



**RMP**  
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PROGRAM FOR WATER QUALITY  
IN SAN FRANCISCO BAY

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# Pollutants of Concern Reconnaissance Monitoring Progress Report, Water Years 2015 - 2018

Prepared by

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SFEI

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SFEI Contribution #942

## Preface

Reconnaissance monitoring for water years 2015, 2016, 2017 and 2018 was completed with funding provided by the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). This report is designed to be updated each year until completion of the study. At least one additional water year (2019) is planned for this study. This initial full draft report was prepared for the Bay Area Stormwater Management Agencies Association (BASMAA) in support of materials submitted on or before March 31<sup>st</sup> 2019 in compliance with the Municipal Regional Stormwater Permit (MRP) Order No. R2-2015-0049. This final report has been updated following review by advisors to the Sources, Pathways, and Loadings Workgroup of the RMP in April 2019.

## Acknowledgements

We appreciate the support and guidance from members of the Sources, Pathways, and Loadings Workgroup of the RMP. The detailed work plan behind this study was developed by the RMP Small Tributaries Loading Strategy (STLS) Team during a series of meetings in the summer of 2014, with slight modifications made during the summers of 2015, 2016, 2017, and 2018. Local members on the STLS Team at that time were Arleen Feng (Alameda Countywide Clean Water Program), Bonnie de Berry (San Mateo Countywide Water Pollution Prevention Program), Lucile Paquette (Contra Costa Clean Water Program), Chris Sommers and Lisa Sabin (Santa Clara Valley Urban Runoff Pollution Prevention Program), and Richard Looker and Jan O'Hara (Regional Water Board). RMP field and logistical support provided by San Francisco Estuary Institute (SFEI) over the first winter of the project included Patrick Kim, Carolyn Doehring, and Phil Trowbridge, in the second winter of the project included Patrick Kim, Amy Richey, and Jennifer Sun, in the winter of WY 2017 included Ila Shimabuku, Amy Richey, Steven Hagerty, Diana Lin, Margaret Sedlak, Jennifer Sun, Katie McKnight, Emily Clark, Don Yee, and Jennifer Hunt, and in the winter of WY 2018 included Ila Shimabuku, Margaret Sedlak, Jennifer Sun, Micha Salomon, and Don Yee. The RMP data management team is acknowledged for their diligent delivery of quality-assured well-managed data. This team was comprised of Amy Franz, Adam Wong, Michael Weaver, John Ross, and Don Yee in WYs 2015, 2016, 2017 and 2018. Helpful written reviews of this report were provided by members of BASMAA (Bonnie de Berry, EOA Inc. on behalf of the San Mateo Countywide Water Pollution Prevention Program; Lucile Paquette, Contra Costa Clean Water Program; Jim Scanlin, Alameda Countywide Clean Water Program); Barbara Mahler (USGS) and Richard Looker (SFBRWQCB). External independent review was provided by SPLWG advisors (Daniel Cain and Barbara Mahler both of the USGS).

## *Suggested citation:*

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## Executive Summary

The San Francisco Bay polychlorinated biphenyl (PCB) and mercury (Hg) total maximum daily loads (TMDLs) call for implementation of control measures to reduce PCB and Hg loads entering the Bay via stormwater. In 2009, the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) issued the first Municipal Regional Stormwater Permit (MRP). This MRP contained provisions aimed at improving information on stormwater pollutant loads in selected watersheds (Provision C.8.) and piloted a number of management techniques to reduce PCB and Hg loading to the Bay from smaller urbanized tributaries (Provisions C.11. and C.12.). In 2015, the Regional Water Board issued the second iteration of the MRP. “MRP 2.0” placed an increased focus on identifying those watersheds, source areas, and source properties that are potentially the most polluted and are therefore most likely to be cost-effective areas for addressing load-reduction requirements.

To support this increased focus, a stormwater reconnaissance monitoring field protocol was developed and implemented in water years (WYs) 2015, 2016, 2017 and 2018. Most of the sites monitored were in Alameda, Santa Clara, and San Mateo Counties, with a few sites in Contra Costa and Solano Counties. At 60 sampling sites, time-weighted composite water samples were collected during individual storm events and analyzed for 40 PCB congeners, total Hg (HgT), and suspended sediment concentration (SSC). At a subset of sites, additional samples were analyzed for selected trace metals, organic carbon (OC), and grain size. Where possible, sampling efficiency was increased by sampling two or three sites during a single storm if the sites were near enough to one another that alternating between them was safe and rapid. This same field protocol is being implemented in the winter of WY 2019 by the RMP. The San Mateo Countywide Water Pollution Prevention Program and the Santa Clara Valley Urban Runoff Pollution Prevention Program have also implemented the sampling protocol with their own funding.

During this study beginning in WY 2015, the RMP began piloting the use of un-staffed “remote” suspended sediment samplers (Hamlin samplers and Walling Tube samplers). These remote samplers were designed to enhance settling and capture of suspended sediment from the water column. At 10 of the manual sampling sites, a remote sample was collected using a Hamlin suspended sediment sampler in parallel with the manual sample, and at 9 sites, a remote sample was collected using a Walling Tube suspended sediment sampler in parallel with the manual sample.

### *Key Findings*

This report presents data from all available stormwater data<sup>1</sup> collected since WY 2003 when stormwater studies first began through SFEI contracts or RMP projects, not just the data collected for this WY 2015-2018 reconnaissance monitoring study (total of 83 sites). Based on this dataset a number of sites with elevated PCB and Hg stormwater concentrations and estimated concentrations on particles were identified. Including RMP sampling prior to WY 2015, now 24 sites (30%) with estimated particle concentrations of PCBs greater than 200 ng/g and 31 sites (38%) with estimated particle concentrations of Hg greater than 0.5 µg/g have been identified. Total PCB concentrations measured in the composite water samples collected from the 83 sites ranged 840-fold, from 533 to 448,000 pg/L (excluding one

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<sup>1</sup> Similar data collected by BASMAA in Santa Clara and San Mateo Counties is not included in this report.

sample where PCBs were below the detection limit). The three highest ranking sites for PCB whole-water concentrations were Pulgas Pump Station South (448,000 pg/L), Santa Fe Channel (198,000 pg/L), and Industrial Rd Ditch in San Carlos (160,000 pg/L). When normalized by SSC to generate estimated particle concentrations, the three sites with highest estimated particle concentrations were Pulgas Pump Station South (8,222 ng/g), Industrial Rd Ditch in San Carlos (6,139 ng/g), and Line 12H at Coliseum Way in Oakland (2,601 ng/g).

Total Hg concentrations in samples collected in water years since 2003 ranged 112-fold, from 5.4 to 603 ng/L. The lower variation in HgT concentrations relative to PCBs is consistent with conceptual models for these substances. HgT is expected to be more uniformly distributed than PCBs because it has more widespread sources in the urban environment, the concentrations and mass used in industrial applications were relatively smaller compared to industrial use of PCBs, and Hg has a larger atmospheric component to its cycle. The greatest HgT concentrations were measured at the Guadalupe River at Hwy 101 (603 ng/L), Guadalupe River at Foxworthy Road/Almaden (529 ng/L), and Zone 5 Line M (505 ng/L). The greatest estimated particle concentrations were measured at Guadalupe River at Foxworthy Road/Almaden (4.1 µg/g), Guadalupe River at Hwy 101 (3.6 µg/g), and the Outfall at Gilman St. in Berkeley (2.8 µg/g). The two Guadalupe River stations are downstream of the historic New Almaden Mining District.

The sites with the highest particle concentrations for PCBs were typically not the sites with the highest concentrations for HgT. The ten highest ranking sites for PCBs based on estimated particle concentrations ranked 45<sup>th</sup>, 27<sup>th</sup>, 19<sup>th</sup>, 22<sup>nd</sup>, 51<sup>st</sup>, 39<sup>th</sup>, 65<sup>th</sup>, 36<sup>th</sup>, 14<sup>th</sup>, and 10<sup>th</sup>, respectively, for estimated HgT particle concentrations.

#### *Remote Suspended Sediment Samplers*

Results from the two remote suspended sediment sampler types generally characterized sites similarly to the composite stormwater sampling methods. Sites with higher concentrations in the sediment collected by the remote samplers were the same as those with higher concentrations in the composite samples. Therefore, the remote samplers will be used in WY 2019 for preliminary screening of new sites to support decisions about further sampling.

In comparing the remote versus manual sampling methods, it is estimated that remote sampling methods generally are more cost-effective because they allow for many sites to be monitored during a single storm event without staff being present on site during the storm event. On the other hand, in using the remote sampling methods, there are initial costs to purchase the equipment, and labor is required to deploy and process samples. In addition, there will always be logistical constraints (such as turbulence, tidal influences, or hydraulic incompatibility) that complicate use of the remote samplers and therefore require manual monitoring at a site. The data collected using the remote sampling methodologies are generally useful for ranking sites for different pollutants but cannot be used for load calculations. Therefore, the remote sampling method may best be used as a companion to manual monitoring methods to reduce costs and collect data for other purposes, providing a cost-effective site screening field monitoring protocol to support decisions about further sampling.

### *Further Data Interpretations*

Relationships between the PCB and HgT estimated particle concentrations, watershed characteristics, and other water quality measurements were evaluated using Spearman Rank correlation analysis. Based on data collected since WY 2003, PCB particle concentrations positively correlate with impervious cover ( $r_s = 0.53$ ), old industrial land use ( $r_s = 0.59$ ), and HgT particle concentrations ( $r_s = 0.36$ ). PCB particle concentrations negatively correlate with watershed area and particle concentrations for arsenic, cadmium, copper, lead, and zinc. HgT particle concentrations do not correlate with those of other trace metals and had similar but weaker relationships to impervious cover, old industrial land use, and watershed area than did PCBs. In contrast, the trace metals arsenic, cadmium, copper, lead, and zinc were all correlated with one another. Overall, the data collected to date do not support the use of any of the trace metals analyzed as a proxy for either PCB or HgT pollution sources.

Old industrial land use is believed to have both the greatest yields as well as total mass of PCB loads in the region. The watersheds for the 83 sites that have been sampled with RMP and grant funding since WY 2003 cover about 26% of the old industrial area in the region. The largest proportion of old industrial area sampled to date in each county has been in Santa Clara County (61% of old industrial area in this county is in the watershed of a sampling site), followed by Alameda (30%), San Mateo (27%), and Contra Costa (9%) counties. Coverage in Santa Clara County is highest because several large watersheds have been sampled and old industrial areas are prevalent upstream of the sampling location in two of the watersheds sampled (Coyote Creek and Guadalupe River). Of the remaining areas in the region with old industrial land use yet to be sampled (78 km<sup>2</sup>), 49% of it lies within 1 km of the Bay and 63% is within 2 km of the Bay. These areas nearer the Bay are more likely to be tidal and to include heavy industrial areas that were historically serviced by rail and ship-based transport, and are often very difficult to sample because of a lack of public rights-of-way and tidal-related constraints. It may also be reasonable to suggest that these areas may have relatively high concentrations compared to industrial areas further from the Bay margin due to a longer use period and the nature of heavy machinery associated with rail and ship transport. A different sampling strategy may be needed to effectively estimate what mass of pollution is associated with these areas.

In the short term, this Pollutants of Concern Reconnaissance Monitoring study will continue at least into WY 2019 to continue to identify areas for follow-up investigation and possible management action. The focus will continue to be on finding new areas of concern, although follow-up sampling will occur at some sites to verify previous sampling results.

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## 1. Introduction

The San Francisco Bay polychlorinated biphenyl (PCB) and mercury total maximum daily loads (TMDLs) (SFBRWQCB, 2006; 2007) call for implementation of control measures to reduce stormwater polychlorinated biphenyl (PCB) loads from an estimated annual baseline load of 20 kg to 2 kg by 2030 and total mercury (HgT) loads from about 160 kg to 80 kg by 2028. Shortly after adoption of the TMDLs, in 2009 the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) issued the first Municipal Regional Stormwater Permit (MRP) for MS4 phase I stormwater agencies (SFBRWQCB, 2009; 2011). In support of the TMDLs, MRP 1.0, as it came to be known, contained a provision for improved information on stormwater loads for pollutants of concern (POCs) in selected watersheds (Provision C.8.) and specific provisions for Hg, methylmercury and PCBs (Provisions C.11 and C.12) that called for reducing Hg and PCB loads from smaller urbanized tributaries. To help address these permit requirements, a Small Tributaries Loading Strategy (STLS) was developed that outlined four key management questions (MQs) as well as a general plan to address these questions (SFEI, 2009).

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?

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?

During the first MRP term (2009-15), the majority of STLS effort was focused on refining pollutant loading estimates and finding and prioritizing potential “high leverage” watersheds and subwatersheds that contribute disproportionately high concentrations or loads to sensitive Bay margins. This work was funded by the RMP and the Bay Area Stormwater Management Agencies Association (BASMAA)<sup>2</sup>. Sufficient pollutant data were collected at 11 urban sites to estimate pollutant loads with varying degrees of certainty (McKee et al., 2015, Gilbreath et al., 2015a). Also, during the first MRP term, a Regional Watershed Spreadsheet Model (RWSM) was developed as a regional-scale planning tool, primarily to estimate long-term pollutant loads from the small tributaries, and secondarily to provide supporting information for prioritizing watersheds or sub-watershed areas for management (Wu et al., 2016; 2017).

In November 2015, the Regional Water Board issued the second iteration of the MRP (SFBRWQCB, 2015). MRP “2.0” places an increased focus on finding high-leverage watersheds, source areas, and source properties that are more polluted, and that are located upstream of sensitive Bay margin areas. Specifically, the permit adds a stipulation that calls for identification of sources or watershed source

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<sup>2</sup> BASMAA is made up of a number of programs that represent Permittees and other local agencies

areas that provide the greatest opportunities for reductions of PCBs and Hg in urban stormwater runoff. To help support this focus and also to refine information to address other Management Questions, the Sources, Pathways, and Loadings Work Group (SPLWG) and the Small Tributaries Loading Strategy Team developed and implemented a stormwater reconnaissance field monitoring protocol in WYs 2015, 2016, 2017 and 2018 to provide data, as part of multiple lines of evidence, for the identification of potential high-leverage areas. The monitoring protocol was adapted from the one first implemented in WY 2011 (McKee et al., 2012) and benefited from lessons learned from that effort. This same field monitoring protocol was also implemented in WYs 2016 - 2018 by the San Mateo Countywide Water Pollution Prevention Program and the Santa Clara Valley Urban Runoff Pollution Prevention Program (EOA, 2017a and 2017b).

This report summarizes and provides a preliminary interpretation and summarization of data collected during WYs 2015, 2016, 2017 and 2018, as well as from previous studies by this workgroup dating back to WY 2003. The data collected and presented here contribute to a broad effort of identifying potential management areas for pollutant reduction. During Calendar Year (CY) 2018, the RMP is funding a data analysis project that aims to mine and analyze all existing stormwater PCB data. The primary goals of that analysis are to develop additional and improved methods for identifying and ranking watersheds of management interest for further investigation, and to guide future sampling design (McKee et al., in review). In addition, the STLS team is evaluating sampling protocols for monitoring stormwater loading trends in response to management efforts (Melwani et al., 2018) and has developed a trends strategy that outlines key elements including modeling needs (Wu, et. al., 2018). Reconnaissance data collected in WYs 2011, 2015, 2016, 2017 and 2018 may provide “baseline” data for identifying concentration or particle concentration trends over time, with the understanding that management actions to control PCB and Hg loads are increasingly being implemented throughout this period.

The report is designed to be updated annually and will be updated again in approximately 12 months to include WY 2019 sampling data currently being collected.

## **2. Methods**

### **2.1 Sampling locations**

Four objectives were used as a basis for site selection.

1. Identifying potential high-leverage watersheds and subwatersheds,
  - a. Watersheds with suspected high pollution,
  - b. Sites with ongoing or planned management actions,
  - c. Source identification within a larger watershed of known concern (nested sampling design).
2. Sampling strategic large watersheds with USGS gauges to provide first-order loading estimates and to support calibration of the Regional Watershed Spreadsheet Model (RWSM),
3. Validating unexpected low (potential false negative) concentrations (to address the possibility of a single storm composite poorly characterizing a sampling location),

4. Filling gaps along environmental gradients or source areas (to allow for the continuing reevaluation of our conceptual understanding of relationships between land uses, source areas and pollutant concentrations and loads).

The majority of samples during WYs 2015-2017 (60-80% of the effort) were dedicated to identifying potential high-leverage watersheds and subwatersheds (objective 1). The remaining resources were allocated to addressing the other three objectives. In WY 2018, 50% of the resources was allocated to identifying potential high-leverage watersheds while the other 50% was allocated to resampling watersheds previously measured in reconnaissance sampling in order to validate concentrations previously measured. RMP SPLWG staff worked with the respective Countywide Programs to identify priority drainages for monitoring including storm drains, ditches/culverts, tidally influenced channels and culverts, and natural channels. During the summers of 2014, 2015, 2016 and 2017, approximately 100 sites were visited, and each was surveyed for safety, logistical constraints, and feasible drainage-line entry points. From this larger set, a final set of about 15-25 sites was selected each year to form the pool from which field staff would select sampling locations for each storm depending on logistics.

Watershed sites with a wide variety of characteristics were sampled in WYs 2015, 2016, 2017 and 2018 (Figure 1 and Table 1). Of these sites, 19 were in Santa Clara County, 19 in San Mateo County, 17 in Alameda County, 9 in Contra Costa County<sup>3</sup> and 1 in Solano County. The drainage area for each sampling location ranged from 0.02 to 233 km<sup>2</sup> and imperviousness based on the National Land Cover Database (Homer et al., 2015) ranged from 2%-88%. Typically, however, the reconnaissance watersheds were characterized as small (75% were smaller than 5.2 km<sup>2</sup>) with a high degree of imperviousness (75% of watersheds were greater than 60% impervious). The percentage of old industrial<sup>4</sup> area in watersheds ranged from 0 to 87% (mean 24%) (dataset used included the land use dataset input to the Regional Watershed Spreadsheet Model (SFEI, 2018). Although most of the sampling sites were selected primarily to identify potential high-leverage watersheds and subwatersheds, Lower Penitencia Creek was resampled in WY 2015 to verify whether the first sample collected there (WY 2011) was a false negative (unexpectedly low concentration). Guadalupe River at Hwy 101 was also resampled for PCBs in WY 2017 as a piggyback opportunity during a large and rare storm sampled primarily to assess trends for mercury (McKee et al., 2018). And in WY 2018, five sites (including: Gull Dr. Outfall, Gull Dr. Stormdrain, Kirker Ck at Pittsburgh Antioch Hwy, Meeker Slough, and the Outfall at Gilman St.) were resampled to verify stormwater concentrations previously measured. A matrix of site characteristics for sampling strategic larger watersheds was also developed (Appendix A), but no larger watersheds were sampled in WYs 2015 or 2016 because the sampling trigger criteria for rainfall and flow were not met, and only one (Colma Creek) was sampled in WY 2017. Trigger criteria were met in January and February 2017 for other strategic larger watersheds under consideration (Alameda Creek at EBRPD Bridge at Quarry Lakes, Dry Creek at Arizona Street, San Francisquito Creek at University Avenue, Matadero Creek at Waverly

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<sup>3</sup> Given the long history of industrial zoning along much of the Contra Costa County waterfront relative to other counties, more sampling is needed to characterize these areas.

