failures; and distribution limits for perennial vegetation (i.e., alder trees).

On November 22, 2013 staff from EOA formally surveyed channel dimensions within the reach previously identified. A longitudinal profile and two crest-of-riffle cross-sections were surveyed using a GTS-235W TopCon Total Station provided by the SFSU Geography Department. Channel cross-sections were marked with permanent, protruding monuments (rebar posts). Figure 2 maps the location of the surveyed profile and cross-sections. Average bankfull cross-sectional area is plotted in Figure 1 with other Bay Area regional curves. San Pedro Creek plots immediately above the Dunne and Leopold (1978) curve. Mean annual rainfall was estimated for the watershed as 36 inches using the spatially gridded long-term average annual precipitation dataset (1981-2010) downloaded from the PRISM Climate Group at Oregon State University. San Pedro Creek's relationship to the various regional curves supports the use of the Dunne and Leopold (1978) curve for areas with mean annual precipitation of 30 inches or more. Although the watershed is in close proximity to the Santa Cruz Mountains, the absence of redwood stands in the watershed reduces the applicability of the Santa Cruz Mountain regional curve (Howell, 2009).

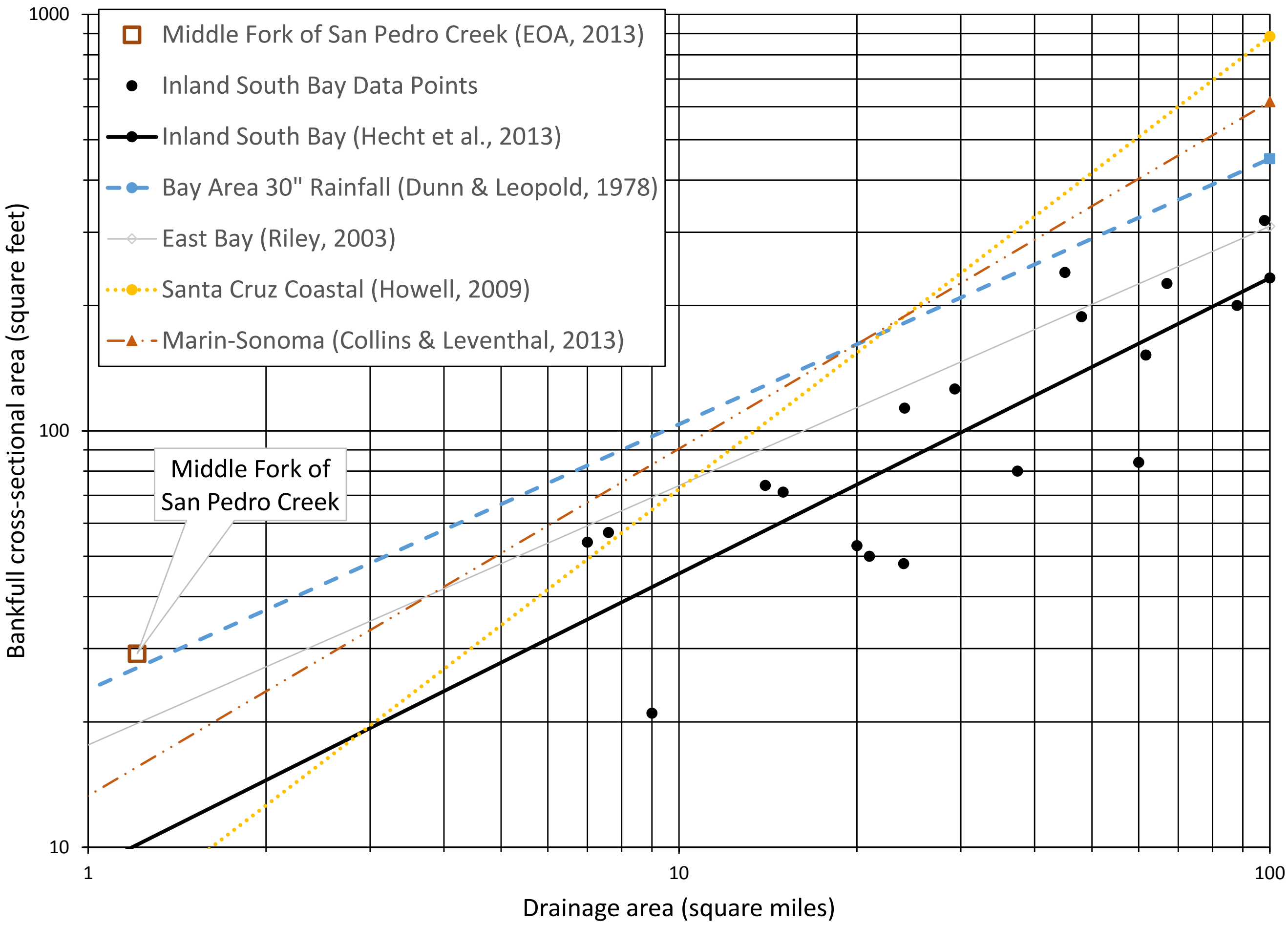


Figure 1. Bankfull cross-sectional area geometry relations, San Francisco Bay Region, California.

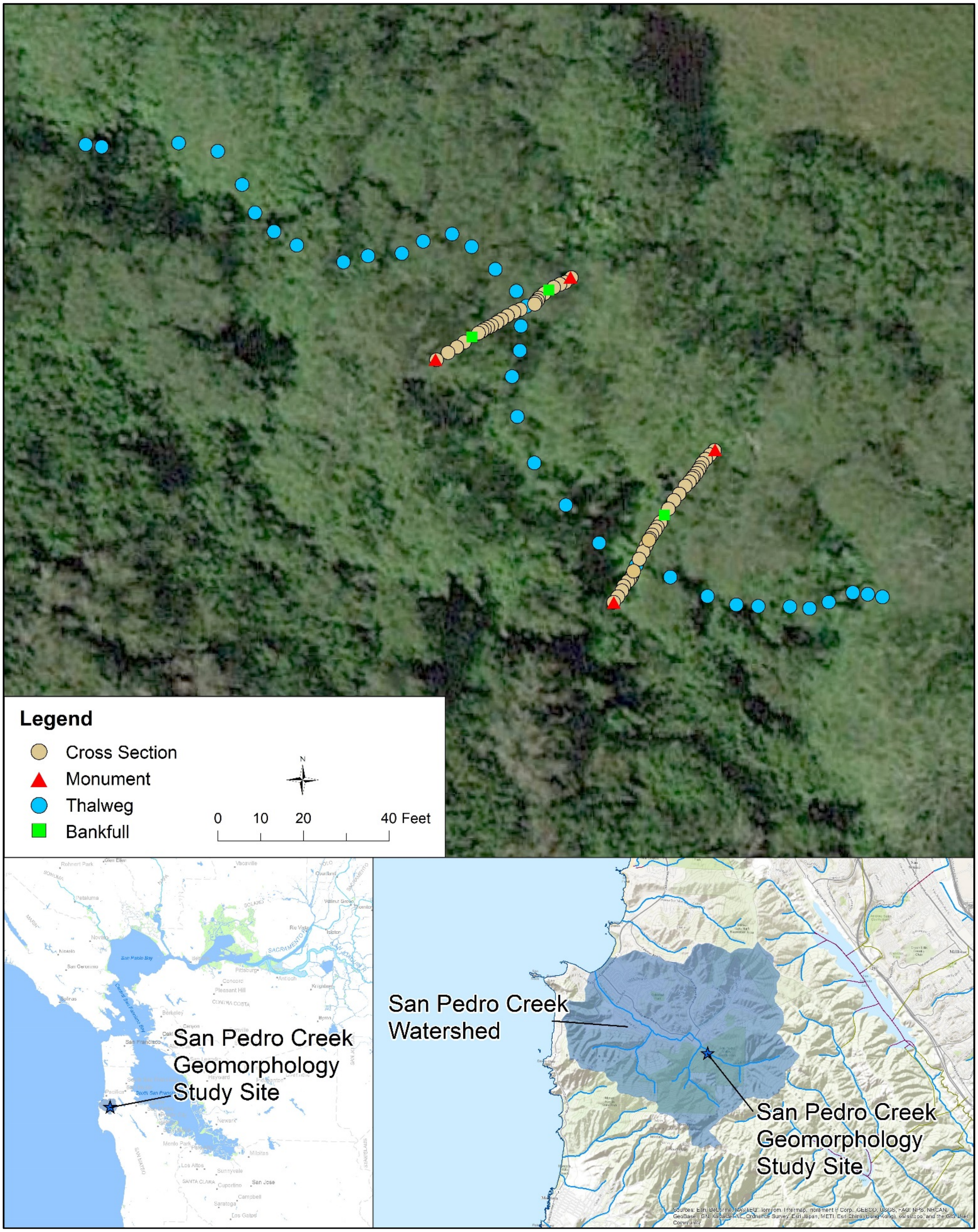


Figure 2. Location map of San Pedro Creek Geomorphic Study Site.

Table 1. San Francisco Bay Area bankfull geometries.

| Watershed | Station | Drainage Area (sq. mi.) | Regulated | Mean Annual Rainfall (inches) | Width (feet) | Depth (feet) | Area (sq. ft.) | Reference |
|---|---|---|---|---|---|---|---|---|
| *San Pedro Creek* | *u/s of Weller Ranch Road* | *1.2* | *N* | *36* | *19.0* | *1.51* | *29.2* | *unpublished EOA field notes 11/22/13* |
| ***Inland South Bay and Monterey Bay (Hecht et al., 2013)*** | | | | | | | | |
| *published curve* | -- | *0.1* | -- | -- | *6.16* | *0.35* | *1.73* | *Hecht et al., 2013* |
| *published curve* | -- | *100* | -- | -- | *45.7* | *3.64* | *233* | *Hecht et al., 2013* |
| **supporting data (Hecht et al., 2013)** | | | | | | | | |
| Llagas Creek | Reach 5 | 29.3 | * | 24 | 25.7 | 4.9 | 126 | Hecht field notes, 2011 |
| Llagas Creek | Buena Vista | 61.7 | * | 24 | 29.5 | 5.1 | 152 | Owens and Baggett, 2011 |
| Llagas Creek | u/s of Buena Vista | 60 | * | 24 | 33.5 | 2.5 | 84 | Senter, Strudley, Hecht field notes, 2012 |
| Llagas Creek | Oak Glen/Chesbro bridge | 20 | * | 24 | 26.5 | 2 | 53 | Senter, Strudley, Hecht field notes, 2012 |
| Llagas Creek | u/s Chesbro, 1st bridge | 14 | N | 24 | 32 | 2.3 | 74 | Senter, Strudley, Hecht field notes, 2012 |
| Llagas Creek | Casa Loma, Serpentine Loop | 9 | N | 24 | 16 | 1.3 | 21 | Senter, Strudley, Hecht field notes, 2012 |
| East Little Llagas Cr. | Reach 14 | 24.1 | N | 18 | 51.5 | 2.7 | 113.4 | Hecht field notes, 2011 |
| San Francisquito | Stanford pump station | 37.4 | * | 26 | 38 | 2.5 | 80 | Richmond field notes, 2011 |
| Stevens Creek | Blackberry Farm | 21 | * | 27 | 25 | 2 | 50 | Balance/SCVWD field notes, 2005 |
| Upper Penitencia Cr. | Berryessa Station | 24 | * | 18 | 24 | 2 | 48 | Chartrand and others, 2011 |
| Upper Carmel River | Bluff Camp | 48 | N | 37 | 54.8 | 3.4 | 188 | Hecht, 1981 |
| Upper Carmel River | Miller Fork | 15 | N | 37 | 34 | 2.1 | 71.3 | Hecht, 1981 |
| Calabazas Creek | u/s of Regnart Creek | 7.6 | N | 22 | -- | -- | 57 | Xu and others, 2009 |
| Adobe Creek | u/s of West Edith Rd. | 7 | N | 20 | -- | -- | 54 | Xu and others, 2010 |
| Guadalupe River | at Reach 6 | 67 | * | 18 | -- | -- | 226 | Xu and others, 2011 |
| Guadalupe River | at St. Johns | 88 | * | 18 | -- | -- | 200 | Xu and others, 2012 |
| Guadalupe River | Almaden Gage 23B | 45 | * | 24 | -- | -- | 240 | Xu and others, 2013 |
| Guadalupe River | d/s of Hwy 101 | 98 | * | 16 | -- | -- | 320 | Xu and others, 2014 |