<sup>4</sup> Note that the definition of “old Industrial” land use used here is based on definitions developed by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) building on GIS development work completed during the development of the RWSM (Wu et al., 2016; 2017).

Street, and Colma Creek at West Orange Avenue), but none were sampled because staff and budgetary resources were allocated elsewhere. The sampling carried out at the reconnaissance monitoring sites completed so far complements the more in-depth sampling campaigns (2-8 years of sampling at each site) that have been carried out at sites designated as the “Loadings Study” (Figure 1).

## 2.2 Field methods

### Mobilization and preparing to sample

Mobilization for sampling was typically triggered by storm forecast. When a minimum rainfall of at least one-quarter inch<sup>5</sup> over 6 hours was forecast, sampling teams were deployed, ideally reaching the sampling site about 1 hour before the onset of rainfall<sup>6</sup>. When possible, one team sampled two sites close to one another to increase efficiency and reduce staffing costs. Upon arrival, the team assembled equipment and carried out final safety checks. Sampling equipment used at a site depended on the accessibility of drainage lines. Some sites were sampled by attaching laboratory-prepared trace-metal-clean Teflon sampling tubing to a painter’s pole and a peristaltic pump with laboratory-cleaned silicone pump-roller tubing (Figure 2a). During sampling, the tube was dipped into the channel or drainage line at mid-channel mid-depth (if shallow) or depth integrating if the depth was more than 0.5 m. In other cases, a DH 84 (Teflon) sampler was used without a pump.

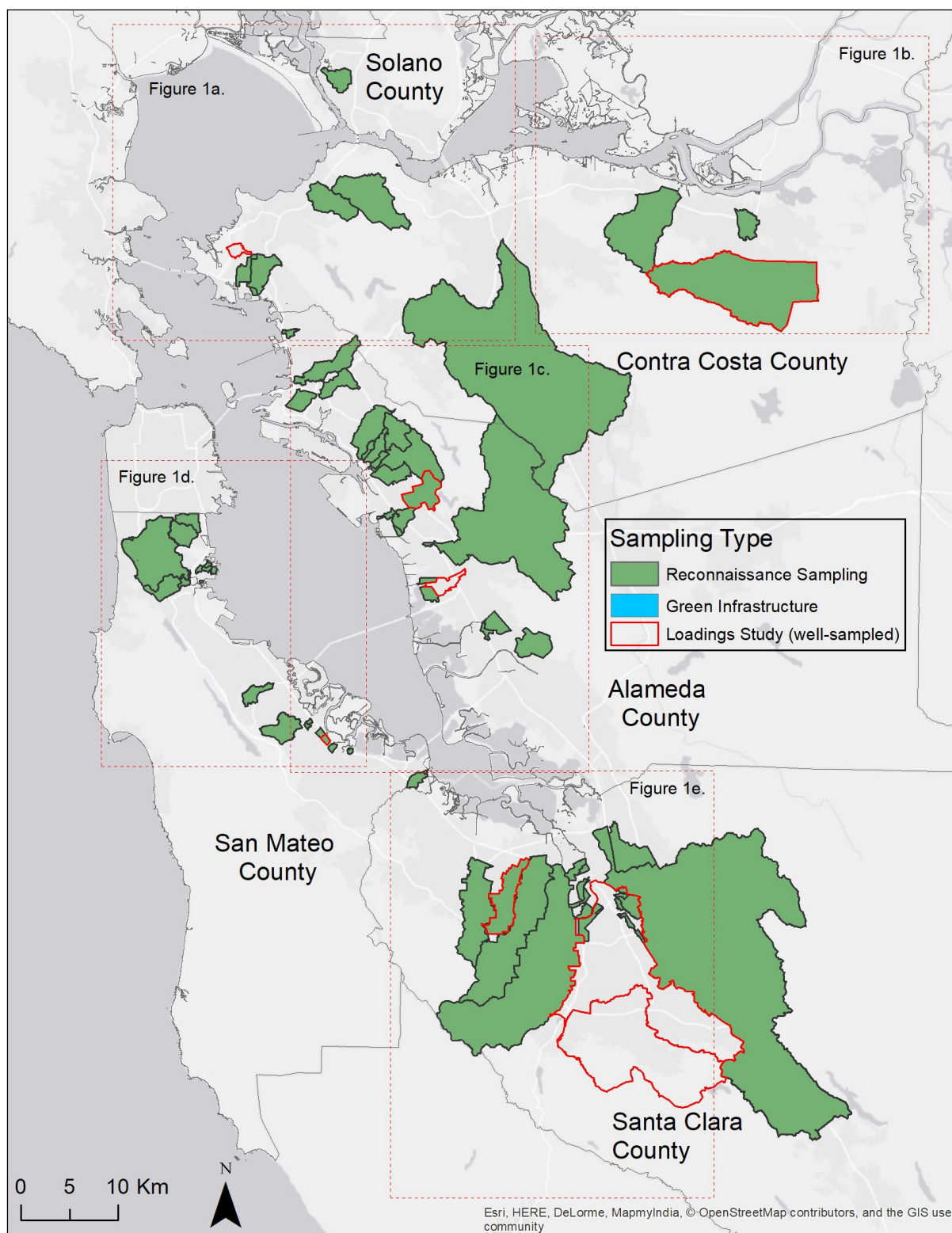
### Manual time-paced composite stormwater sampling procedures

At each site, a time-paced composite sample was collected with a variable number of sub-samples, or aliquots. Based on the weather forecast, prevailing on-site conditions, and radar imagery, field staff estimated the duration of the storm and selected an aliquot size for each analyte (0.1-0.5 L) and number of aliquots (minimum=2; mode=5) to ensure the minimum volume requirements for each analyte (Hg, 0.25L; SSC, 0.3L; PCBs, 1L; Grain Size, 1L; TOC, 0.25L) were reached before the storm’s end. Because the minimum volume requirements were less than the size of the sample bottles, there was flexibility to add aliquots in the event a storm continued longer than predicted. The final volume of the aliquots was determined just before the first aliquot was taken and remained fixed for the sampling event. Similarly, the time period between aliquots was decided just before the second aliquot was taken and then remained the same for the rest of the event. All aliquots for a storm were collected into the same bottle, which was kept in a cooler on ice and/or refrigerated at 4 °C before transport to a laboratory (see Yee et al. (2017) for information about bottles, preservatives and holding times).

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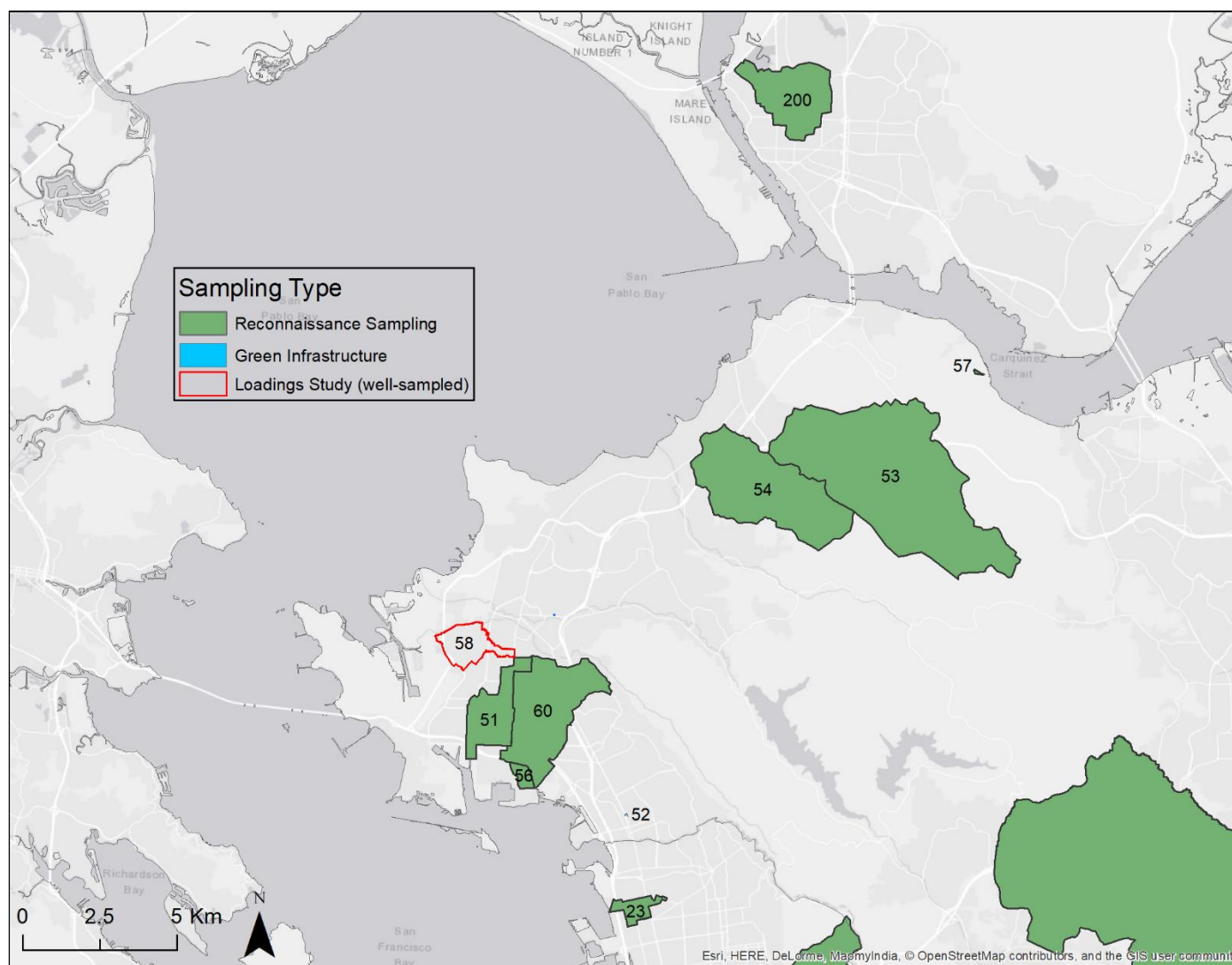
<sup>5</sup> Note, this was relaxed in some years due to a lack of larger storms. Ideally, mobilization would only proceed with a minimum forecast of at least 0.5”.

<sup>6</sup> Antecedent dry-weather was not considered prior to deployment. Antecedent conditions can have impacts on the concentration of certain build-up/wash-off pollutants like metals. For PCBs, however, antecedent dry-weather may be less important for the mobilization of in-situ legacy sources.

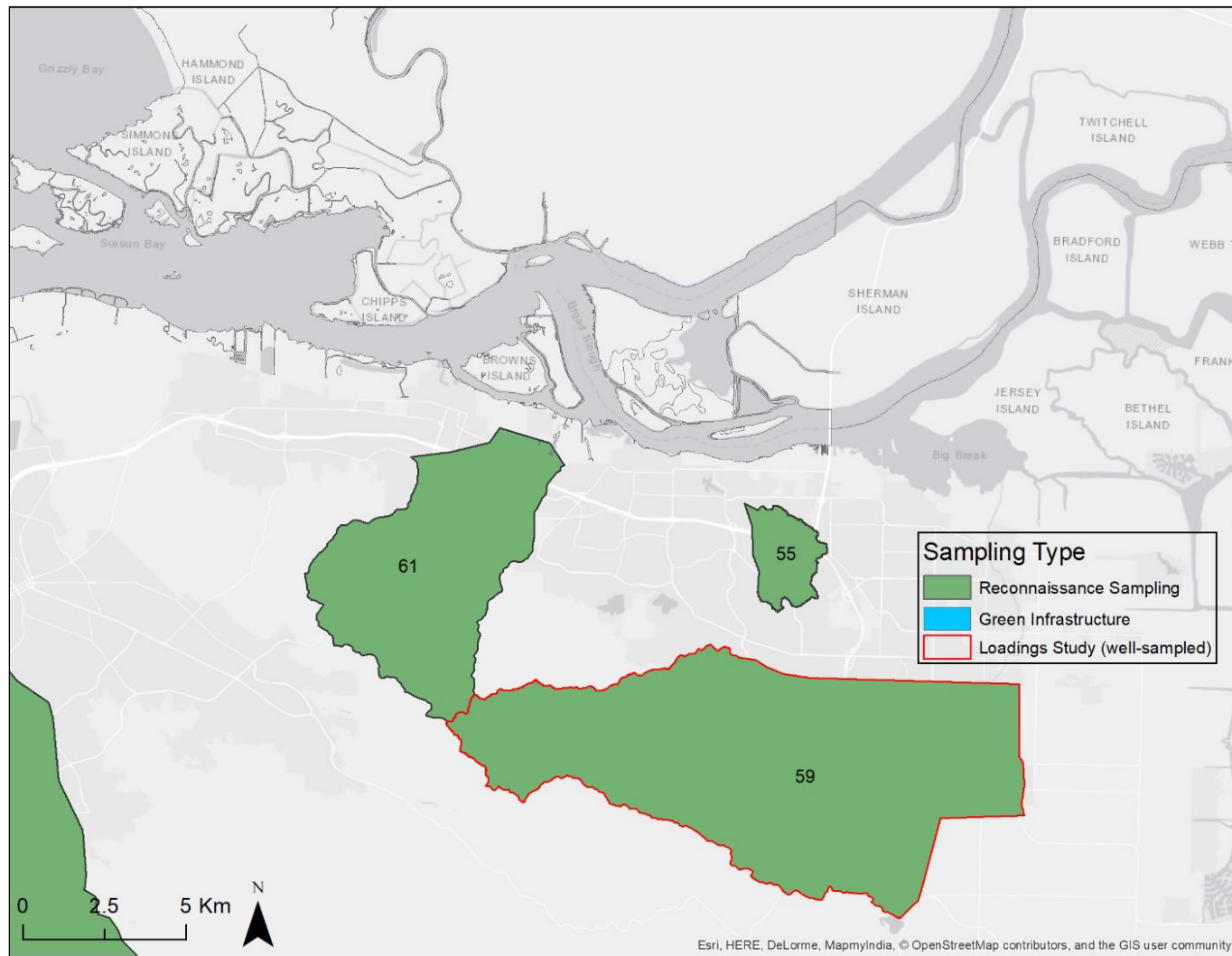


**Figure 1.** Watersheds sampled to date. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier.



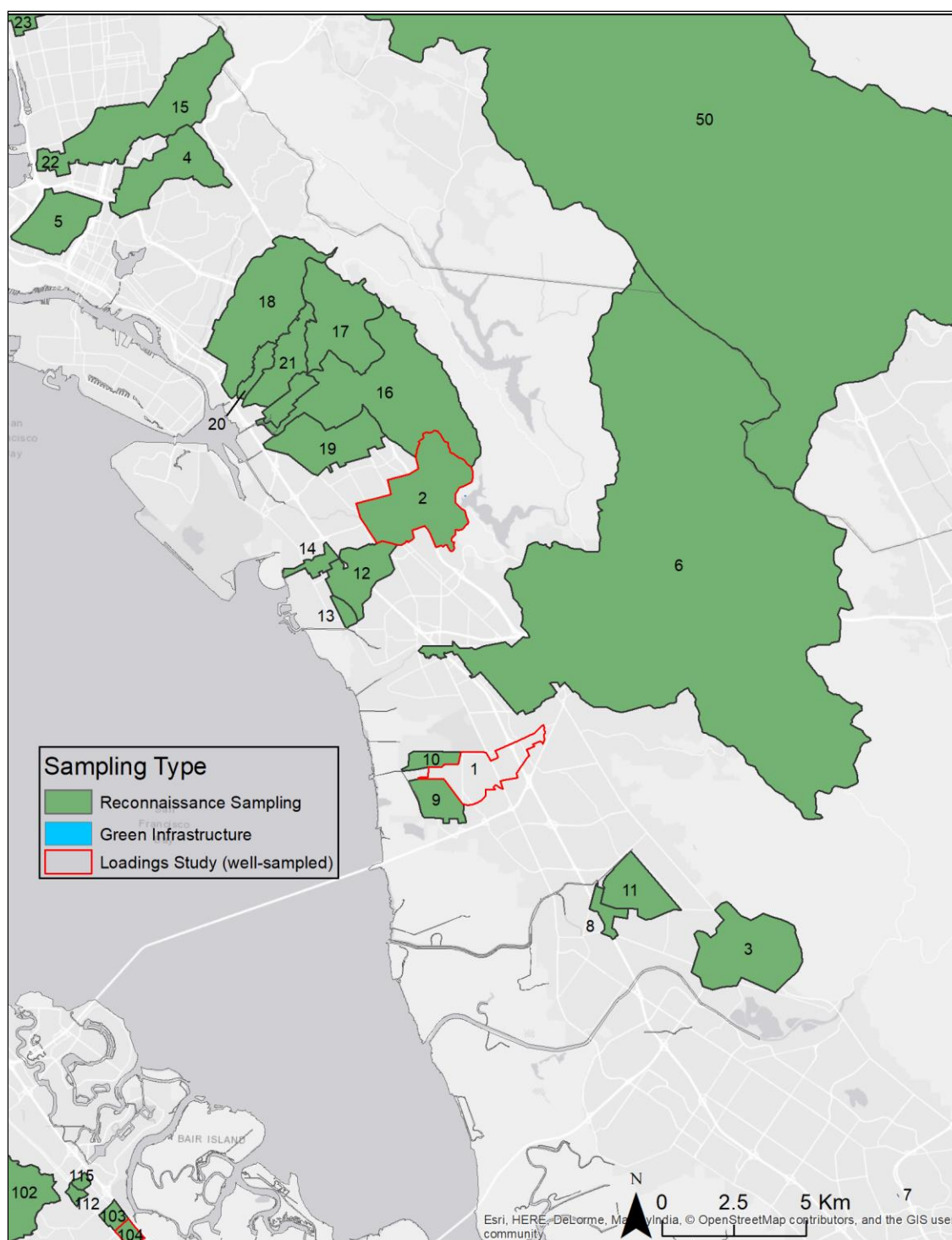


**Figure 1a.** Watershed boundaries of sites sampled in western Contra Costa County and Solano County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.