| **Watershed** | **Station** | **Drainage Area** *(sq. mi.)* | **Regulated** | **Mean Annual Rainfall** *(inches)* | **Width** *(feet)* | **Depth** *(feet)* | **Area** *(sq. ft.)* | **Reference** |
|---|---|---|---|---|---|---|---|---|
| ***Bay Area at 30" Annual Precipitation (Dunne and Leopold, 1978)*** | | | | | | | | |
| *published curve* | -- | *0.1* | -- | *30* | 7 | 0.8 | 5.5 | Dunne and Leopold, 1978 |
| *published curve* | -- | *100* | -- | *30* | 80 | 5 | 450 | Dunne and Leopold, 1978 |
| ***East Bay (Riley, 2003)*** | | | | | | | | |
| *published curve* | -- | *0.1* | -- | *25* | -- | -- | 4.2 | Riley, 2003 |
| *published curve* | -- | *100* | -- | *25* | -- | -- | 310 | Riley, 2003 |
| ***Coastal Santa Cruz Mountains (Howell, 2009)*** | | | | | | | | |
| *published curve* | -- | *0.1* | -- | -- | *4.66* | *0.06* | *0.49* | Howell, 2009 |
| *published curve* | -- | *100* | -- | -- | *85.6* | *10.7* | *886* | Howell, 2009 |
| ***Marin-Sonoma Counties (Collins and Leventhal, 2013)*** | | | | | | | | |
| *published curve* | -- | *0.1* | -- | -- | *4.41* | *0.44* | *1.95* | Collins and Leventhal, 2013 |
| *published curve* | -- | *100* | -- | -- | *110* | *5.57* | *617* | Collins and Leventhal, 2013 |

Surveyed cross-section data are listed in Table 2 and plotted in Figure 3; local elevations were normalized to plot the cross-sections together. Bankfull shape and dimensions at the two riffle cross-sections are similar; however, the upstream riffle (Riffle #1) has steeper slopes on the left bank; whereas, the downstream riffle (Riffle #2) has a steeper right bank. This is illustrative of the overall alternating channel morphology. Floodplain terraces are not topographically evident and can be assumed at approximately two times bankfull.

The longitudinal profile for the surveyed reach is shown in Figure 4. Locations of the two surveyed cross-sections along the profile are shown for reference. The measured slope along the surveyed profile is 0.2 percent.

No flow gages have been installed on San Pedro Creek. Therefore, the Manning's equation was employed to estimate bankfull discharge. The manning's roughness coefficient for the reach was estimated in the field using United States Geological Survey (USGS) guidance (Arcement and Schneider, date unknown).

Table 2. San Pedro Creek bankfull dimensions.

| | | |
|---|---|---|
| Drainage area | *(square miles)* | 1.21 |
| Mean annual rainfall, at station | *(inches)* | 36 |
| Coordinates | *(lat/long)* | 37.57797/-121.47132 |
| | | |
| **Riffle #1 (upstream)** | | |
| Bankfull width | *(feet)* | 16.9 |
| Bankfull depth, average | *(feet)* | 1.3 |
| Bankfull area | *(square feet)* | 22.0 |
| | | |
| **Riffle #2 (downstream)** | | |
| Bankfull width | *(feet)* | 19.0 |
| Bankfull depth | *(feet)* | 1.5 |
| Bankfull area | *(square feet)* | 29.2 |
| | | |
| **Bankfull discharge (Mannings)** | *(cfs)* | 101 |

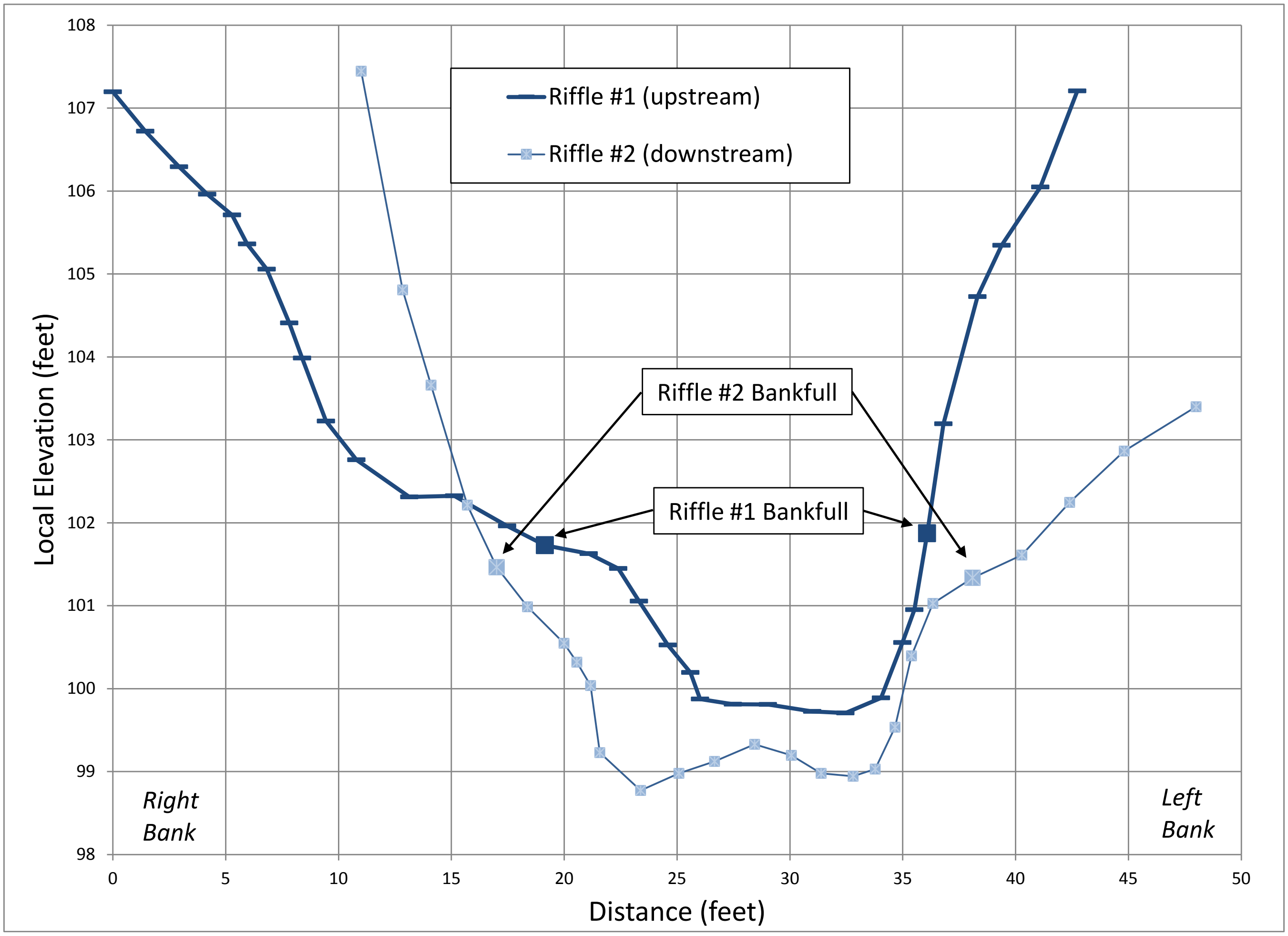


Figure 3. Surveyed cross-sections, Middle Fork of San Pedro Creek.