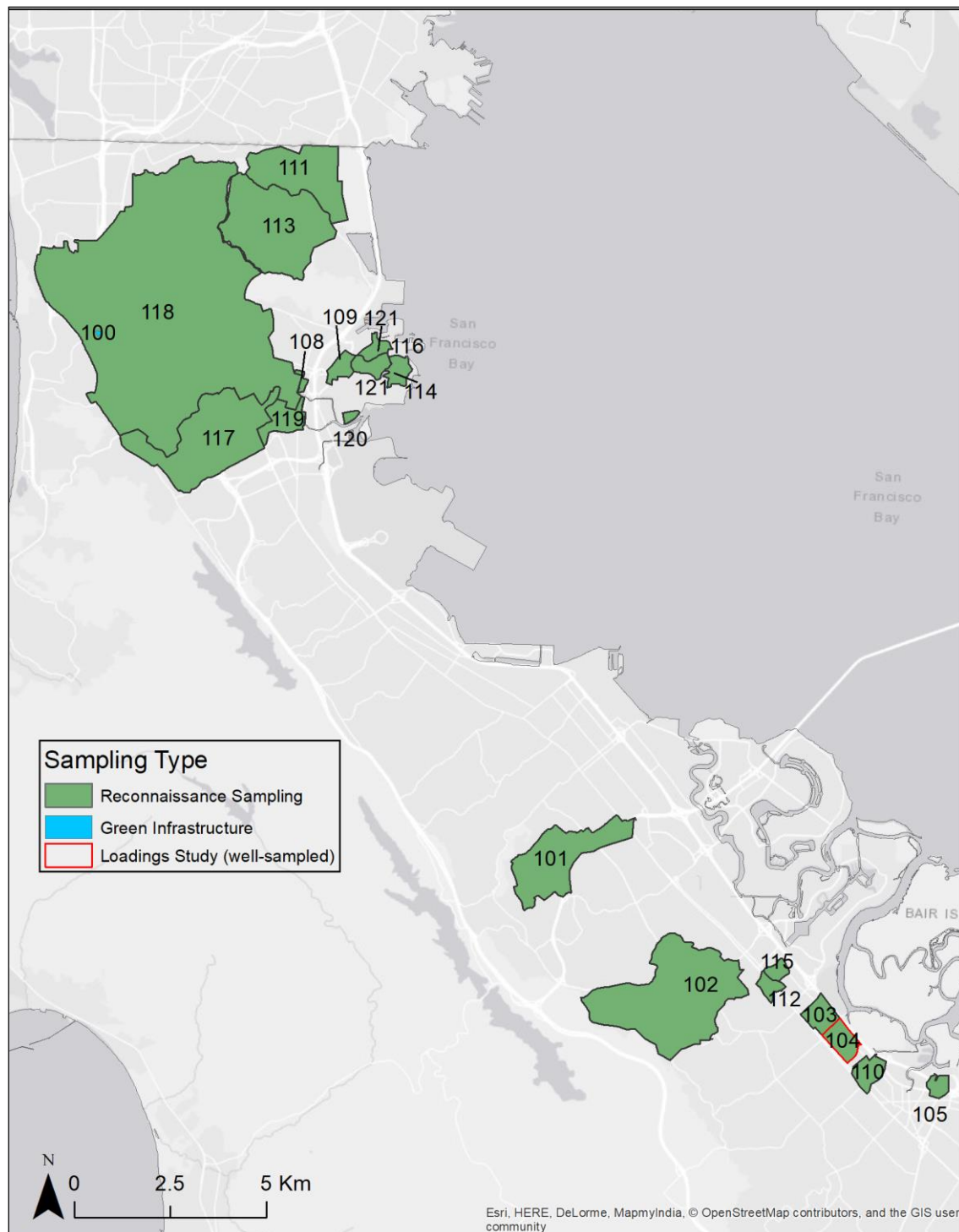


**Figure 1b.** Watershed boundaries of sites sampled in eastern Contra Costa County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.

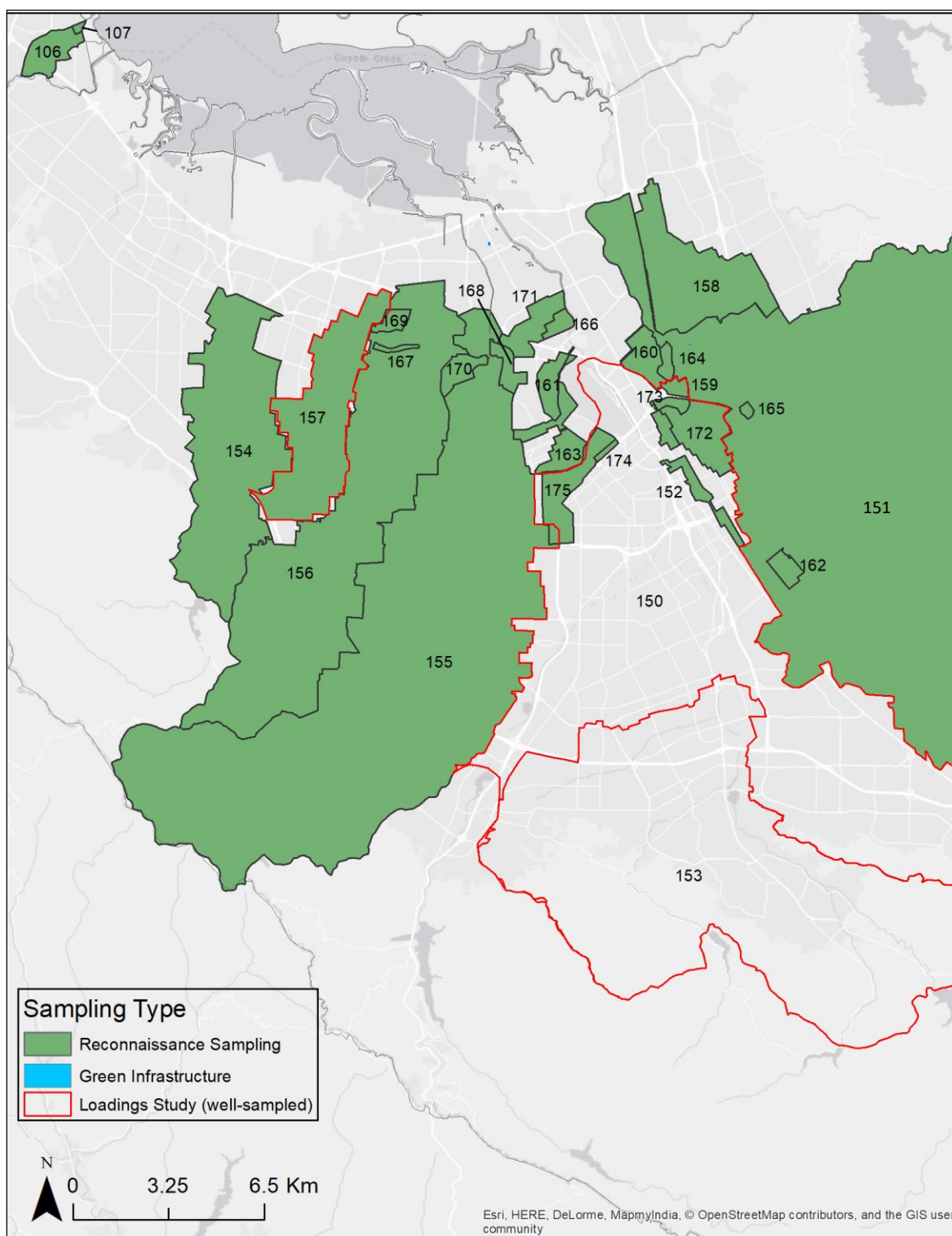




**Figure 1c.** Watershed boundaries of sites sampled in Alameda County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.



**Figure 1d.** Watershed boundaries of sites sampled in northern San Mateo County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.



**Figure 1e.** Watershed boundaries of sites sampled in Santa Clara County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.

## WYs 2015 through 2018 POC Reconnaissance Monitoring

**Table 1.** Key characteristics of the 83 sampling locations. Gaps in continuous numbering allow for the future addition of locations so that the unique identifying numbers for each county remain in the same count of 50.

| Map Key | County  | City        | Watershed Name                               | Catchment Code                                  | MS4 or Receiving Water   | Latitude  | Longitude   | Sample Date                           | Area (sq km) | Impervious Cover (%) | Old Industrial (%) |
|---------|---------|-------------|--|---|--------------------------|-----------|-------------|---------------------------------------|--------------|----------------------|--------------------|
| 1       | Alameda | Hayward     | Zone 4 Line A                                | Z4LA  | MS4                      | 37.645328 | -122.137364 | WY 2007-2010                          | 4.2          | 68%                  | 12%                |
| 2       | Alameda | San Leandro | San Leandro Creek                            | SLC   | MS4                      | 37.726119 | -122.162696 | 12/5/10 &<br>12/19/10; WYs<br>2012-14 | 8.9          | 38%                  | 0%                 |
| 3       | Alameda | Union City  | Zone 5 Line M                                | Z5LM  | MS4                      | 37.586476 | -122.028427 | 12/17/10 &<br>3/19/11                 | 8.1          | 34%                  | 5%                 |
| 4       | Alameda | Oakland     | Glen Echo Creek                              | Glen Echo Creek                                 | MS4                      | 37.818271 | -122.260326 | 2/15/11                               | 5.5          | 39%                  | 0%                 |
| 5       | Alameda | Oakland     | Ettie Street Pump Station                    | ESPS  | MS4                      | 37.826043 | -122.288942 | 2/17/11                               | 4.0          | 75%                  | 22%                |
| 6       | Alameda | San Leandro | San Lorenzo Creek                            | San Lorenzo Creek                               | MS4                      | 37.684836 | -122.138599 | 12/17/10 &<br>12/19/10                | 125          | 13%                  | 0%                 |
| 7       | Alameda | Fremont     | Fremont Osgood Road<br>Bioretention Influent | Fremont Osgood<br>Road Bioretention<br>Influent | Bioretention<br>Influent | 37.518394 | -121.945225 | 2012, 2013                            | 0.00         | 76%                  | 0%                 |
| 8       | Alameda | Union City  | Line 3A-M at 3A-D                            | AC-Line 3A-M                                    | MS4                      | 37.61285  | -122.06629  | 12/11/14                              | 0.88         | 73%                  | 12%                |
| 9       | Alameda | Hayward     | Line 4-E                                     | AC-Line 4-E                                     | MS4                      | 37.64415  | -122.14127  | 12/16/14                              | 2.00         | 81%                  | 27%                |
| 10      | Alameda | Hayward     | Line 4-B-1                                   | AC-Line 4-B-1                                   | MS4                      | 37.64752  | -122.14362  | 12/16/14                              | 0.96         | 85%                  | 28%                |
| 11      | Alameda | Union City  | Line 3A-M-1 at Industrial PS                 | AC-Line 3A-M-1                                  | MS4                      | 37.61893  | -122.05949  | 12/11/14                              | 3.44         | 78%                  | 26%                |
| 12      | Alameda | San Leandro | Line 9-D                                     | AC-Line 9-D                                     | MS4                      | 37.69383  | -122.16248  | 4/7/15                                | 3.59         | 78%                  | 46%                |
| 13      | Alameda | San Leandro | Line 9-D-1 PS at outfall to<br>Line 9-D      | AC-2016-15                                      | MS4                      | 37.69168  | -122.16679  | 1/5/16                                | 0.48         | 88%                  | 62%                |
| 14      | Alameda | San Leandro | Line 13-A at end of slough                   | AC-2016-14                                      | MS4                      | 37.70497  | -122.19137  | 3/10/16                               | 0.83         | 84%                  | 68%                |
| 15      | Alameda | Emeryville  | Zone 12 Line A under<br>Temescal Ck Park     | AC-2016-3                                       | MS4                      | 37.83450  | -122.29159  | 1/6/16                                | 9.41         | 42%                  | 0.6%               |
| 16      | Alameda | Oakland     | Line 12K at Coliseum<br>Entrance             | Line12KEntrance                                 | MS4                      | 37.75446  | -122.20431  | 2/9/17                                | 16.40        | 31%                  | 1%                 |
| 17      | Alameda | Oakland     | Line 12J at mouth to 12K                     | Line12J   | MS4                      | 37.75474  | -122.20136  | 12/15/16                              | 8.81         | 30%                  | 2%                 |
| 18      | Alameda | Oakland     | Line 12F below PG&E<br>station               | Line12F   | MS4                      | 37.76218  | -122.21431  | 12/15/16                              | 10.18        | 56%                  | 3%                 |
| 19      | Alameda | Oakland     | Line 12M at Coliseum Way                     | Line12MColWay                                   | MS4                      | 37.74689  | -122.20069  | 2/9/17                                | 5.30         | 69%                  | 22%                |
| 20      | Alameda | Oakland     | Line 12H at Coliseum Way                     | Line12H   | MS4                      | 37.76238  | -122.21217  | 12/15/16                              | 0.97         | 71%                  | 10%                |
| 21      | Alameda | Oakland     | Line 12I at Coliseum Way                     | Line12I   | MS4                      | 37.75998  | -122.21020  | 12/15/16                              | 3.41         | 63%                  | 9%                 |

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| Map Key | County       | City                | Watershed Name   | Catchment Code            | MS4 or Receiving Water | Latitude    | Longitude    | Sample Date                    | Area (sq km) | Impervious Cover (%) | Old Industrial (%) |
|---------|--------------|---------------------|--|---------------------------|------------------------|-------------|--------------|--------------------------------|--------------|----------------------|--------------------|
| 22      | Alameda      | Emeryville          | Zone 12 Line A at Shellmound                             | Line12AShell              | MS4                    | 37.83424    | -122.29352   | 1/8/18                         | 10.48        | 41%                  | 6%                 |
| 23      | Alameda      | Berkeley            | Outfall at Gilman St.                                    | AC-2016-1                 | MS4                    | 37.87761    | -122.30984   | 12/21/15 & 1/9/18              | 0.84         | 76%                  | 32%                |
| 50      | Contra Costa | Concord             | Walnut Creek   | Walnut Creek              | Receiving Water        | 37.96962    | -122.053778  | 12/28/10                       | 232          | 15%                  | 0%                 |
| 51      | Contra Costa | Richmond            | Santa Fe Channel   | Santa Fe Channel          | MS4                    | 37.92118056 | -122.3619972 | 12/05/10                       | 3.3          | 69%                  | 3%                 |
| 52      | Contra Costa | El Cerrito          | El Cerrito Bioretention Influent                         | ELC                       | Bioretention Influent  | 37.905884   | -122.304929  | WY 2012, 2014-15, 2017         | 0.00         | 74%                  | 0%                 |
| 53      | Contra Costa | Rodeo               | Rodeo Creek at Seaclyff Ct. Pedestrian Br.               | RodeoCk                   | Receiving Water        | 38.01604    | -122.25381   | 1/18/17                        | 23.41        | 2%                   | 3%                 |
| 54      | Contra Costa | Hercules            | Refugio Ck at Tsushima St                                | RefugioCk                 | Receiving Water        | 38.01775    | -122.27710   | 1/18/17                        | 10.73        | 23%                  | 0%                 |
| 55      | Contra Costa | Antioch             | East Antioch nr Trembath                                 | EAntioch                  | Receiving Water        | 38.00333    | -121.78106   | 1/8/17                         | 5.26         | 26%                  | 3%                 |
| 56      | Contra Costa | Richmond            | MeekerWest   | MeekerWest                | Receiving Water        | 37.91313    | -122.33871   | 1/9/18                         | 0.41         | 70%                  | 69%                |
| 57      | Contra Costa | Port Costa          | Little Bull Valley                                       | Little Bull Valley        | Receiving Water        | 38.03680    | -122.17662   | 3/1/18                         | 0.02         | 67%                  | 2%                 |
| 58      | Contra Costa | Richmond            | North Richmond Pump Station                              | NRPS                      | MS4                    | 37.953903   | -122.373997  | WY 2011, 2013-14               | 2.0          | 62%                  | 18%                |
| 59      | Contra Costa | Oakley              | Lower Marsh Creek  | LMC                       | Receiving Water        | 37.990723   | -121.696118  | 3/24/11; WYs 2012-14           | 84           | 10%                  | 0%                 |
| 60      | Contra Costa | Richmond            | Meeker Slough  | Meeker Slough             | Receiving Water        | 37.91786    | -122.33838   | 12/3/14 & 1/9/18               | 7.34         | 64%                  | 6%                 |
| 61      | Contra Costa | Pittsburg           | Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir | KirkerCk                  | Receiving Water        | 38.01275    | -121.84345   | 1/8/17 & 4/6/18                | 36.67        | 18%                  | 5%                 |
| 100     | San Mateo    | Daly City           | Gellert Park Daly City Library Bioretention Influent     | Gellert Park              | Bioretention Influent  | 37.663037   | -122.470585  | WY 2009                        | 0.02         | 40%                  | 0%                 |
| 101     | San Mateo    | San Mateo           | Borel Creek  | Borel Creek               | MS4                    | 37.551273   | -122.309424  | 3/18/11                        | 3.2          | 31%                  | 0%                 |
| 102     | San Mateo    | Belmont             | Belmont Creek  | Belmont Creek             | MS4                    | 37.517328   | -122.276109  | 3/18/11                        | 7.2          | 27%                  | 0%                 |
| 103     | San Mateo    | San Carlos          | Pulgas Pump Station-North                                | Pulgas Pump Station-North | MS4                    | 37.5045833  | -122.2490056 | 2/17/11 & 3/18/11              | 0.55         | 84%                  | 52%                |
| 104     | San Mateo    | San Carlos          | Pulgas Pump Station-South                                | Pulgas Pump Station-South | MS4                    | 37.5045833  | -122.2490056 | 2/17/11 & 3/18/11; WYs 2013-14 | 0.58         | 87%                  | 54%                |
| 105     | San Mateo    | Redwood City        | Oddstad PS   | SM-267                    | MS4                    | 37.49172    | -122.21886   | 12/2/14                        | 0.28         | 74%                  | 11%                |
| 106     | San Mateo    | East Palo Alto      | Runnymede Ditch  | SM-70                     | MS4                    | 37.46883    | -122.12701   | 2/6/15                         | 2.05         | 53%                  | 2%                 |
| 107     | San Mateo    | East Palo Alto      | SD near Cooley Landing                                   | SM-72                     | MS4                    | 37.47492    | -122.12640   | 2/6/15                         | 0.11         | 73%                  | 39%                |
| 108     | San Mateo    | South San Francisco | South Linden PS  | SM-306                    | MS4                    | 37.65018    | -122.41127   | 2/6/15                         | 0.14         | 83%                  | 22%                |