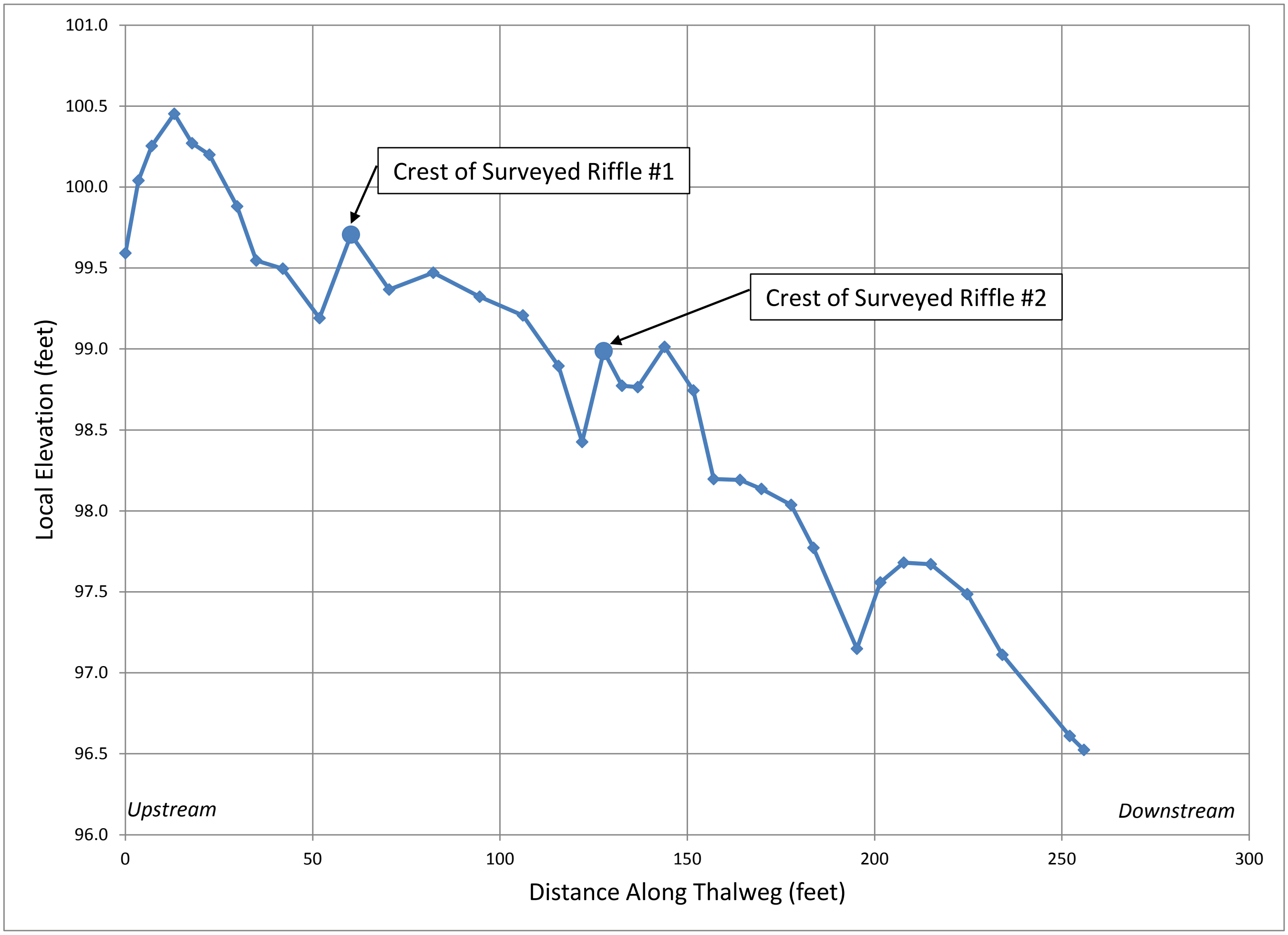


Figure 4. Surveyed longitudinal profile (upstream to downstream) in vicinity of riffle cross-sections, Middle Fork of San Pedro Creek.

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SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

# Appendix C

## Water Years 2012 & 2013 POC Loads Monitoring Report

SMCWPPP Integrated Monitoring Report, Part A

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

**Prepared by**

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**San Francisco Estuary Institute, Richmond, California**

**On**

**February 21, 2014**

**For**

**Bay Area Stormwater Management Agencies Association (BASMAA)**

**And**

**Regional Monitoring Program for Water Quality in San Francisco Bay (RMP)**
**Sources Pathways and Loadings Workgroup (SPLWG)**
**Small Tributaries Loading Strategy (STLS)**

## Acknowledgements

We were glad for the support and guidance of the Sources, Pathways and Loadings Workgroup of the Regional Monitoring Program for Water Quality in San Francisco Bay. The detailed work plan behind this work was developed through the Small Tributaries Loading Strategy (STLS) during a series of meetings in the summer of 2011. Local members on the STLS are Arleen Feng, Lucy Buchan, Khalil Abusaba and Chris Sommers (for BASMAA) and Richard Looker, Jan O'Hara, and Tom Mumley (for the Water Board). Khalil Abusaba, AMEC Environment and Infrastructure and Chris Sommers, EOA INC. provided helpful written reviews on the draft report that we incorporated to improve this final report. This project was completed with funding provided by the Bay Area Stormwater Management Agencies Association (BASMAA) and the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP).

This progress report can be cited as:

Gilbreath, A.N., Gluchowski, D.C., Hunt, J.A., Wu, J., and McKee, L.J., 2014. Pollutants of concern (POC) loads monitoring data progress report, water year (WYs) 2012 and 2013. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 712. San Francisco Estuary Institute, Richmond, California.