# WYs 2015 through 2018 POC Reconnaissance Monitoring

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|---------|-------------|---------------------|---|-----------------------|------------------------|------------|--------------|--|--------------|----------------------|--------------------|
| 109     | San Mateo   | South San Francisco | Gateway Ave SD  | SM-293                | MS4                    | 37.65244   | -122.40257   | 2/6/15                                 | 0.36         | 69%                  | 52%                |
| 110     | San Mateo   | Redwood City        | Veterans PS   | SM-337                | MS4                    | 37.49723   | -122.23693   | 12/15/14                               | 0.52         | 67%                  | 7%                 |
| 111     | San Mateo   | Brisbane            | Tunnel Ave Ditch  | SM-350/368/more       | Receiving Water        | 37.69490   | -122.39946   | 3/5/16                                 | 3.02         | 47%                  | 8%                 |
| 112     | San Mateo   | San Carlos          | Taylor Way SD   | SM-32                 | MS4                    | 37.51320   | -122.26466   | 3/11/16                                | 0.27         | 67%                  | 11%                |
| 113     | San Mateo   | Brisbane            | Valley Dr SD  | SM-17                 | MS4                    | 37.68694   | -122.40215   | 3/5/16                                 | 5.22         | 21%                  | 7%                 |
| 114     | San Mateo   | South San Francisco | Forbes Blvd Outfall   | SM-319                | MS4                    | 37.65889   | -122.37996   | 3/5/16                                 | 0.40         | 79%                  | 0%                 |
| 115     | San Mateo   | San Carlos          | Industrial Rd Ditch   | SM-75                 | MS4                    | 37.51831   | -122.26371   | 3/11/16                                | 0.23         | 85%                  | 79%                |
| 116     | San Mateo   | South San Francisco | Gull Dr SD  | SM-314                | MS4                    | 37.66033   | -122.38510   | 3/5/16 & 1/9/18                        | 0.30         | 78%                  | 54%                |
| 117     | San Mateo   | South San Francisco | S Spruce Ave SD at Mayfair Ave (296)                        | SSpruce               | MS4                    | 37.65084   | -122.41811   | 1/8/17                                 | 5.15         | 39%                  | 1%                 |
| 118     | San Mateo   | South San Francisco | Colma Ck at S. Linden Blvd                                  | ColmaCk               | MS4                    | 37.65017   | -122.41189   | 2/7/17                                 | 35.07        | 41%                  | 3%                 |
| 119     | San Mateo   | South San Francisco | S Linden Ave SD (291)                                       | SLinden               | MS4                    | 37.64420   | -122.41390   | 1/8/17                                 | 0.78         | 88%                  | 57%                |
| 120     | San Mateo   | South San Francisco | Outfall to Colma Ck on service rd nr Littlefield Ave. (359) | ColmaCkOut            | MS4                    | 37.64290   | -122.39677   | 2/7/17                                 | 0.09         | 88%                  | 87%                |
| 121     | San Mateo   | South San Francisco | Gull Dr Outfall   | SM-315                | MS4                    | 37.66033   | -122.38502   | 3/5/16 & 1/9/18                        | 0.43         | 75%                  | 42%                |
| 150     | Santa Clara | San Jose            | Guadalupe River at Hwy 101                                  | Guad 101              | Receiving Water        | 37.37355   | -121.93269   | WYs 2003-2006, 2010, 2012-2014; 1/8/17 | 233.00       | 39%                  | 3%                 |
| 151     | Santa Clara | Milpitas            | Lower Coyote Creek  | Lower Coyote Creek    | Receiving Water        | 37.421814  | -121.928153  | 2005                                   | 327          | 22%                  | 1%                 |
| 152     | Santa Clara | San Jose            | San Pedro Storm Drain                                       | San Pedro Storm Drain | MS4                    | 37.343769  | -121.900781  | 2006                                   | 1.3          | 72%                  | 16%                |
| 153     | Santa Clara | San Jose            | Guadalupe River at Foxworthy Road/ Almaden Expressway       | GRFOX                 | Receiving Water        | 37.278396  | -121.877944  | 2010                                   | 107          | 22%                  | 0%                 |
| 154     | Santa Clara | Mountain View       | Stevens Creek   | Stevens Creek         | Receiving Water        | 37.391306  | -122.069586  | 2/18/11                                | 26           | 38%                  | 1%                 |
| 155     | Santa Clara | Santa Clara         | San Tomas Creek   | San Tomas Creek       | Receiving Water        | 37.388992  | -121.968634  | 12/28/10                               | 108          | 33%                  | 0%                 |
| 156     | Santa Clara | Santa Clara         | Calabazas Creek   | Calabazas Creek       | Receiving Water        | 37.4034556 | -121.9867056 | 12/28/10                               | 50           | 44%                  | 3%                 |
| 157     | Santa Clara | Sunnyvale           | Sunnyvale East Channel                                      | SunCh                 | Receiving Water        | 37.394728  | -122.010441  | 3/19/11; WYs 2012-14                   | 15           | 59%                  | 4%                 |

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| Map Key | County      | City        | Watershed Name                       | Catchment Code       | MS4 or Receiving Water | Latitude | Longitude  | Sample Date         | Area (sq km) | Impervious Cover (%) | Old Industrial (%) |
|---------|-------------|-------------|--------------------------------------|----------------------|------------------------|----------|------------|---------------------|--------------|----------------------|--------------------|
| 158     | Santa Clara | Milpitas    | Lower Penitencia Ck                  | Lower Penitencia     | Receiving Water        | 37.42985 | -121.90913 | WY 2011; 12/11/14   | 11.50        | 65%                  | 2%                 |
| 159     | Santa Clara | San Jose    | E. Gish Rd SD                        | SC-066GAC550         | MS4                    | 37.36632 | -121.90203 | 12/11/14            | 0.44         | 84%                  | 71%                |
| 160     | Santa Clara | San Jose    | Charcot Ave SD                       | SC-051CTC275         | MS4                    | 37.38413 | -121.91076 | 4/7/15              | 1.79         | 79%                  | 25%                |
| 161     | Santa Clara | Santa Clara | Seaboard Ave SD SC-050GAC580         | SC-050GAC580         | MS4                    | 37.37637 | -121.93793 | 12/11/14            | 1.35         | 81%                  | 68%                |
| 162     | Santa Clara | San Jose    | Rock Springs Dr SD                   | SC-084CTC625         | MS4                    | 37.31751 | -121.85459 | 2/6/15              | 0.83         | 80%                  | 10%                |
| 163     | Santa Clara | Santa Clara | Seaboard Ave SD SC-050GAC600         | SC-050GAC600         | MS4                    | 37.37636 | -121.93767 | 12/11/14            | 2.80         | 62%                  | 18%                |
| 164     | Santa Clara | San Jose    | Ridder Park Dr SD                    | SC-051CTC400         | MS4                    | 37.37784 | -121.90302 | 12/15/14            | 0.50         | 72%                  | 57%                |
| 165     | Santa Clara | San Jose    | Outfall to Lower Silver Ck           | SC-067SCL080         | MS4                    | 37.35789 | -121.86741 | 2/6/15              | 0.17         | 79%                  | 78%                |
| 166     | Santa Clara | Santa Clara | Victor Nelo PS Outfall               | SC-050GAC190         | MS4                    | 37.38991 | -121.93952 | 1/19/16             | 0.58         | 87%                  | 4%                 |
| 167     | Santa Clara | Santa Clara | Lawrence & Central Expwys SD         | SC-049CZC800         | MS4                    | 37.37742 | -121.99566 | 1/6/16              | 1.20         | 66%                  | 1%                 |
| 168     | Santa Clara | Santa Clara | E Outfall to San Tomas at Scott Blvd | SC-049STA550         | MS4                    | 37.37991 | -121.96842 | 3/6/16              | 0.67         | 66%                  | 31%                |
| 169     | Santa Clara | Santa Clara | Duane Ct and Ave Triangle SD         | SC-049CZC200         | MS4                    | 37.38852 | -121.99901 | 12/13/15 & 1/6/2016 | 1.00         | 79%                  | 23%                |
| 170     | Santa Clara | Santa Clara | Condensa St SD                       | SC-049STA710         | MS4                    | 37.37426 | -121.96918 | 1/19/16             | 0.24         | 70%                  | 32%                |
| 171     | Santa Clara | Santa Clara | Haig St SD                           | SC-050GAC030         | MS4                    | 37.38664 | -121.95223 | 3/6/16              | 2.12         | 72%                  | 10%                |
| 172     | Santa Clara | San Jose    | Rosemary St SD 066GAC550C            | Rosemary             | MS4                    | 37.36118 | -121.90594 | 1/8/17              | 3.67         | 64%                  | 11%                |
| 173     | Santa Clara | San Jose    | North Fourth St SD 066GAC550B        | NFourth              | MS4                    | 37.36196 | -121.90535 | 1/8/17              | 1.01         | 68%                  | 27%                |
| 174     | Santa Clara | San Jose    | GR outfall 066GAC900                 | GR outfall 066GAC900 | MS4                    | 37.35392 | -121.91223 | 4/7/18              | 0.17         | 66%                  | 1%                 |
| 175     | Santa Clara | San Jose    | GR outfall 066GAC850                 | GR outfall 066GAC850 | MS4                    | 37.35469 | -121.91279 | 4/7/18              | 3.35         | 61%                  | 6%                 |
| 200     | Solano      | Vallejo     | Austin Ck at Hwy 37                  | AustinCk             | Receiving Water        | 38.12670 | -122.26791 | 3/24/17             | 4.88         | 61%                  | 2%                 |

### Remote suspended sediment sampling procedures

Two remote samplers, the Hamlin (Lubliner, 2012) and the Walling Tube (Phillips et al., 2000), were deployed at approximately mid-channel/storm drain to collect suspended sediment samples. To date, 10 locations have been successfully sampled with the Hamlin sampler and 9 locations with the Walling Tube sampler (Table 2). Both samplers were trialed together at 5 sites; therefore, a total of 14 sites have now been sampled successfully (along with one deployment that was unsuccessful). During deployment, the Hamlin sampler<sup>7</sup> was stabilized on the bed of the storm drain or concrete channel either by its own weight (approximately 25 lbs) or by attaching barbell weight plates to the bottom of the sampler (Figure 2b). The Walling Tube could not be deployed in storm drains because of its size and the requirement that it be horizontal, and therefore Walling Tube samplers were used only in open channels and secured either by barbell weights attached by hose clamps to a concrete bed, or to a natural bed with hose clamps attached to temporarily installed rebar (Figure 2c). To minimize the chance of sampler loss, both samplers were secured by a stainless steel cable to a temporary rebar anchor or another object such as a tree or fencepost.

The remote samplers were deployed for the duration of the manual sampling and removed from the channel bed/storm drain bottom shortly after the last water-quality-sample aliquot was collected. Water and sediment collected in the samplers were decanted into one or two large glass bottles. When additional water was needed to flush the settled sediment from the remote samplers into the collecting bottles, site water from the sampled channel was used. The collected samples were split and placed into laboratory containers and shipped to the laboratory for analysis. Most samples were analyzed as whole-water samples (because of insufficient solid mass to analyze as a sediment sample); only one sample was analyzed as a sediment sample. Between sampling sites, the remote samplers were thoroughly cleaned using a brush and Alconox detergent, followed by a dionized water (DI) rinse.

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<sup>7</sup> In future years, if the Hamlin is deployed within a natural bed channel, elevating the sampler a greater distance from the bed may be considered but was not done in WYs 2015-2018.



(a)



(b)



(c)



(d)



**Figure 2.** Sampling equipment used in the field. (a) Painter's pole, Teflon tubing and an ISCO used as a slave pump; (b) Teflon bottle attached to the end of a DH81 sampling pole; (c) a Hamlin suspended sediment sampler secured atop a 45-lb plate; and (d) a Walling Tube suspended sediment sampler secured by 5-lb weights along the body of the tube (because it is sitting atop a concrete bed) and rebar driven into the natural bed at the back of the sampler.

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**Table 2.** Locations where remote sediment samplers were pilot tested.

| Site                          | Date      | Sampler(s) deployed      | Comments   |
|-------------------------------|-----------|--------------------------|--|
| Meeker Slough                 | 11/2015   | Hamlin and Walling Tube  | Sampling effort was unsuccessful because of very high velocities. Both samplers washed downstream because they were not sufficiently weighted down and debris caught on the securing lines.  |
| Outfall to Lower Silver Creek | 2/06/15   | Hamlin and Walling Tube  | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Charcot Ave Storm Drain       | 4/07/15   | Hamlin                   | Sampling effort was successful. This sample was analyzed as a sediment sample.   |
| Cooley Landing Storm Drain    | 2/06/15   | Hamlin                   | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Duane Ct and Ave Triangle SD  | 1/6/2016  | Hamlin                   | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Victor Nelo PS Outfall        | 1/19/2016 | Hamlin and Walling Tube  | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Forbes Blvd Outfall           | 3/5/2016  | Hamlin                   | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Tunnel Ave Ditch              | 3/5/2016  | Hamlin and Walling Tuber | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Taylor Way SD                 | 3/11/2016 | Hamlin                   | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Colma Creek Outfall           | 2/7/2017  | Walling Tube             | Sampling effort was successful; however, sampler became submerged for several hours during a high tide cycle and was retrieved afterwards. We hypothesize that this may have added cleaner sediment into the sampler and therefore the result may be biased low. This sample was analyzed as a water sample. |
| Austin Creek                  | 3/24/2017 | Hamlin and Walling Tube  | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Refugio Creek                 | 1/18/2017 | Walling Tube             | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Rodeo Creek                   | 1/18/2017 | Walling Tube             | Sampling effort was successful. This sample was analyzed as a water sample.  |
| Outfall at Gilman St.         | 1/9/2018  | Hamlin and Walling Tube  | Sampling effort was successful; however, Hamlin sampler could not be gently lowered into place on the bed and instead was dropped from approximately 1.5 ft above the bed; it is possible, therefore, that the sampler did not lie horizontally along the bed. This sample was analyzed as a water sample.   |
| Meeker West                   | 1/9/2018  | Walling Tube             | Sampling effort was successful. This sample was analyzed as a water sample.  |

### 2.3 Laboratory analytical methods

The target analytes for this study are listed in Table 3. The analytical methods and quality control tests are further described in the RMP Quality Assurance Program Plan (Yee et al., 2017). Laboratory methods were chosen based on a combination of factors, including method detection limits, accuracy and precision, and cost (BASMAA, 2011; 2012) (Table 3). For some sites where remote samplers were deployed, both particulate and dissolved phases of Hg, PCBs, and organic carbon (OC) were analyzed for comparison with whole-water concentrations and particulate-only concentrations from manually collected water samples.

**Table 3.** Laboratory analysis methods.

| Analysis                                 | Matrix      | Analytical Method   | Lab   | Filtered | Field Preservation | Contract Lab / Preservation Hold Time            |
|--|-------------|---------------------|-------|----------|--------------------|--|
| PCBs (40) <sup>8</sup> -Total            | Water       | EPA 1668            | AXYS  | No       | NA                 | NA   |
| PCBs (40) <sup>8</sup> -Dissolved        | Water       | EPA 1668            | AXYS  | Yes      | NA                 | NA   |
| PCBs (40) <sup>8</sup>                   | Sediment    | EPA 1668            | AXYS  | NA       | NA                 | NA   |
| Mercury-Total                            | Water       | EPA 1631E           | BRL   | No       | NA                 | BRL preservation with BrCl within 28 days        |
| Mercury-Dissolved                        | Water       | EPA 1631E           | BRL   | Yes      | Na                 | BRL preservation with BrCl within 28 days        |
| Mercury                                  | Sediment    | EPA 1631E, Appendix | BRL   | NA       | NA                 | 7 days   |
| Metals-Total (As, Cd, Pb, Cu, Zn)        | Water       | EPA 1638 mod        | BRL   | No       | HNO <sub>3</sub>   | BRL preservation with Nitric acid within 14 days |
| SSC                                      | Water       | ASTM D3977          | USGS  | No       | NA                 | NA   |
| Grain size                               | Water       | USGS GS method      | USGS  | No       | NA                 | NA   |
| Organic carbon-Total (WY 2015)           | Water       | 5310 C              | EBMUD | No       | HCL                | NA   |
| Organic carbon-Dissolved (WY 2015)       | Water       | 5310 C              | EBMUD | Yes      | HCL                | NA   |
| Organic carbon-Total (WY 2016-2018)      | Water       | EPA 9060A           | ALS   | No       | HCL                | NA   |
| Organic carbon-Dissolved (WY 2016, 2017) | Water       | EPA 9060A           | ALS   | Yes      | HCL                | NA   |
| Organic carbon (WY 2016, 2017)           | Particulate | EPA 440.0           | ALS   | NA       | NA                 | NA   |

<sup>8</sup> Samples were analyzed for 40 PCB congeners (PCB-8, PCB-18, PCB-28, PCB-31, PCB-33, PCB-44, PCB-49, PCB-52, PCB-56, PCB-60, PCB-66, PCB-70, PCB-74, PCB-87, PCB-95, PCB-97, PCB-99, PCB-101, PCB-105, PCB-110, PCB-118, PCB-128, PCB-132, PCB-138, PCB-141, PCB-149, PCB-151, PCB-153, PCB-156, PCB-158, PCB-170, PCB-174, PCB-177, PCB-180, PCB-183, PCB-187, PCB-194, PCB-195, PCB-201, PCB-203).