## Table of contents

## 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

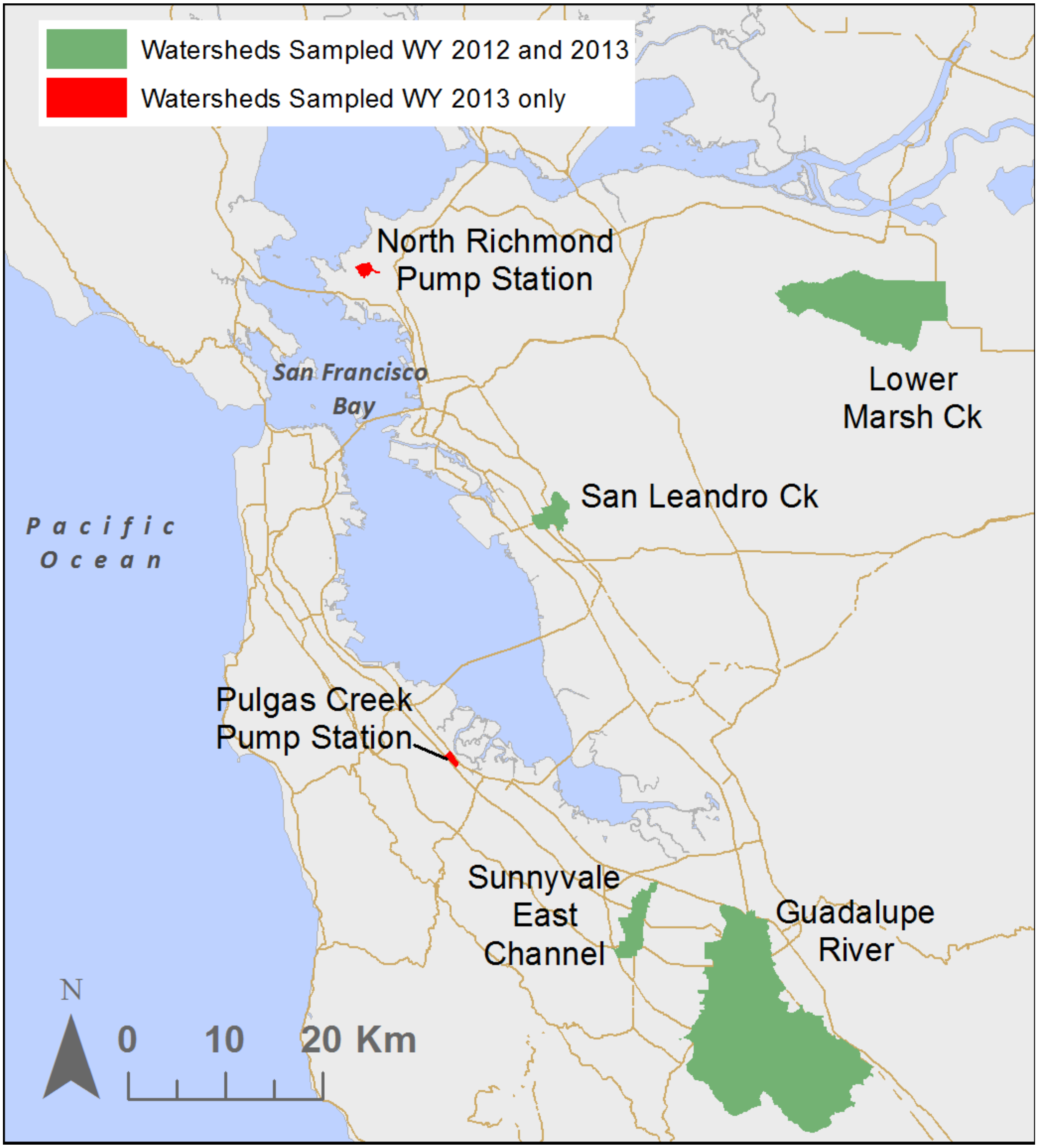


**Figure 1. Water year 2012 and 2013 sampling watersheds.**

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

| County program | Watershed name | Water years sampled | Watershed area ($km^2$)[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