## 2.4 Interpretive methods

### Estimated particle concentrations

The reconnaissance monitoring field protocol is designed to collect one composite whole water sample during a single storm at each site to characterize concentrations during storm flow. Measured PCB and Hg concentrations at a site could have large inter-storm variability related to storm size, intensity and antecedent conditions, as observed from previous studies when a large number of storms were sampled (Gilbreath et al., 2015a); this variability cannot be captured in a single composite sample. However, variability can be reduced if concentrations are normalized to SSC, which produces an estimate of the pollutant concentration associated with particles in the sample. The estimated particle concentration (EPC; ratio of mass of a given pollutant of concern to mass of suspended sediment) has been demonstrated to have less inter-storm variability than whole water concentrations, and therefore the EPC is likely a better characterization of water quality at a site than water concentration alone and a better metric for comparison between sites (McKee et al., 2012; Rügner et al., 2013; McKee et al., 2015). EPCs were used as the primary index to compare sites without regard to climate or rainfall intensity. For each analyte at each site the EPC was computed for each composite water sample (Equation 1):

$$EPC (ng/mg) = (pollutant\ concentration\ (ng/L)) / (SSC\ (mg/L)) \quad (1)$$

Although normalizing PCB and Hg concentrations to SSC provides an improved metric for comparing sites, climatic conditions can nonetheless influence relative ranking based on EPCs. The nature of that influence may differ between watershed locations depending on source characteristics. For example, a higher proportion of polluted sediment may be triggered during dry years when there is little dilution by sediment erosion from rural parts of the watershed. This scenario is most likely to occur in mixed land-use watersheds with large amounts of pervious area. In contrast, a small patch of polluted soil in a highly impervious watershed may be eroded and transported any time that rainfall intensity reaches some threshold. In this instance, a false negative could occur if sampling only occurs during rain events that do not meet that intensity threshold. Only with many years of data during many types of storms can such processes be identified.

Because of concerns regarding inter-storm variability, relative ranking of sites based on EPC from only one or two storms should be interpreted with caution and added to a broad set of evidence. Such comparisons may be sufficient for providing evidence to differentiate a group of sites with higher pollutant concentrations from a contrasting group with lower pollutant concentrations (acknowledging the risk that some data for watersheds in this group will be false negatives). However, to generate information on the absolute relative ranking between individual sites, a more rigorous sampling campaign targeting many storms over many years would be required (c.f. the Guadalupe River study: McKee et al., 2017; McKee et al., 2018, or the Zone 4 Line A study: Gilbreath and McKee, 2015; McKee and Gilbreath 2015). Alternatively, a more advanced data analysis would be needed that takes into account a variety of parameters (PCB and suspended sediment sources and mobilization processes, PCB congeners, rainfall intensity, rainfall antecedence, flow production and volume) in the normalization and ranking procedure. As mentioned above, the RMP has funded a project in CY 2018 to complete this type of investigation (McKee et al., in review).

### Derivations of central tendency for comparisons with past data

A mean, median, geometric mean, time-weighted mean, or flow-weighted mean have all been used to summarize the central tendency of data from RMP studies with discrete stormwater samples. To compare the single-sample concentrations collected in 2015-18 with discrete sample concentrations collected previously, the sum of concentrations of the pollutant of interest in discrete samples for an event at a site was divided by the sum of the SSC. Because of the use of this alternative method, EPCs reported here differ slightly from those reported previously for some sites (McKee et al., 2012; McKee et al., 2014; Wu et al., 2016).

## 3. Results and Discussion

This report presents data from all available stormwater data<sup>9</sup> collected since WY 2003 when stormwater studies first began through SFEI contracts or RMP projects, including data collected in intensive loadings studies from WYs 2003-2010 and 2012-2014, a similar reconnaissance study done in WY 2011, and studies of green infrastructure done since WY 2009. The data are presented in the context of three key questions:

- a) What are the concentrations and EPCs observed at each of the sites based on the composite water samples? (related to MQs 1 and 2; see page 1)
- b) How do the EPCs measured at each of the sites for composite water samples compare to EPCs derived from samples collected by the remote suspended-sediment samplers? (influences collection of data to address MQs 1 & 2)
- c) How do concentrations and EPCs for PCBs and Hg relate to other trace contaminant concentrations and land use? (related to MQs 1 & 2)

These data contribute to a broad effort to identify potential management areas, and the rankings based on either stormwater concentration or EPCs are part of a weight-of-evidence approach for locating and prioritizing areas that may be disproportionately impacting downstream water quality. As the number of sample sites has increased, the relative rankings of particular sites have changed, but the highest-ranking sites have generally remained high.

### 3.1 SSC stormwater concentrations

Suspended sediment concentrations from the 84 sampling locations ranged from 16 to 2626 mg/L, with a median of 93 mg/L. About 25% of the watersheds included in these statistics have greater than 5% agricultural and uncompacted open spaces. If those watersheds are removed, the 61 remaining are nearly wholly urban (maximum agricultural plus uncompacted open space of 2.1%). The urban, impervious watersheds have low SSC (relative to the watersheds with greater than 5% open and uncompacted area). Summary statistics for SSC for these 61 urban watersheds are given in Table 4.

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<sup>9</sup> Similar data collected by BASMAA in Santa Clara and San Mateo Counties is not included in this report.

**Table 4.** Summary statistics (count, minimum, maximum and percentiles) of SSC (in mg/L) for urban watersheds with agricultural and uncompacted open space <2.2%.

|                             | All Counties | Alameda | Contra Costa | San Mateo | Santa Clara |
|-----------------------------|--------------|---------|--------------|-----------|-------------|
| Number of sampled (n)       | 61           | 18      | 6            | 16        | 20          |
| Minimum                     | 16           | 60      | 41           | 16        | 27          |
| 10 <sup>th</sup> Percentile | 26           | 68      | 49           | 20        | 34          |
| 25 <sup>th</sup> Percentile | 44           | 81      | 53           | 25        | 45          |
| 50 <sup>th</sup> Percentile | 73           | 111     | 60           | 43        | 65          |
| 75 <sup>th</sup> Percentile | 132          | 178     | 110          | 62        | 119         |
| 90 <sup>th</sup> Percentile | 182          | 388     | 123          | 183       | 149         |
| Maximum                     | 671          | 671     | 151          | 265       | 250         |

### 3.2 PCBs stormwater concentrations and estimated particle concentrations

Total PCB concentrations from the 83 sampling sites<sup>10</sup> ranged from 533 to 448,000 pg/L excluding one sample that included a large number of individual congeners below the method detection limit (<MDL; Table 5). Based on water composite concentrations for all available data, the 10 highest ranking sites for PCBs are (from higher to lower): Pulgas Pump Station-South, Santa Fe Channel, Industrial Rd Ditch, Line 12H at Coliseum Way, Sunnyvale East Channel, Pulgas Pump Station-North, Ettie Street Pump Station, Ridder Park Dr Storm Drain, Gull Dr. Outfall, and Outfall to Lower Silver Creek (Table 5, Figure 3). Old industrial land use and PCB concentration were weakly correlated ( $r=0.55$ ); old industrial land use for these 10 sites ranges from 3-79% (mean 40%, median 47%), illustrating that land use alone is insufficient to identify high leverage areas. Rather, localized sources (e.g., former transformer manufacturing location) are likely the most important factor controlling PCB concentrations, although these sources frequently are located in old industrial areas.

Based on EPCs, the 10 highest-ranking sites for PCBs are: Pulgas Pump Station-South, Industrial Rd Ditch, Line 12H at Coliseum Way, Santa Fe Channel, Gull Dr SD, Pulgas Pump Station-North, Outfall to Colma Ck on service road near Littlefield Ave., Outfall to Lower Silver Creek, Ettie Street Pump Station, and South Linden Ave. SD. Sites ranked highest based on stormwater concentrations and those ranked highest based on EPCs corresponded well. Seven sampling sites are among the 10 highest-ranking sites for both metrics (Figure 4); most sites in the top 10 for either concentrations or EPCs were within the top 20 of the other list, while only one site (South Linden Ave. SD) was ranked high (10<sup>th</sup>) in EPCs but low on water concentration (35<sup>th</sup>) because of very low suspended sediment concentration. One or more sites of interest were identified through this sampling effort each year (Figure 3). Of the 10 sites sampled in WY 2018, one of them ranked in the top 10 for PCB EPCs.

A high rank in water concentration and a low rank in EPC indicates the presence of PCB sources but dilution by relatively high loading of clean sediment (e.g. >75<sup>th</sup> percentile of SSC, Table 5). Examples include Line 13A at end of slough (357 mg SS/L) and Line 12K at Coliseum Entrance (671 mg SS/L). Conversely, a high rank in EPC and low rank in water concentration indicates that mobilization of PCB-

<sup>10</sup> There are 84 sites in Table 5 but one site, San Pedro Stormdrain, only analyzed samples for Hg, not PCBs.

contaminated sediment is high relative to mobilization of cleaner sediment; these samples often have a relatively low SSC. Examples include South Linden Ave. SD (16 mg SS/L), Austin Ck at Hwy 37 (20 mg SS/L) and Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Circle (27 mg SS/L). This latter scenario is more likely to occur in watersheds that are highly impervious with little erosion and transport of clean sediment from undeveloped areas.

Most of the sites investigated have PCB EPCs that are higher than those needed for attainment of the TMDL. The PCB load allocation of 2 kg from the TMDL (SFBRWQCB 2008) translates to a mean water concentration of 1,330 pg/L and a mean particle concentration of 1.4 ng/g. These calculations assume an annual average flow from small tributaries of 1.5 km<sup>3</sup> (Wu et al., 2017) and an average annual suspended sediment load of 1.4 million metric tons (McKee et al., 2013). Only five sampling locations investigated to date (Gellert Park bioretention influent stormwater, Duane Ct. and Triangle Ave., East Antioch nr Trembath, Refugio Ck at Tsushima St. and Little Bull Valley) have a composite averaged PCB water concentration of <1,330 pg/L (Table 5) and none of the 83 sampling locations have composite averaged PCB EPCs of <1.4 ng/g (Table 5; Figure 3). The lowest PCB EPC measured to date is for Marsh Creek (2.9 ng/g).



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**Table 5.** PCB and total mercury (HgT) water concentrations and estimated particle concentrations (EPCs) measured in the Bay Area based on all RMP data collected in stormwater since water year 2003 (83 sites in total for PCBs and 84 sites for HgT). The data are sorted from high to low for PCB EPC to provide preliminary information on potential leverage. Note: Ranks with a half number (.5) indicate two watersheds with the same rank. NR = not ranked because concentration was below the MDL or because the study was part of a bioretention study and data is based on a relatively very small watershed.

| Watershed/<br>Catchment   | County          | Water<br>Year<br>sampled | Area<br>(km <sup>2</sup> ) | Impervious<br>cover (%) | Old<br>Industrial<br>land use<br>(%) | Polychlorinated biphenyls (PCBs)    |      |  |      | Total Mercury (HgT)                 |      |  |      | Suspended Sediment<br>Concentration (SSC) |      |
|---|-----------------|--------------------------|----------------------------|-------------------------|--------------------------------------|-------------------------------------|------|--|------|-------------------------------------|------|--|------|---|------|
|   |                 |                          |                            |                         |                                      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Composite /mean water<br>concentration    |      |
|   |                 |                          |                            |                         |                                      | (ng/g)                              | Rank | (ng/L)                                 | Rank | (ng/g)                              | Rank | (ng/L)                                 | Rank | (mg/L)                                    | Rank |
| Pulgas Pump Station-<br>South                                     | San<br>Mateo    | 2011-<br>2014            | 0.58                       | 87%                     | 54%                                  | 8222                                | 1    | 448                                    | 1    | 350                                 | 45.5 | 19                                     | 58   | 54  | 62   |
| Industrial Rd Ditch   | San<br>Mateo    | 2016                     | 0.23                       | 85%                     | 79%                                  | 6139                                | 2    | 160                                    | 3    | 535                                 | 27   | 14                                     | 68   | 26  | 79   |
| Line 12H at Coliseum<br>Way                                       | Alameda         | 2017                     | 0.97                       | 71%                     | 10%                                  | 2601                                | 3    | 156                                    | 4    | 602                                 | 19   | 36                                     | 43   | 60  | 55   |
| Santa Fe Channel  | Contra<br>Costa | 2011                     | 3.3                        | 69%                     | 3%                                   | 1295                                | 4    | 198                                    | 2    | 570                                 | 22.5 | 86                                     | 12.5 | 151                                       | 22   |
| Gull Dr SD  | San<br>Mateo    | 2016                     | 0.30                       | 78%                     | 54%                                  | 903                                 | 5    | 39.8                                   | 11   | 320                                 | 51   | 5.4                                    | 81   | 43  | 70   |
| Pulgas Pump Station-<br>North                                     | San<br>Mateo    | 2011                     | 0.55                       | 84%                     | 52%                                  | 893                                 | 6    | 60.3                                   | 6    | 400                                 | 39   | 24                                     | 54.5 | 60  | 55   |
| Outfall to Colma Ck<br>on service rd nr<br>Littlefield Ave. (359) | San<br>Mateo    | 2017                     | 0.09                       | 88%                     | 87%                                  | 788                                 | 7    | 33.9                                   | 16   | 210                                 | 65   | 9                                      | 78   | 43  | 68   |
| Outfall to Lower Silver<br>Creek                                  | Santa<br>Clara  | 2015                     | 0.17                       | 79%                     | 78%                                  | 783                                 | 8    | 44.6                                   | 10   | 420                                 | 36   | 24                                     | 54.5 | 57  | 60   |
| Ettie Street Pump<br>Station                                      | Alameda         | 2011                     | 4.0                        | 75%                     | 22%                                  | 759                                 | 9    | 59.0                                   | 7    | 690                                 | 14   | 55                                     | 24.5 | 80  | 48   |
| S Linden Ave SD (291)   | San<br>Mateo    | 2017                     | 0.78                       | 88%                     | 57%                                  | 736                                 | 10   | 11.8                                   | 35   | 775                                 | 10   | 12                                     | 74   | 16  | 84   |
| Gull Dr Outfall   | San<br>Mateo    | 2016 &<br>2018           | 0.43                       | 75%                     | 42%                                  | 599                                 | 11   | 49.5                                   | 9    | 180                                 | 70.5 | 7.6                                    | 79   | 62  | 53   |
| Austin Ck at Hwy 37   | Solano          | 2017                     | 4.9                        | 61%                     | 2%                                   | 573                                 | 12   | 11.5                                   | 37   | 640                                 | 17   | 13                                     | 72.5 | 20  | 83   |
| Ridder Park Dr Storm<br>Drain                                     | Santa<br>Clara  | 2015                     | 0.50                       | 72%                     | 57%                                  | 488                                 | 13   | 55.5                                   | 8    | 330                                 | 49   | 37                                     | 42   | 114                                       | 32   |
| MeekerWest  | Contra<br>Costa | 2018                     | 0.41                       | 70%                     | 69%                                  | 458                                 | 14   | 28.0                                   | 20   | 530                                 | 29   | 32                                     | 46   | 61  | 54   |



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| Watershed/<br>Catchment  | County          | Water<br>Year<br>sampled | Area<br>(km <sup>2</sup> ) | Impervious<br>cover (%) | Old<br>Industrial<br>land use<br>(%) | Polychlorinated biphenyls (PCBs)    |      |  |      | Total Mercury (HgT)                 |      |  |      | Suspended Sediment<br>Concentration (SSC) |      |
|--|-----------------|--------------------------|----------------------------|-------------------------|--------------------------------------|-------------------------------------|------|--|------|-------------------------------------|------|--|------|---|------|
|  |                 |                          |                            |                         |                                      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Composite /mean water<br>concentration    |      |
|  |                 |                          |                            |                         |                                      | (ng/g)                              | Rank | (ng/L)                                 | Rank | (ng/g)                              | Rank | (ng/L)                                 | Rank | (mg/L)                                    | Rank |
| Outfall at Gilman St.  | Alameda         | 2016 &<br>2018           | 0.84                       | 76%                     | 32%                                  | 451                                 | 15   | 37.2                                   | 13   | 2820                                | 3    | 233                                    | 5    | 81  | 47   |
| Line 12I at Coliseum<br>Way                                    | Alameda         | 2017                     | 3.4                        | 63%                     | 9%                                   | 398                                 | 16   | 37.0                                   | 14   | 129                                 | 76   | 12                                     | 76   | 93  | 43   |
| Sunnyvale East<br>Channel                                      | Santa<br>Clara  | 2011                     | 15                         | 59%                     | 4%                                   | 343                                 | 17   | 96.6                                   | 5    | 200                                 | 67   | 50                                     | 28   | 250                                       | 13   |
| Line 3A-M at 3A-D  | Alameda         | 2015                     | 0.88                       | 73%                     | 12%                                  | 337                                 | 18   | 24.8                                   | 21   | 1170                                | 4    | 86                                     | 12.5 | 74  | 49   |
| North Richmond<br>Pump Station                                 | Contra<br>Costa | 2011-<br>2014            | 2.0                        | 62%                     | 18%                                  | 241                                 | 19   | 13.2                                   | 33   | 810                                 | 9    | 47                                     | 29.5 | 58  | 58   |
| Seabord Ave Storm<br>Drain SC-050GAC580                        | Santa<br>Clara  | 2015                     | 1.4                        | 81%                     | 68%                                  | 236                                 | 20   | 19.9                                   | 26   | 550                                 | 25   | 47                                     | 29.5 | 85  | 44   |
| Line 12M at Coliseum<br>Way                                    | Alameda         | 2017                     | 5.3                        | 69%                     | 22%                                  | 222                                 | 21   | 24.1                                   | 22   | 365                                 | 42   | 40                                     | 38   | 109                                       | 36   |
| Line 4-E   | Alameda         | 2015                     | 2.0                        | 81%                     | 27%                                  | 219                                 | 22   | 37.4                                   | 12   | 350                                 | 45.5 | 59                                     | 21   | 170                                       | 19   |
| Kirker Ck at Pittsburg<br>Antioch Hwy and<br>Verne Roberts Cir | Contra<br>Costa | 2017 &<br>2018           | 36.67                      | 18%                     | 5%                                   | 219                                 | 23   | 5.64                                   | 55   | 540                                 | 26   | 16                                     | 62   | 27  | 77   |
| Glen Echo Creek  | Alameda         | 2011                     | 5.5                        | 39%                     | 0%                                   | 191                                 | 24   | 31.1                                   | 18   | 210                                 | 66   | 73                                     | 17   | 348                                       | 11   |
| Seabord Ave Storm<br>Drain SC-050GAC600                        | Santa<br>Clara  | 2015                     | 2.8                        | 62%                     | 18%                                  | 186                                 | 25   | 13.5                                   | 32   | 530                                 | 28   | 38                                     | 40.5 | 73  | 50   |
| Line 12F below PG&E<br>station                                 | Alameda         | 2017                     | 10                         | 56%                     | 3%                                   | 184                                 | 26   | 21.0                                   | 25   | 373                                 | 40   | 43                                     | 35   | 114                                       | 32   |
| South Linden Pump<br>Station                                   | San<br>Mateo    | 2015                     | 0.14                       | 83%                     | 22%                                  | 182                                 | 27   | 7.81                                   | 49   | 680                                 | 15   | 29                                     | 50   | 43  | 68   |
| Taylor Way SD  | San<br>Mateo    | 2016                     | 0.27                       | 67%                     | 11%                                  | 169                                 | 28   | 4.23                                   | 60   | 1156                                | 5    | 29                                     | 51   | 25  | 80   |
| Line 9-D   | Alameda         | 2015                     | 3.6                        | 78%                     | 46%                                  | 153                                 | 29   | 10.5                                   | 40   | 240                                 | 59.5 | 17                                     | 60.5 | 69  | 52   |
| Meeker Slough  | Contra<br>Costa | 2015 &<br>2018           | 7.3                        | 64%                     | 6%                                   | 140                                 | 30   | 7.91                                   | 48   | 770                                 | 11   | 45                                     | 32   | 57  | 61   |
| Rock Springs Dr Storm<br>Drain                                 | Santa<br>Clara  | 2015                     | 0.83                       | 80%                     | 10%                                  | 128                                 | 31   | 5.25                                   | 56   | 930                                 | 7    | 38                                     | 40.5 | 41  | 71   |
| GR outfall<br>066GAC900  | Santa<br>Clara  | 2018                     | 0.17                       | 66%                     | 1%                                   | 125                                 | 32   | 3.36                                   | 65   | 644                                 | 16   | 17                                     | 59   | 27  | 77   |

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| Watershed/<br>Catchment                | County      | Water<br>Year<br>sampled   | Area<br>(km <sup>2</sup> ) | Impervious<br>cover (%) | Old<br>Industrial<br>land use<br>(%) | Polychlorinated biphenyls (PCBs)    |      |  |      | Total Mercury (HgT)                 |      |  |      | Suspended Sediment<br>Concentration (SSC) |      |
|--|-------------|----------------------------|----------------------------|-------------------------|--------------------------------------|-------------------------------------|------|--|------|-------------------------------------|------|--|------|---|------|
|  |             |                            |                            |                         |                                      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Composite /mean water<br>concentration    |      |
|  |             |                            |                            |                         |                                      | (ng/g)                              | Rank | (ng/L)                                 | Rank | (ng/g)                              | Rank | (ng/L)                                 | Rank | (mg/L)                                    | Rank |
| Charcot Ave Storm Drain                | Santa Clara | 2015                       | 1.8                        | 79%                     | 24%                                  | 123                                 | 33   | 14.9                                   | 29   | 560                                 | 24   | 67                                     | 19   | 121                                       | 31   |
| Veterans Pump Station                  | San Mateo   | 2015                       | 0.52                       | 67%                     | 7%                                   | 121                                 | 34   | 3.52                                   | 64   | 470                                 | 32   | 14                                     | 67   | 29  | 76   |
| Gateway Ave Storm Drain                | San Mateo   | 2015                       | 0.36                       | 69%                     | 52%                                  | 117                                 | 35   | 5.24                                   | 57   | 440                                 | 33   | 20                                     | 57   | 45  | 66   |
| Guadalupe River at Hwy 101             | Santa Clara | 2003-2006, 2010, 2012-2014 | 233                        | 39%                     | 3%                                   | 115                                 | 36   | 23.7                                   | 23   | 3600                                | 2    | 603                                    | 1    | 560                                       | 5    |
| Line 9D1 PS at outfall to Line 9D      | Alameda     | 2016                       | 0.48                       | 88%                     | 62%                                  | 110                                 | 37   | 18.1                                   | 28   | 720                                 | 13   | 118                                    | 8.5  | 164                                       | 20   |
| Tunnel Ave Ditch                       | San Mateo   | 2016                       | 3.0                        | 47%                     | 8%                                   | 109                                 | 38   | 10.5                                   | 39   | 760                                 | 12   | 73                                     | 18   | 96  | 39   |
| Valley Dr SD                           | San Mateo   | 2016                       | 5.2                        | 21%                     | 7%                                   | 109                                 | 39   | 10.4                                   | 41   | 276                                 | 57   | 27                                     | 53   | 96  | 39   |
| Runnymede Ditch                        | San Mateo   | 2015                       | 2.1                        | 53%                     | 2%                                   | 108                                 | 40   | 28.5                                   | 19   | 190                                 | 69   | 52                                     | 27   | 265                                       | 12   |
| E Gish Rd Storm Drain                  | Santa Clara | 2015                       | 0.45                       | 84%                     | 70%                                  | 99                                  | 41   | 14.4                                   | 30   | 590                                 | 21   | 85                                     | 14   | 145                                       | 25   |
| Line 3A-M-1 at Industrial Pump Station | Alameda     | 2015                       | 3.4                        | 78%                     | 26%                                  | 96                                  | 42   | 8.92                                   | 43   | 340                                 | 47   | 31                                     | 47   | 93  | 42   |
| Line 13A at end of slough              | Alameda     | 2016                       | 0.83                       | 84%                     | 68%                                  | 96                                  | 43   | 34.3                                   | 15   | 331                                 | 48   | 118                                    | 8.5  | 357                                       | 9    |
| Line 12A at Shellmound                 | Alameda     | 2018                       | 10.48                      | 41%                     | 6%                                   | 95                                  | 44   | 10.8                                   | 38   | 406                                 | 37   | 46                                     | 31   | 114                                       | 32   |
| Rosemary St SD 066GAC550C              | Santa Clara | 2017                       | 3.7                        | 64%                     | 11%                                  | 89                                  | 45   | 4.11                                   | 62   | 591                                 | 20   | 27                                     | 52   | 46  | 65   |
| North Fourth St SD 066GAC550B          | Santa Clara | 2017                       | 1.0                        | 68%                     | 27%                                  | 87                                  | 46   | 4.17                                   | 61   | 477                                 | 31   | 23                                     | 56   | 48  | 63   |
| Zone 4 Line A                          | Alameda     | 2007-2010                  | 4.2                        | 68%                     | 12%                                  | 82                                  | 47   | 18.4                                   | 27   | 170                                 | 72   | 30                                     | 49   | 176                                       | 18   |
| Forbes Blvd Outfall                    | San Mateo   | 2016                       | 0.40                       | 79%                     | 0%                                   | 80                                  | 48   | 1.84                                   | 73   | 637                                 | 18   | 15                                     | 66   | 23  | 81   |

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| Watershed/<br>Catchment                 | County         | Water<br>Year<br>sampled | Area<br>(km <sup>2</sup> ) | Impervious<br>cover (%) | Old<br>Industrial<br>land use<br>(%) | Polychlorinated biphenyls (PCBs)    |      |  |      | Total Mercury (HgT)                 |      |  |      | Suspended Sediment<br>Concentration (SSC) |      |
|---|----------------|--------------------------|----------------------------|-------------------------|--------------------------------------|-------------------------------------|------|--|------|-------------------------------------|------|--|------|---|------|
|   |                |                          |                            |                         |                                      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Estimated Particle<br>Concentration |      | Composite /mean<br>water concentration |      | Composite /mean water<br>concentration    |      |
|   |                |                          |                            |                         |                                      | (ng/g)                              | Rank | (ng/L)                                 | Rank | (ng/g)                              | Rank | (ng/L)                                 | Rank | (mg/L)                                    | Rank |
| Storm Drain near<br>Cooley Landing      | San<br>Mateo   | 2015                     | 0.11                       | 73%                     | 39%                                  | 79                                  | 49   | 6.47                                   | 53   | 430                                 | 34   | 35                                     | 44   | 82  | 46   |
| Lawrence & Central<br>Expwys SD         | Santa<br>Clara | 2016                     | 1.2                        | 66%                     | 1%                                   | 78                                  | 50   | 4.51                                   | 59   | 226                                 | 61   | 13                                     | 69.5 | 58  | 59   |
| Condensa St SD                          | Santa<br>Clara | 2016                     | 0.24                       | 70%                     | 32%                                  | 74                                  | 51   | 2.60                                   | 71   | 329                                 | 50   | 12                                     | 77   | 35  | 74   |
| San Leandro Creek                       | Alameda        | 2011-<br>2014            | 8.9                        | 38%                     | 0%                                   | 66                                  | 52   | 8.61                                   | 46   | 860                                 | 8    | 117                                    | 10   | 136                                       | 29   |
| Oddstad Pump<br>Station                 | San<br>Mateo   | 2015                     | 0.28                       | 74%                     | 11%                                  | 62                                  | 53   | 9.20                                   | 42   | 370                                 | 41   | 55                                     | 24.5 | 148                                       | 24   |
| Line 4-B-1                              | Alameda        | 2015                     | 1.0                        | 85%                     | 28%                                  | 57                                  | 54   | 8.67                                   | 45   | 280                                 | 55.5 | 43                                     | 34   | 152                                       | 21   |
| Line 12A under<br>Temescal Ck Park      | Alameda        | 2016                     | 9.4                        |                         | 1%                                   | 54                                  | 55   | 7.80                                   | 50   | 290                                 | 54   | 42                                     | 36   | 143                                       | 26   |
| Victor Nelo PS Outfall                  | Santa<br>Clara | 2016                     | 0.58                       | 87%                     | 4%                                   | 51                                  | 56   | 2.29                                   | 72   | 351                                 | 43   | 16                                     | 64   | 45  | 66   |
| Line 12K at Coliseum<br>Entrance        | Alameda        | 2017                     | 16                         | 31%                     | 1%                                   | 48                                  | 57   | 32.0                                   | 17   | 429                                 | 35   | 288                                    | 4    | 671                                       | 4    |
| GR outfall<br>066GAC850                 | Santa<br>Clara | 2018                     | 3.35                       | 61%                     | 6%                                   | 45                                  | 58   | 6.63                                   | 51   | 107                                 | 79   | 16                                     | 63   | 149                                       | 23   |
| Haig St SD                              | Santa<br>Clara | 2016                     | 2.1                        | 72%                     | 10%                                  | 43                                  | 59   | 1.45                                   | 75   | 194                                 | 68   | 7                                      | 80   | 34  | 75   |
| Colma Ck at S. Linden<br>Blvd           | San<br>Mateo   | 2017                     | 35                         | 41%                     | 3%                                   | 37                                  | 60   | 2.65                                   | 70   | 215                                 | 64   | 15                                     | 65   | 71  | 51   |
| Line 12J at mouth to<br>12K             | Alameda        | 2017                     | 8.8                        | 30%                     | 2%                                   | 35                                  | 61   | 6.48                                   | 52   | 401                                 | 38   | 73                                     | 16   | 183                                       | 17   |
| S Spruce Ave SD at<br>Mayfair Ave (296) | San<br>Mateo   | 2017                     | 5.1                        | 39%                     | 1%                                   | 30                                  | 62   | 3.36                                   | 66   | 350                                 | 44   | 39                                     | 39   | 111                                       | 35   |
| Lower Coyote Creek                      | Santa<br>Clara | 2005                     | 327                        | 22%                     | 1%                                   | 30                                  | 63   | 4.58                                   | 58   | 240                                 | 59.5 | 34                                     | 45   | 142                                       | 28   |
| Calabazas Creek                         | Santa<br>Clara | 2011                     | 50                         | 44%                     | 3%                                   | 29                                  | 64   | 11.5                                   | 36   | 150                                 | 75   | 59                                     | 21   | 393                                       | 7    |
| E Outfall to San<br>Tomas at Scott Blvd | Santa<br>Clara | 2016                     | 0.67                       | 66%                     | 31%                                  | 27                                  | 65   | 2.80                                   | 69   | 127                                 | 77   | 13                                     | 69.5 | 103                                       | 38   |
| San Lorenzo Creek                       | Alameda        | 2011                     | 125                        | 13%                     | 0%                                   | 25                                  | 66   | 12.9                                   | 34   | 180                                 | 70.5 | 41                                     | 37   | 228                                       | 15   |

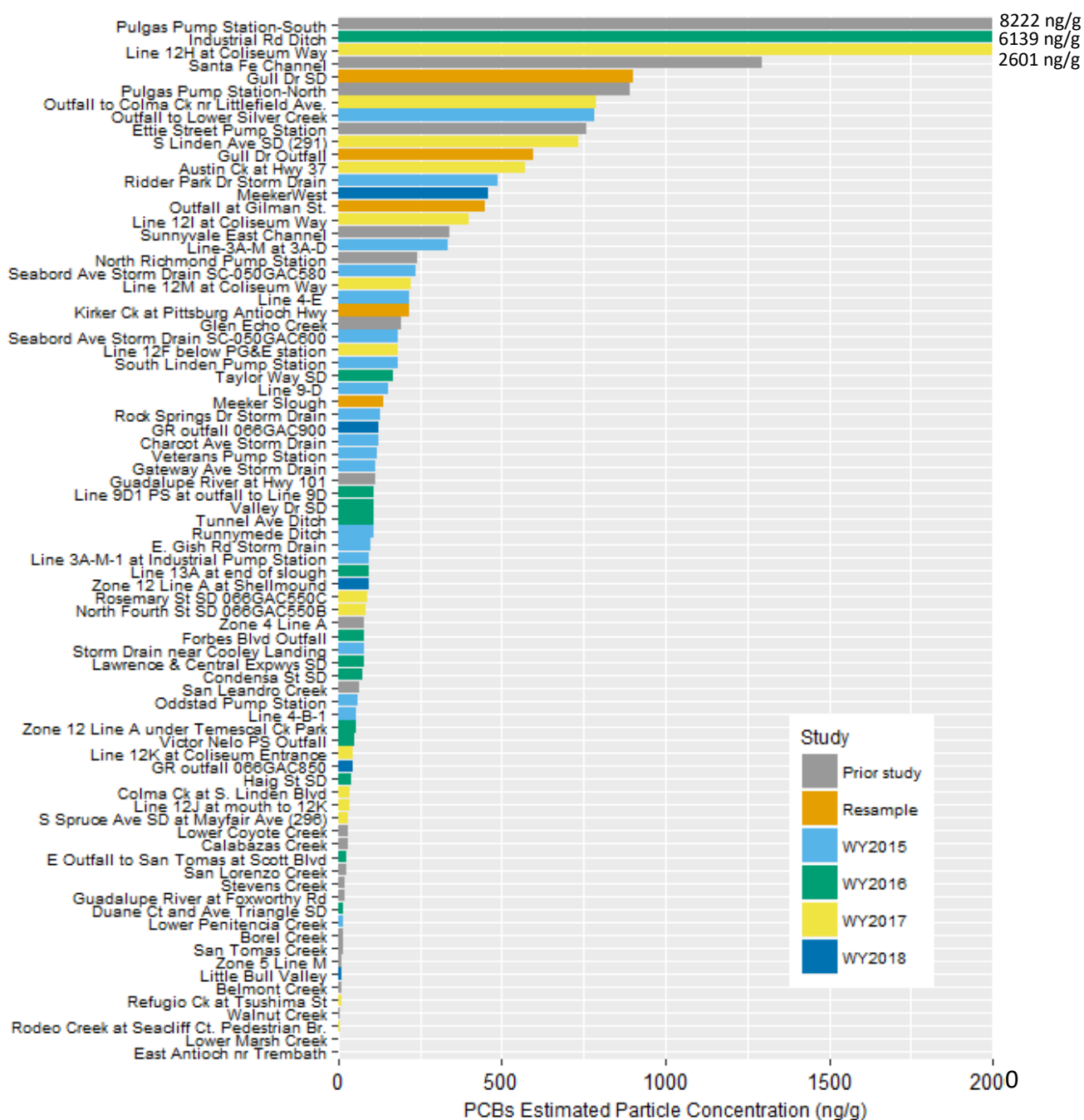
## WYs 2015 through 2018 POC Reconnaissance Monitoring