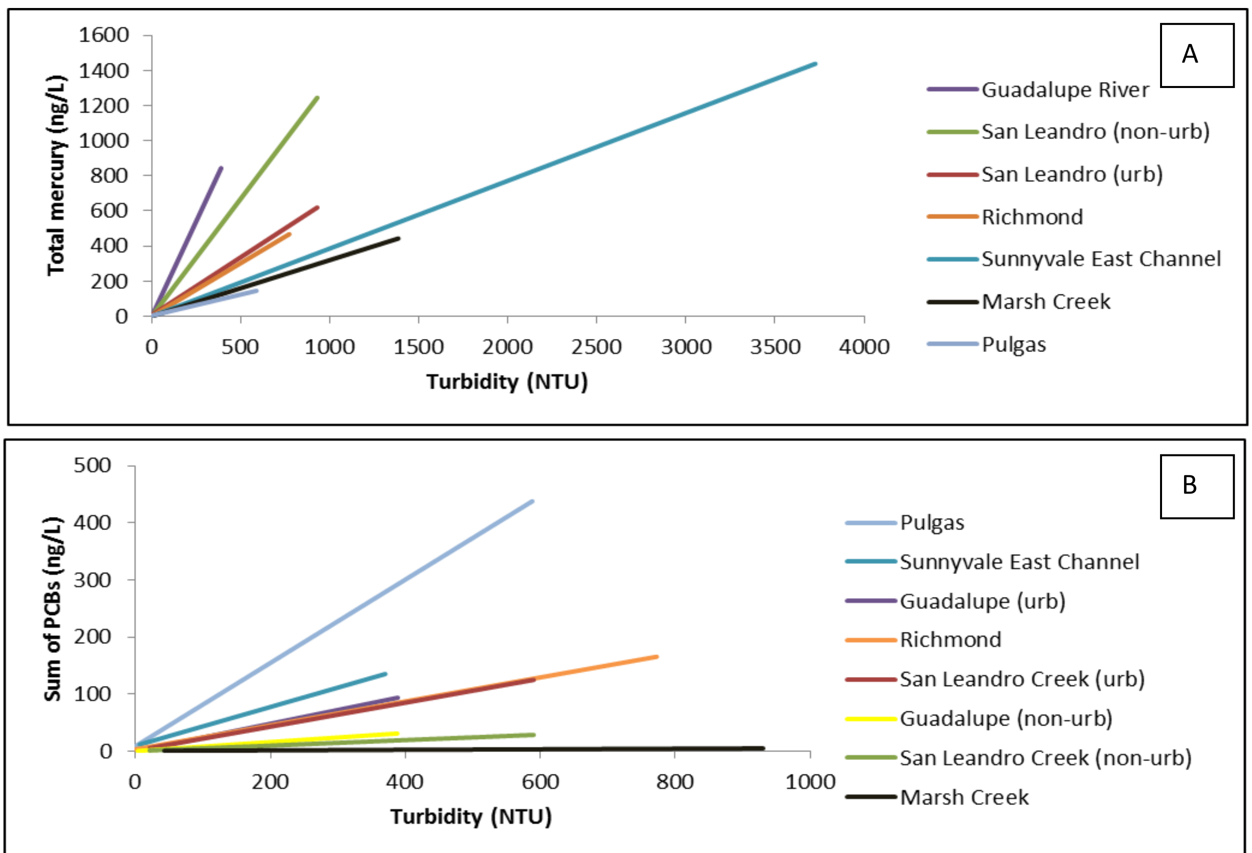


**Figure 2. Comparison of regression slopes between watersheds based on data collected during sampling to-date A) total Mercury and B) PCBs (Note Sunnyvale, Richmond and Pulgas includes data for water year 2013 only; Pulgas turbidity maximum is storm maximum not record maximum). Note these comparisons 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 ($\mu g/m^2$) | HgT ($\mu g/m^2$) | MeHgT ($\mu g/m^2$) | 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 1$^{st}$ to September 30$^{th}$) 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.

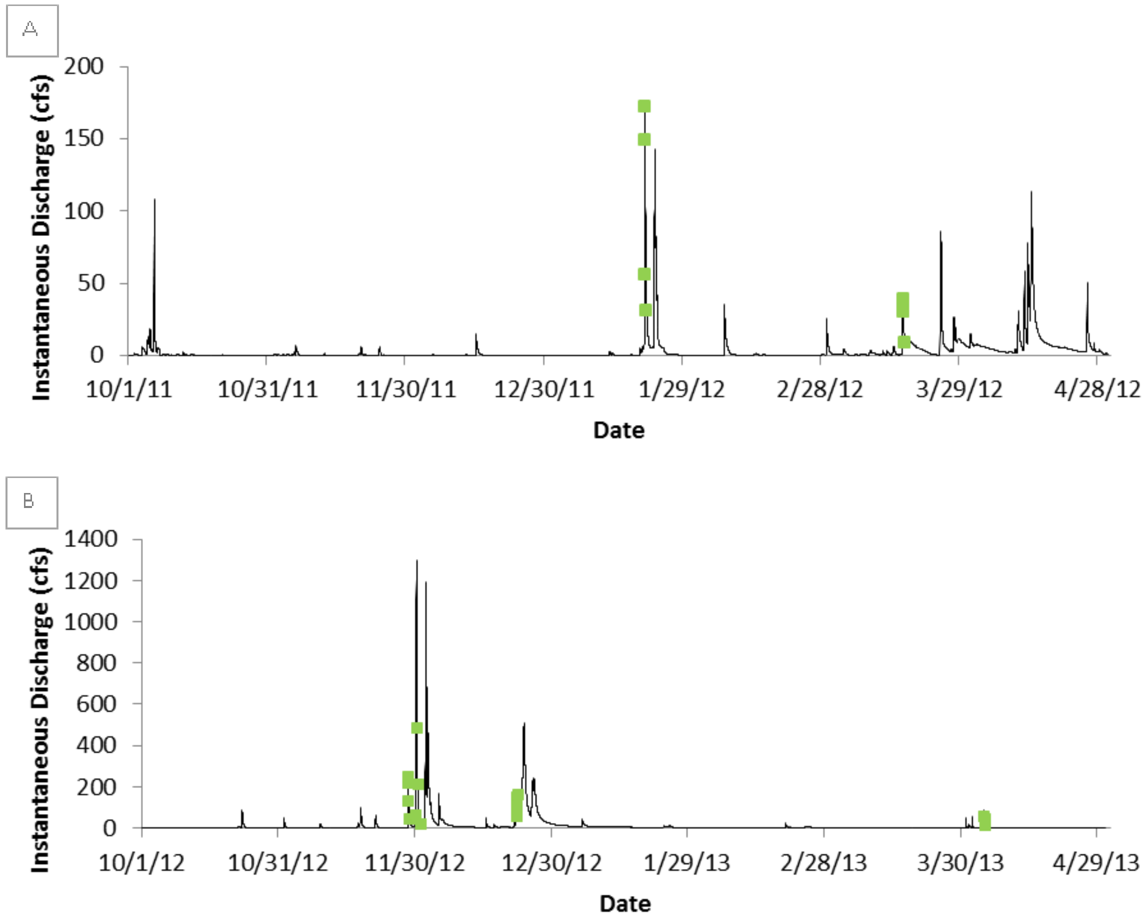



**Figure 3. Flow characteristics in Marsh Creek during water year 2012 (A) based on published data and for the water year 2013 (B) based on preliminary 15 minute data provided by the United States Geological Survey, gauge number 11337600) with sampling events plotted in green. Note, USGS normally publishes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

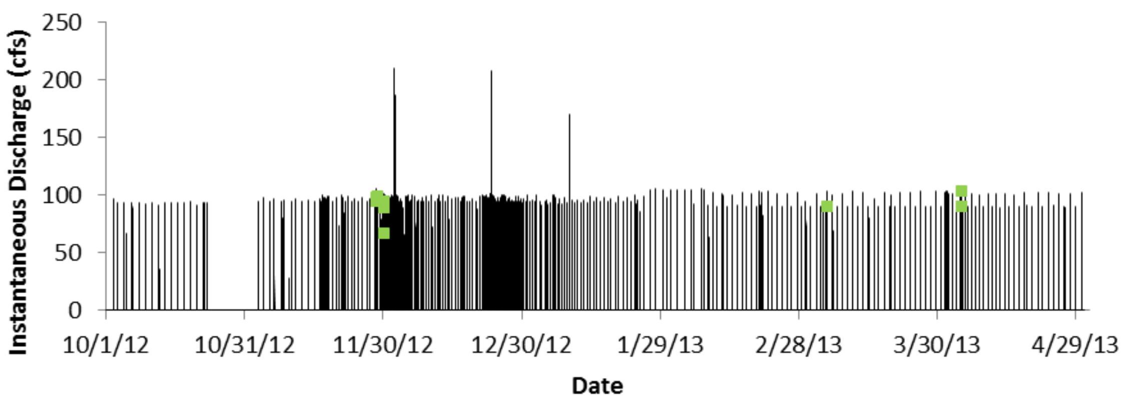



**Figure 4. Preliminary flow characteristics at North Richmond Pump Station during Water Year 2013 with sampling events plotted in green. Note, flow information may be updated in the future as we continue to refine how we interpret the well depth, pump RMP, pump efficiency curves, and well geometry information.**