| Watershed/<br>Catchment                                     | County          | Water<br>Year<br>sampled  | Area<br>(km <sup>2</sup> ) | Impervious<br>cover (%) | Old<br>Industrial<br>land use<br>(%) | Polychlorinated biphenyls (PCBs)    |                 |  |                 | Total Mercury (HgT)                 |                 |  |                 | Suspended Sediment<br>Concentration (SSC) |      |
|---|-----------------|---------------------------|----------------------------|-------------------------|--------------------------------------|-------------------------------------|-----------------|--|-----------------|-------------------------------------|-----------------|--|-----------------|---|------|
|   |                 |                           |                            |                         |                                      | Estimated Particle<br>Concentration |                 | Composite /mean<br>water concentration |                 | Estimated Particle<br>Concentration |                 | Composite /mean<br>water concentration |                 | Composite /mean water<br>concentration    |      |
|   |                 |                           |                            |                         |                                      | (ng/g)                              | Rank            | (ng/L)                                 | Rank            | (ng/g)                              | Rank            | (ng/L)                                 | Rank            | (mg/L)                                    | Rank |
| Stevens Creek   | Santa Clara     | 2011                      | 26                         | 38%                     | 1%                                   | 23                                  | 67              | 8.16                                   | 47              | 220                                 | 62.5            | 77                                     | 15              | 350                                       | 10   |
| Guadalupe River at<br>Foxworthy Road/<br>Almaden Expressway | Santa Clara     | 2010                      | 107                        | 22%                     | 0%                                   | 19                                  | 68              | 3.12                                   | 67              | 4090                                | 1               | 529                                    | 2               | 129                                       | 30   |
| Duane Ct and Ave<br>Triangle SD                             | Santa Clara     | 2016                      | 1.0                        | 79%                     | 23%                                  | 17                                  | 69              | 0.832                                  | 77              | 268                                 | 58              | 13                                     | 71              | 48  | 63   |
| Lower Penitencia<br>Creek                                   | Santa Clara     | 2011,<br>2015             | 12                         | 65%                     | 2%                                   | 16                                  | 70              | 1.59                                   | 74              | 160                                 | 73.5            | 17                                     | 60.5            | 106                                       | 37   |
| Borel Creek   | San<br>Mateo    | 2011                      | 3.2                        | 31%                     | 0%                                   | 15                                  | 71              | 6.13                                   | 54              | 160                                 | 73.5            | 58                                     | 23              | 363                                       | 8    |
| San Tomas Creek   | Santa<br>Clara  | 2011                      | 108                        | 33%                     | 0%                                   | 14                                  | 72              | 2.83                                   | 68              | 280                                 | 55.5            | 59                                     | 21              | 211                                       | 16   |
| Little Bull Valley  | Contra<br>Costa | 2018                      | 0.02                       | 67%                     | 2%                                   | 13                                  | 73              | 0.543                                  | 78              | 312                                 | 53              | 13                                     | 72.5            | 41  | 71   |
| Zone 5 Line M   | Alameda         | 2011                      | 8.1                        | 34%                     | 5%                                   | 13                                  | 74.5            | 21.1                                   | 24              | 570                                 | 22.5            | 505                                    | 3               | 886                                       | 3    |
| Belmont Creek   | San<br>Mateo    | 2011                      | 7.2                        | 27%                     | 0%                                   | 13                                  | 74.5            | 3.60                                   | 63              | 220                                 | 62.5            | 53                                     | 26              | 241                                       | 14   |
| Refugio Ck at<br>Tsushima St                                | Contra<br>Costa | 2017                      | 11                         | 23%                     | 0%                                   | 9                                   | 76              | 0.533                                  | 79              | 509                                 | 30              | 30                                     | 48              | 59  | 57   |
| Walnut Creek  | Contra<br>Costa | 2011                      | 232                        | 15%                     | 0%                                   | 7                                   | 77              | 8.83                                   | 44              | 70                                  | 80              | 94                                     | 11              | 1343                                      | 2    |
| Rodeo Creek at<br>Seacliff Ct. Pedestrian<br>Br.            | Contra<br>Costa | 2017                      | 23                         | 2%                      | 3%                                   | 5                                   | 78              | 13.9                                   | 31              | 45                                  | 81              | 119                                    | 7               | 2626                                      | 1    |
| Lower Marsh Creek   | Contra<br>Costa | 2011-<br>2014             | 84                         | 10%                     | 0%                                   | 3                                   | 79              | 1.45                                   | 76              | 110                                 | 78              | 44                                     | 33              | 400                                       | 6    |
| San Pedro Storm<br>Drain                                    | Santa<br>Clara  | 2006                      | 1.3                        | 72%                     | 16%                                  | No data                             | No data         | No data                                | No data         | 1120                                | 6               | 160                                    | 6               | 143                                       | 27   |
| East Antioch nr<br>Trembath                                 | Contra<br>Costa | 2017                      | 5.3                        | 26%                     | 3%                                   | NR <sup>a</sup>                     | NR <sup>a</sup> | <MDL                                   | NR <sup>a</sup> | 313                                 | 52              | 12                                     | 75              | 39  | 73   |
| El Cerrito<br>Bioretention Influent                         | Contra<br>Costa | 2012,<br>2014-15,<br>2017 | 0.00                       | 74%                     | 0%                                   | 310                                 | NR <sup>a</sup> | 29.7                                   | NR <sup>a</sup> | 196                                 | NR <sup>a</sup> | 19                                     | NR <sup>a</sup> | 96  | 41   |

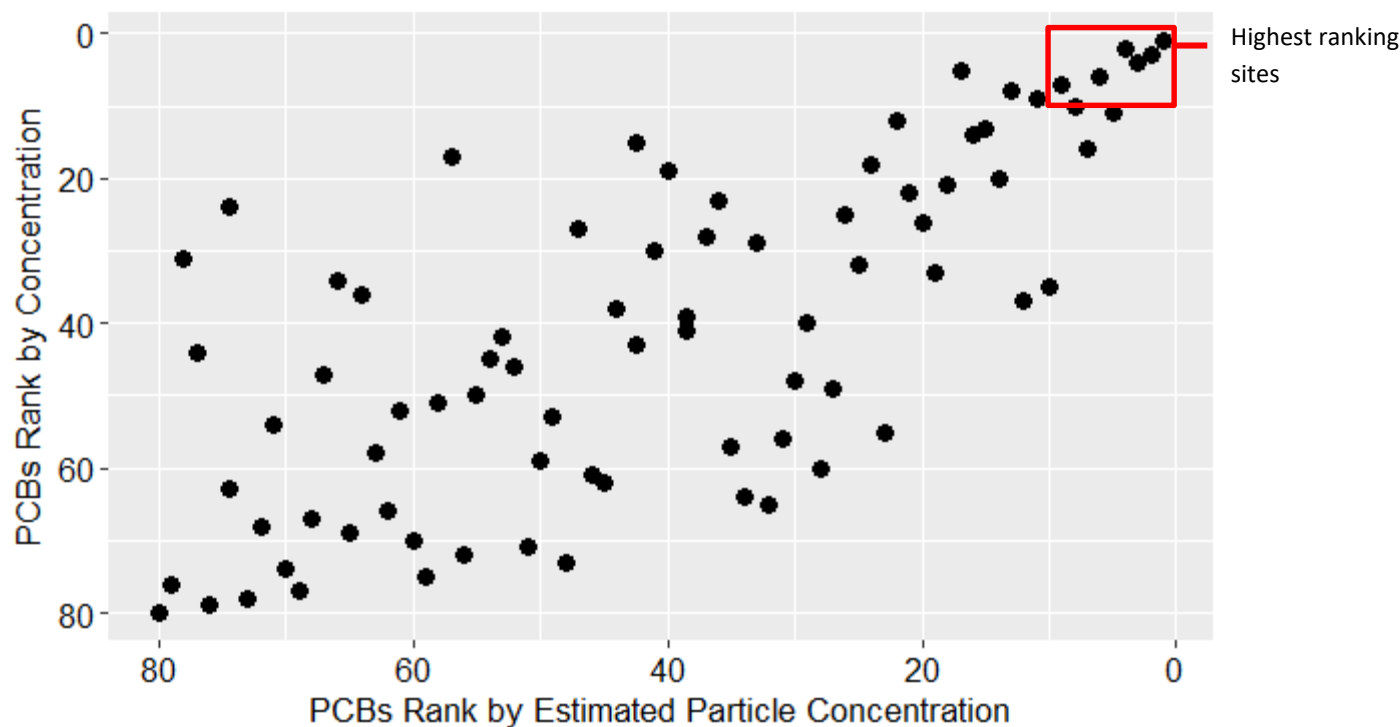
WYs 2015 through 2018 POC Reconnaissance Monitoring

| Watershed/<br>Catchment                                    | County       | Water<br>Year<br>sampled | Area<br>(km <sup>2</sup> ) | Impervious<br>cover (%) | Old<br>Industrial<br>land use<br>(%) | Polychlorinated biphenyls (PCBs)    |                 |  |                 | Total Mercury (HgT)                 |                 |  |                 | Suspended Sediment<br>Concentration (SSC) |      |
|--|--------------|--------------------------|----------------------------|-------------------------|--------------------------------------|-------------------------------------|-----------------|--|-----------------|-------------------------------------|-----------------|--|-----------------|---|------|
|  |              |                          |                            |                         |                                      | Estimated Particle<br>Concentration |                 | Composite /mean<br>water concentration |                 | Estimated Particle<br>Concentration |                 | Composite /mean<br>water concentration |                 | Composite /mean water<br>concentration    |      |
|  |              |                          |                            |                         |                                      | (ng/g)                              | Rank            | (ng/L)                                 | Rank            | (ng/g)                              | Rank            | (ng/L)                                 | Rank            | (mg/L)                                    | Rank |
| Fremont Osgood<br>Road Bioretention<br>Influent            | Alameda      | 2012,<br>2013            | 0.00                       | 76%                     | 0%                                   | 45                                  | NR <sup>a</sup> | 2.906                                  | NR <sup>a</sup> | 120                                 | NR <sup>a</sup> | 10                                     | NR <sup>a</sup> | 83  | 45   |
| Gellert Park Daly City<br>Library Bioretention<br>Influent | San<br>Mateo | 2009                     | 0.02                       | 40%                     | 0%                                   | 36                                  | NR <sup>a</sup> | 0.725                                  | NR <sup>a</sup> | 1010                                | NR <sup>a</sup> | 22                                     | NR <sup>a</sup> | 22  | 82   |

## WYs 2015 through 2018 POC Reconnaissance Monitoring



**Figure 3.** PCB estimated particle concentrations (EPCs) for watershed sampling sites measured for water years 2003-2018 (where more than one storm is sampled at a site, the reported concentration is the average of the storm composite samples). Note that PCB EPCs for Pulgas Pump Station-South (8,222 ng/g), Industrial Road Ditch (6,139 ng/g), and Line 12H at Coliseum Way (2,601 ng/g) extend beyond upper bound of the graph. The sample count represented by each bar in the graph is provided in Appendix D.



**Figure 4.** Comparison of site rankings for PCBs based on estimated particle concentrations (EPCs) and on water concentrations. 1 = highest rank; 80 = lowest rank.

### 3.3 Mercury stormwater concentrations and estimated particle concentrations

Total mercury concentrations in composite water samples ranged 110-fold from 5.4 to 603 ng/L among the 84 sites sampled to date (Table 4). Based on water concentrations, the 10 highest ranking sites for HgT are the Guadalupe River at Hwy 101 (3% old industrial and with the legacy New Almaden Mining District upstream), Guadalupe River at Foxworthy Road/ Almaden Expressway (0% old industrial and with the legacy New Almaden Mining District upstream), Zone 5 Line M (5% old industrial), Line 12K at the Coliseum Entrance (1% old industrial), Outfall at Gilman St. (32% old industrial), San Pedro Storm Drain (16% old industrial), Rodeo Creek at Seacliff Ct. Pedestrian Br. (3% old industrial), Line 13-A at end of slough (68% old industrial), Line 9-D-1 PS at outfall to Line 9-D (62% old industrial) and San Leandro Creek at San Leandro Blvd. (0% old industrial) (Table 4). There is a weak and negative relationship between mercury concentrations<sup>11</sup> and old industrial land use, in contrast to the weak and positive relationship between concentrations measured in water and industrial land use for PCBs. None of the top 10 sites for Hg were among the top 10 for PCBs, also suggesting there is no direct relationship between mercury and PCBs in stormwater runoff in the Bay Area. Thus, management of highly polluted PCB sites will likely lead to Hg load reductions that are not necessarily similarly large.

There are several watersheds with relatively low Hg concentrations. The HgT load allocation of 82 kg from the TMDL (SFBRWQCB, 2006) translates to a mean water concentration of 53 ng/L, based on an

<sup>11</sup> There is a weak and negative relationship between old industrial land use and Hg concentrations in water.

annual average flow from small tributaries of  $1.5 \text{ km}^3$  (Wu et al., 2017). Fifty-eight of 84 sampling locations have composite HgT water concentrations below this concentration (Table 4). There are likely few Hg sources in these watersheds besides atmospheric deposition<sup>12</sup>.

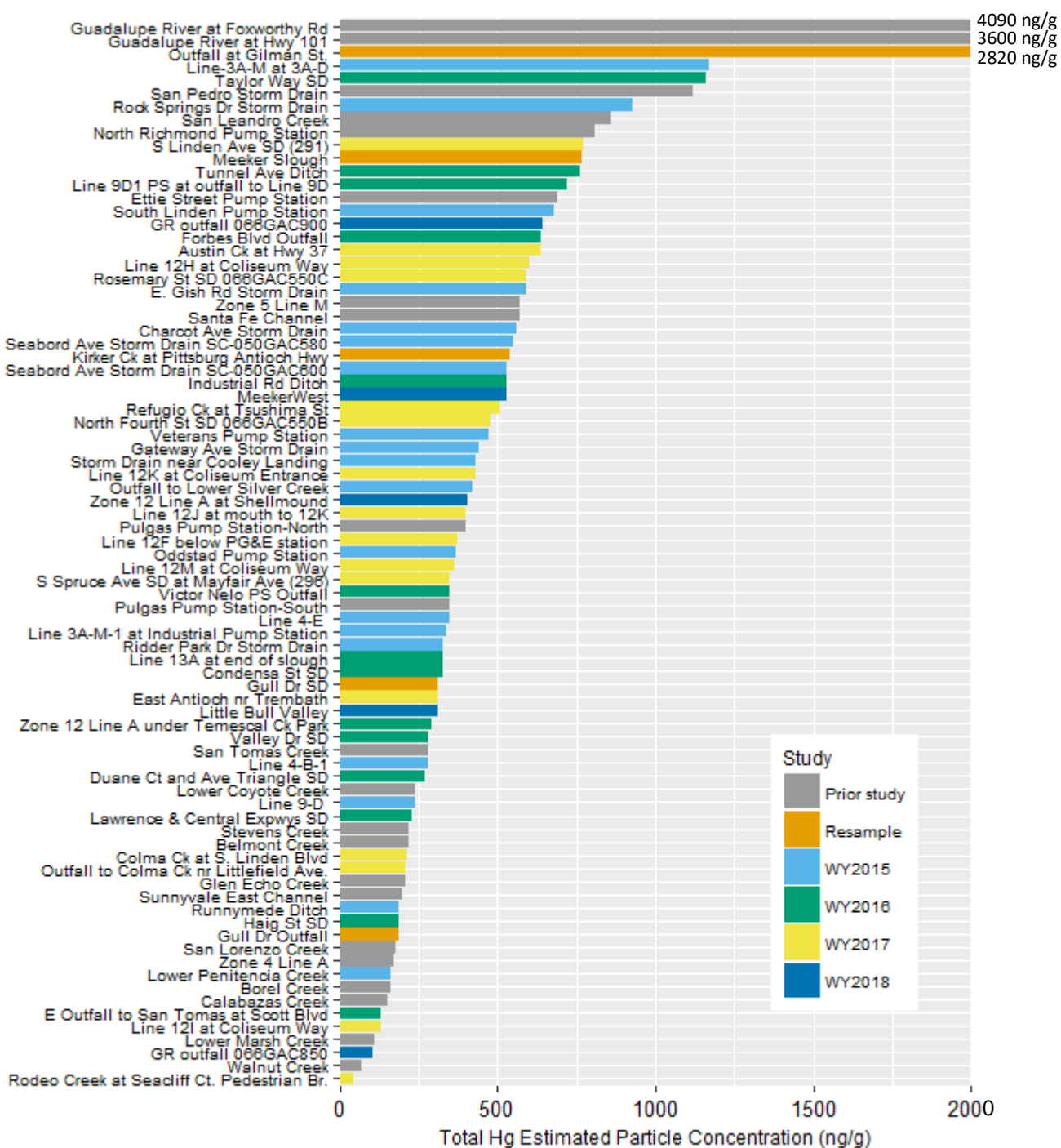
Estimated particle concentrations of HgT ranged between 45 and 4090 ng/g. The 10 most polluted sites for HgT based on EPCs are Guadalupe River at Foxworthy Road/ Almaden Expressway, Guadalupe River at Hwy 101, Outfall at Gilman St., Line 3A-M at 3A-D, Taylor Way SD, San Pedro Storm Drain, Rock Springs Dr. Storm Drain, San Leandro Creek, North Richmond Pump Station and South Linden Ave. SD (Table 4; Figure 5). Management action in these watersheds might be most cost effective for reducing HgT loads. Only one of these 10 sites was among the 10 most highly-ranked sites for PCBs (South Linden Ave. SD), but 6 additional watersheds rank in the 20 most highly-ranked sites for both pollutants (Figure 6), providing the opportunity to address both PCBs and HgT. Twenty-five sites sampled to date have EPCs <250 ng/g, which, given a reasonable expectation of error of 25% around the measurements, could be considered equivalent to or less than 200 ng/g of Hg on suspended solids, the particulate Hg concentration specified in the Bay and Guadalupe River TMDLs (SFBRWQCB, 2006; 2008). Unlike for PCBs, there is no relation between water concentration and EPC for HgT (Figure 7). Therefore, ranking of sites for HgT should be approached more cautiously than for PCBs.

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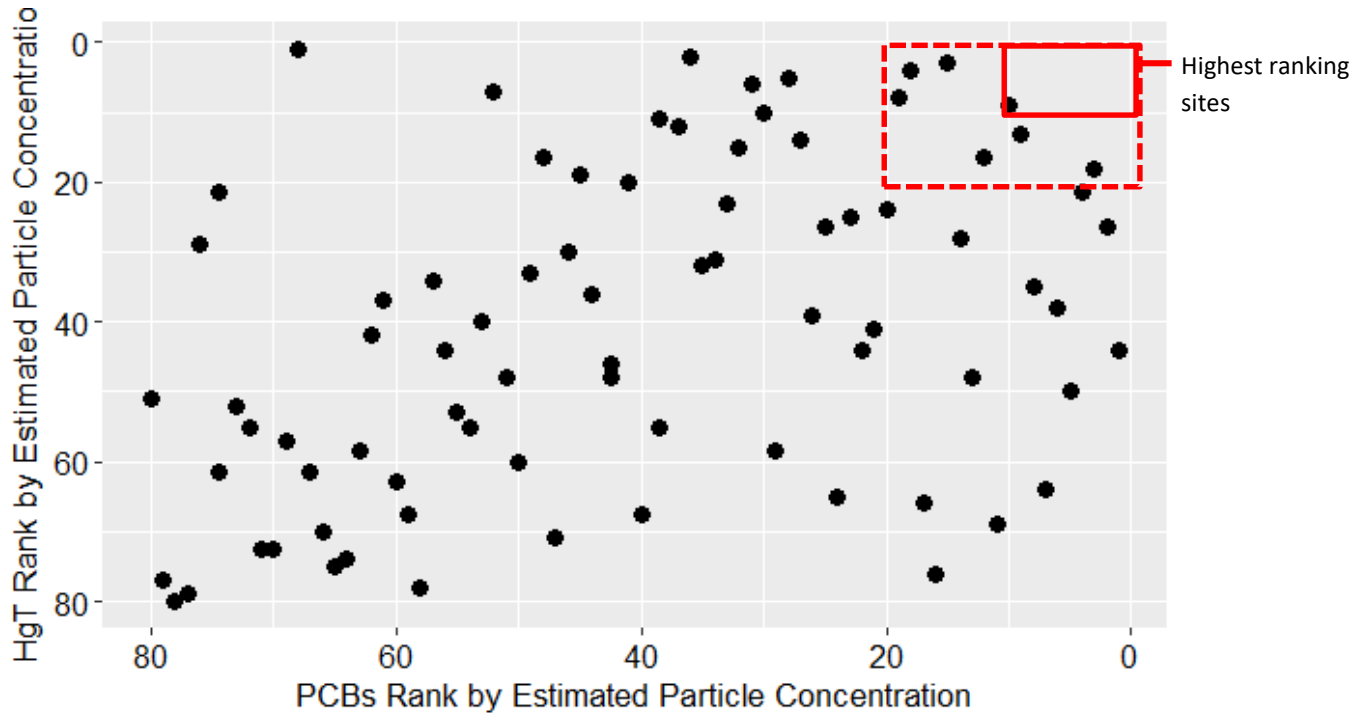
<sup>12</sup> Multiple studies in the Bay Area on atmospheric deposition rates for HgT reported very similar wet deposition rates of  $4.2 \text{ } \mu\text{g}/\text{m}^2/\text{y}$  (Tsai and Hoenicke, 2001) and  $4.4 \text{ } \mu\text{g}/\text{m}^2/\text{y}$  (Steding and Flegal, 2002), and Tsai and Hoenicke reported a total (wet + dry) deposition rate of 18-21  $\mu\text{g}/\text{m}^2/\text{y}$ . Tsai and Hoenicke computed volume-weighted mean mercury concentrations in precipitation based on 59 samples collected across the Bay Area of 8.0 ng/L. They reported that wet deposition contributed 18% of total annual deposition; scaled to volume of runoff, an equivalent stormwater concentration is 44 ng/L ( $8 \text{ ng}/\text{L}/0.18 = 44 \text{ ng}/\text{L}$ ).