#### *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 1$^{st}$ 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 17$^{th}$ 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

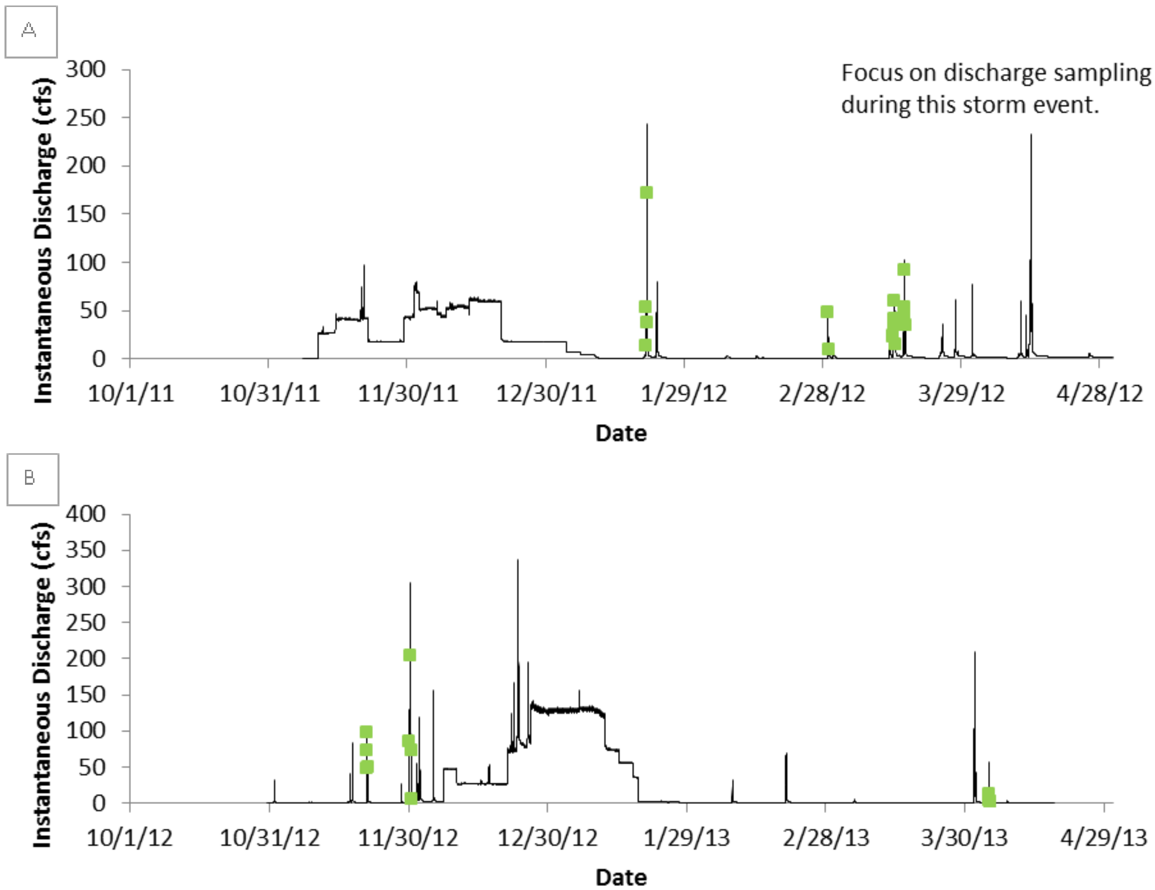



**Figure 5. Preliminary flow characteristics (primary y axis) in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A) and WY 2013 (B) with sampling events plotted in green. Note, flow information will be updated in the future when additional data.**

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.

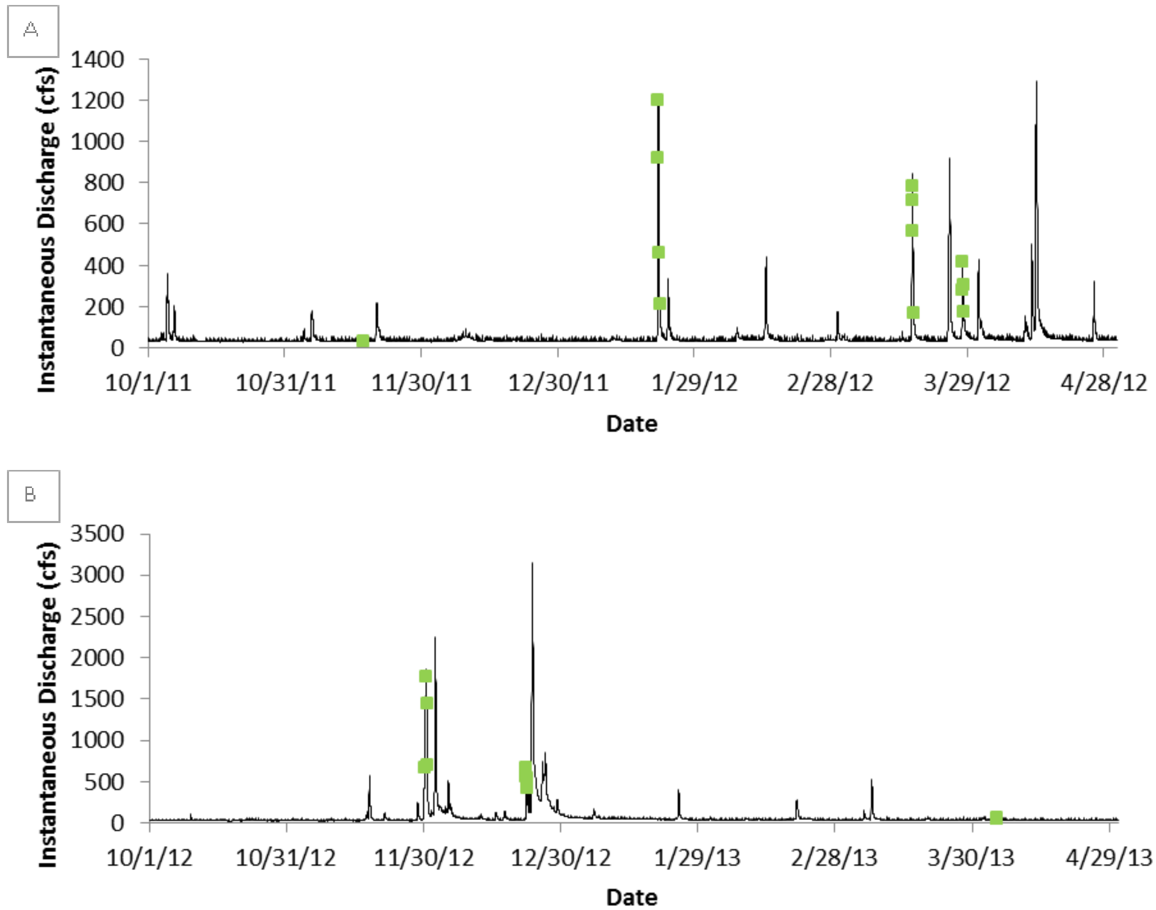



**Figure 6. Flow characteristics in Guadalupe River during water year 2012 (A) based on published data and preliminary 15 minute data for water year 2013 (B) provided by the USGS (gauge number 11169025), with sampling events plotted in green. The fuzzy nature of the low flow data are caused by baseflow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

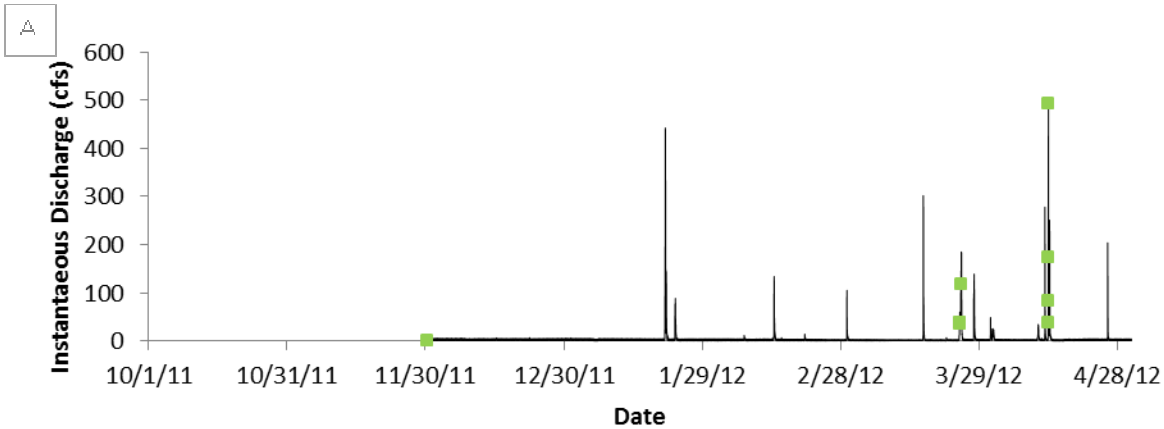
Santa Clara Valley Water District (SCVWD) has maintained a flow gauge on Sunnyvale East Channel from WY 1983 to present. Unfortunately, the record is known to be poor quality (pers. comm., Ken Stumpf, SCVWD), which was apparent when the record was regressed against rainfall ($R^2$ = 0.58) (Lent et al., 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



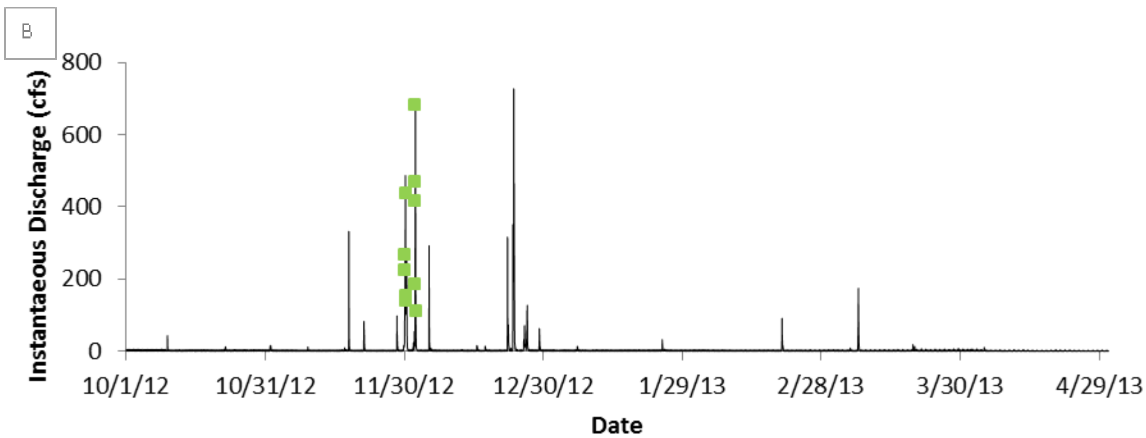




**Figure 7. Preliminary flow characteristics in Sunnyvale East Channel at East Ahwanee Avenue during WY 2012 (A) and WY 2013 (B) with sampling events marked in green. The flow record is based on the District rating curve for this station as verified by velocity sampling completed to-date. The rating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

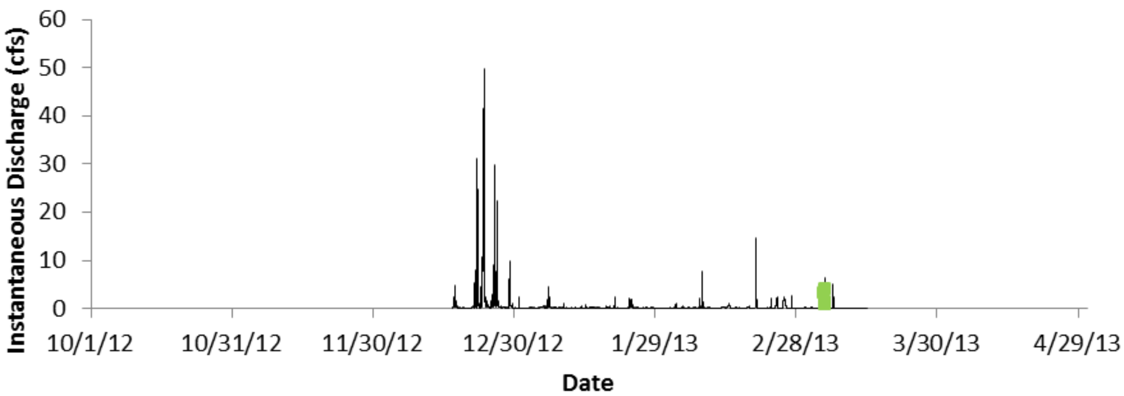



**Figure 8. Preliminary flow characteristics at Pulgas Creek Pump Station South during Water Year 2013 with sampling events plotted in green. Pulgas Creek Pump Station turbidity and suspended sediment concentration**

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.

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[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% | - | - | - |