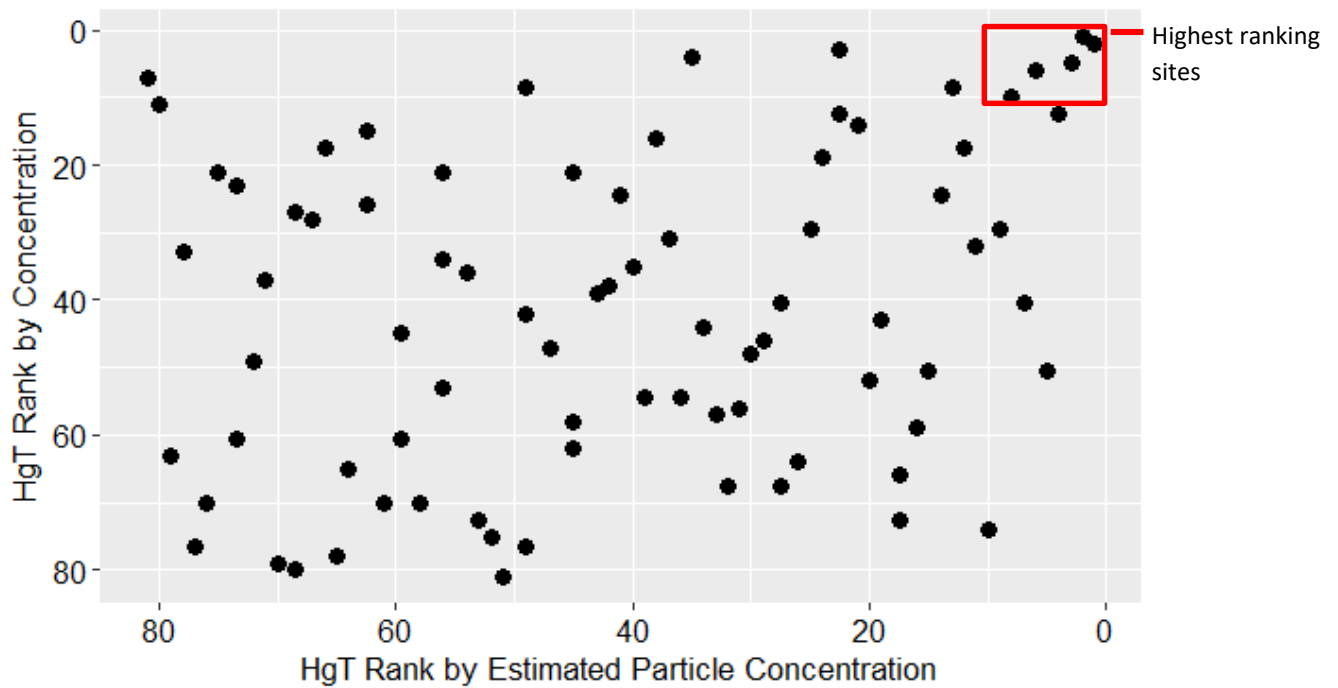
## WYs 2015 through 2018 POC Reconnaissance Monitoring



**Figure 5.** All watershed sampling locations measured to date (water years 2003-2018) ranked by total mercury (HgT) estimated particle concentrations (EPCs). The sample count represented by each bar in the graph is provided in Appendix D.



**Figure 6.** Comparison of site rankings for PCB and total mercury (HgT) estimated particle concentrations (EPCs). 1 = highest rank; 80 = lowest rank. One watershed ranks in the top 10 for both PCBs and HgT (in the solid red box), and seven watersheds rank in the top 20 for both pollutants (in the dashed red box).



**Figure 7.** Comparison of site rankings for total mercury (HgT) estimated particle concentrations and water concentrations. 1 = highest rank; 81 = lowest rank.

### 3.4 Trace element (As, Cd, Cu, Mg, Pb, Se and Zn) concentrations

Trace metal (As, Cd, Cu, Pb and Zn) concentrations measured in selected watersheds during WYs 2015, 2016, and 2017 were similar in range to those previously measured in the Bay Area.

- Arsenic (As): Concentrations ranged from less than the MDL (0.34 µg/L for that sample) to 2.66 µg/L (Table 6). Total As concentrations of this magnitude have been measured in the Bay Area previously (Guadalupe River at Hwy 101: mean=1.9 µg/L; Zone 4 Line A: mean=1.6 µg/L) and are lower than those measured at the North Richmond Pump Station (mean=11 µg/L) (Appendix A3 in McKee et al., 2015).
- Cadmium (Cd): Concentrations ranged from 0.023-0.55 µg/L (Table 6), similar to mean concentrations measured at Guadalupe River at Hwy 101 (0.23 µg/L), North Richmond Pump Station (mean = 0.32 µg/L), and Zone 4 Line A (mean = 0.25 µg/L) (Appendix A3 in McKee et al., 2015).
- Copper (Cu): Concentrations ranged from 3.63 to 52.7 µg/L (Table 6). These concentrations are typical of those measured in other Bay Area watersheds (mean concentrations for all of the following: Guadalupe River at Hwy 101: 19 µg/L; Lower Marsh Creek: 14 µg/L; North Richmond Pump Station: Cu 16 µg/L; Pulgas Pump Station-South: Cu 44 µg/L; San Leandro Creek: Cu 16 µg/L; Sunnyvale East Channel: Cu 18 µg/L; and Zone 4 Line A: Cu 16 µg/L) (Appendix A3 in McKee et al., 2015).
- Lead (Pb): Concentrations ranged from 0.910 to 21.3 µg/L (Table 6). Total Pb concentrations of this magnitude have been measured in the Bay Area previously (mean concentrations for all of the following: Guadalupe River at Hwy 101: 14 µg/L; North Richmond Pump Station: Pb 1.8 µg/L; and Zone 4 Line A: 12 µg/L) (Appendix A3 in McKee et al., 2015).
- Zinc (Zn): Concentrations ranged from 39.4-337 µg/L (Table 6). Zinc were comparable to mean concentrations measured in the Bay Area previously (Zone 4 Line A: 105 µg/L; Guadalupe River at Hwy 101: 72 µg/L) (see Appendix A3 in McKee et al., 2015).

In WY 2016, Mg (528-7350 µg/L) and Se (<MDL-0.39 µg/L) were added to the list of analytes. Both Mg and Se largely reflect geologic sources in watersheds. No measurements of Mg have been previously reported in the Bay Area. The measured concentrations of Se are on the lower end of previously reported concentrations (North Richmond Pump Station: 2.7 µg/L; Walnut Creek: 2.7 µg/L; Lower Marsh Creek: 1.5 µg/L; Guadalupe River at Hwy 101: 1.3 µg/L; Pulgas Creek Pump Station - South: 0.93 µg/L; Sunnyvale East Channel: 0.62 µg/L; Zone 4 Line A: 0.48 µg/L; Mallard Island: 0.46 µg/L; Santa Fe Channel - Richmond: 0.28 µg/L; San Leandro Creek: 0.22 µg/L) (Table A3: McKee et al., 2015). Given the high proportion of Se transported in the dissolved phase and the inverse correlation with flow (David et al., 2015; McKee and Gilbreath, 2015; McKee et al., 2017), Se concentrations measured with the current sampling protocol, with a focus on high flow, likely were biased low relative to those measured with sampling designs that included low flow and baseflow samples (North Richmond Pump Station: 2.7 µg/L; Guadalupe River at Hwy 101: 1.3 µg/L; Zone 4 Line A: 0.48 µg/L; Mallard Island: 0.46 µg/L). Care therefore should be taken if Se concentrations reported here were to be used in the future to estimate regional loads.

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**Table 6.** Concentrations of selected trace elements measured during winter storms of water years 2015, 2016, and 2017. The highest and lowest concentration for each trace element is in bold.

| Watershed/Catchment                  | Sample Date | As<br>(µg/L)   | Cd<br>(µg/L) | Cu<br>(µg/L) | Pb<br>(µg/L) | Mg<br>(µg/L)  | Se<br>(µg/L)   | Zn<br>(µg/L) |
|--------------------------------------|-------------|----------------|--------------|--------------|--------------|---------------|----------------|--------------|
| Charcot Ave SD                       | 4/7/2015    | 0.623          | 0.0825       | 16.1         | 2.02         |               |                | 115          |
| Condensa St SD                       | 1/19/2016   | 1.07           | 0.055        | 6.66         | 3.37         | 3,650         | 0.39           | 54.3         |
| E. Gish Rd SD                        | 12/11/2014  | 1.52           | <b>0.552</b> | 23.3         | 19.4         |               |                | 152          |
| East Antioch nr Trembath             | 1/8/2017    | 1.57           | 0.119        | <b>3.53</b>  | 1.68         | 5,363         | 0.53           | <b>36.3</b>  |
| Forbes Blvd Outfall                  | 3/5/2016    | 1.5            | 0.093        | 31.7         | 3.22         | 7,350         | <b>&lt;MDL</b> | 246          |
| Gateway Ave SD                       | 2/6/2015    | 1.18           | 0.053        | 24.3         | 1.04         |               |                | 78.8         |
| Gull Dr SD                           | 3/5/2016    | <b>&lt;MDL</b> | <b>0.023</b> | 3.63         | 1.18         | <b>528</b>    | <b>&lt;MDL</b> | 39.4         |
| Line 9-D-1 PS at outfall to Line 9-D | 1/5/2016    | 1.07           | 0.524        | 22.5         | 20.9         | 2,822         | 0.2            | 217          |
| Line 3A-M at 3A-D                    | 12/11/2014  | 2.08           | 0.423        | 19.9         | 17.3         |               |                | 118          |
| Line 3A-M-1 at Industrial PS         | 12/11/2014  | 1.07           | 0.176        | 14.8         | 7.78         |               |                | 105          |
| Line 4-B-1                           | 12/16/2014  | 1.46           | 0.225        | 17.7         | 8.95         |               |                | 108          |
| Line 4-E                             | 12/16/2014  | 2.12           | 0.246        | 20.6         | 13.3         |               |                | 144          |
| Line 9-D                             | 4/7/2015    | 0.47           | 0.053        | 6.24         | <b>0.91</b>  |               |                | 67           |
| Lower Penitencia Ck                  | 12/11/2014  | 2.39           | 0.113        | 16.4         | 4.71         |               |                | 64.6         |
| Meeker Slough                        | 12/3/2014   | 1.75           | 0.152        | 13.6         | 14.0         |               |                | 85.1         |
| North Fourth St SD 066GAC550B        | 1/8/2017    | 1.15           | 0.125        | 14.0         | 5.70         | <b>11,100</b> | <b>0.67</b>    | 75.7         |
| Oddstad PS                           | 12/2/2014   | 2.45           | 0.205        | 23.8         | 5.65         |               |                | 117          |
| Outfall to Lower Silver Ck           | 2/6/2015    | 2.11           | 0.267        | 21.8         | 5.43         |               |                | <b>337</b>   |
| Ridder Park Dr SD                    | 12/15/2014  | <b>2.66</b>    | 0.335        | 19.6         | 11.0         |               |                | 116          |
| Rock Springs Dr SD                   | 2/6/2015    | 0.749          | 0.096        | 20.4         | 2.14         |               |                | 99.2         |
| Runnymede Ditch                      | 2/6/2015    | 1.84           | 0.202        | <b>52.7</b>  | <b>21.3</b>  |               |                | 128          |
| S Spruce Ave SD at Mayfair Ave (296) | 1/8/2017    | 2.2            | 0.079        | 9.87         | 5.31         | 3,850         | 0.13           | 54.8         |
| SD near Cooley Landing               | 2/6/2015    | 1.74           | 0.100        | 9.66         | 1.94         |               |                | 48.4         |
| Seaboard Ave SD SC-050GAC580         | 12/11/2014  | 1.29           | 0.295        | 27.6         | 10.2         |               |                | 168          |
| Seaboard Ave SD SC-050GAC600         | 12/11/2014  | 1.11           | 0.187        | 21           | 8.76         |               |                | 132          |
| South Linden PS                      | 2/6/2015    | 0.792          | 0.145        | 16.7         | 3.98         |               |                | 141          |
| Taylor Way SD                        | 3/11/2016   | 1.47           | 0.0955       | 10.0         | 4.19         | 5,482         | <b>&lt;MDL</b> | 61.6         |
| Veterans PS                          | 12/15/2014  | 1.32           | 0.093        | 8.83         | 3.86         |               |                | 41.7         |
| Victor Nelo PS Outfall               | 1/19/2016   | 0.83           | 0.140        | 16.3         | 3.63         | 1,110         | 0.04           | 118          |
| Minimum                              |             | <b>&lt;MDL</b> | <b>0.023</b> | <b>3.53</b>  | <b>0.91</b>  | <b>528</b>    | <b>&lt;MDL</b> | <b>36.3</b>  |
| Maximum                              |             | <b>2.66</b>    | <b>0.552</b> | <b>52.7</b>  | <b>21.3</b>  | <b>11,100</b> | <b>0.67</b>    | <b>337</b>   |

### 3.5 Relationships between PCBs and Hg and other trace substances and land-cover attributes

Beginning in WY 2003, numerous sites have been evaluated for selected trace elements in addition to HgT. These sites include the fixed station loads monitoring sites on Guadalupe River at Hwy 101 (McKee et al., 2017, Zone 4 Line A (Gilbreath and McKee, 2015; McKee and Gilbreath, 2015), North Richmond Pump Station (Hunt et al., 2012) and four sites at which only Cu was measured (Lower Marsh Creek, San Leandro Creek, Pulgas Pump Station-South, and Sunnyvale East Channel) (Gilbreath et al., 2015a). Copper data were also collected at the inlets to several pilot performance studies for bioretention (El Cerrito: Gilbreath et al., 2012; Fremont: Gilbreath et al., 2015b), and Cu, Cd, Pb, and Zn data were collected at the Daly City Library Gellert Park demonstration bioretention site (David et al., 2015). During WYs 2015, 2016, and 2017, trace element data were collected at an additional 29 locations (Table 5). The pooled data comprise 39 sites for Cu; 33 for Cd, Pb, and Zn; and 32 for As. Data for Mg and Se were not included because of small sample size. Organic carbon was collected at 28 locations in this study and at an additional 21 locations in previous studies.

PCBs correlate positively with impervious cover and old industrial land use, and inversely with watershed area (Table 6), on the basis of Spearman rank correlation analysis<sup>13</sup>. The three highest PCB concentrations were measured in small watersheds with a high proportion of impervious cover and old industrial area (Figure 8). However, the lack of a stronger correlation between these PCBs and these geospatial variables indicates that not all small, highly impervious watersheds have high PCB concentrations. The data also indicate the presence of outliers that may be worth exploring with additional data.

HgT data associated with the main channel of the Guadalupe River were removed from the analysis because of historic mining influence in the watershed<sup>14</sup>. These observations are consistent with previous analysis (McKee et al., 2012), and with the concept that larger watersheds tend to have mixed land use and thus a lower proportional amount of PCB source areas relative to smaller watersheds that are more urbanized and more industrialized. There was also a positive but relatively weak correlation between PCBs and HgT, consistent with the general relationships between impervious cover and both PCBs and HgT. This observation contrasts with conclusions drawn from the WY 2011 dataset, for which there was a stronger correlation between PCBs and HgT (McKee et al., 2012). This difference might reflect a stronger focus on PCBs during the WY 2015-2018 sampling campaigns, which included more drainage-line outfalls to creeks with higher imperviousness and old industrial land use, or it might be an artifact of small sample size without sample representation along all environmental gradients. Additionally, or alternatively, the weakness of the relationship between PCBs and HgT may partly be associated with the larger role of atmospheric recirculation in the mercury cycle than the PCB cycle and with large

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<sup>13</sup> The rank correlation was preferred because it makes no assumption of the type of relationship (linear or other) or the data distribution (normal data distribution is a requirement of a Pearson Product Moment correlation); in the Spearman correlation, every data pair has an equal influence on the coefficient.

<sup>14</sup> Historic mining in the Guadalupe River watershed caused a unique positive relationship between Hg, Cr, and Ni, and unique inverse correlations between Hg and other typically urban metals such as Cu and Pb (McKee et al., 2017).

differences between the use history of each pollutant. Correlations between HgT and impervious cover, old industrial land use, and watershed area are similar to but weaker than those for PCBs and these geospatial variables. Neither PCBs nor Hg are strongly correlated with other trace metals. Based on the available pooled data, there is no support for the use of trace metals as a surrogate investigative tool for either PCB or HgT pollution sources.

### 3.6 Comparison between remote and composite sampling methods

Remote samplers show promise as a screening tool based on data collected to date. The EPCs for the samples from the remote samplers and manual water composites were compared for the three differing field sampling techniques (Table 7a and Table 7b). Grain size was measured for the remote suspended sediment samples and the manual water composite samples collected in parallel. The grain-size distribution for the Walling tube samples agreed well with the manual water-composite samples (Figure 10). The grain-size distribution for the Hamlin samples typically was coarser than for the Walling tube or manual water composite samples. The pollutant results are likely affected by grain size and are discussed further below.

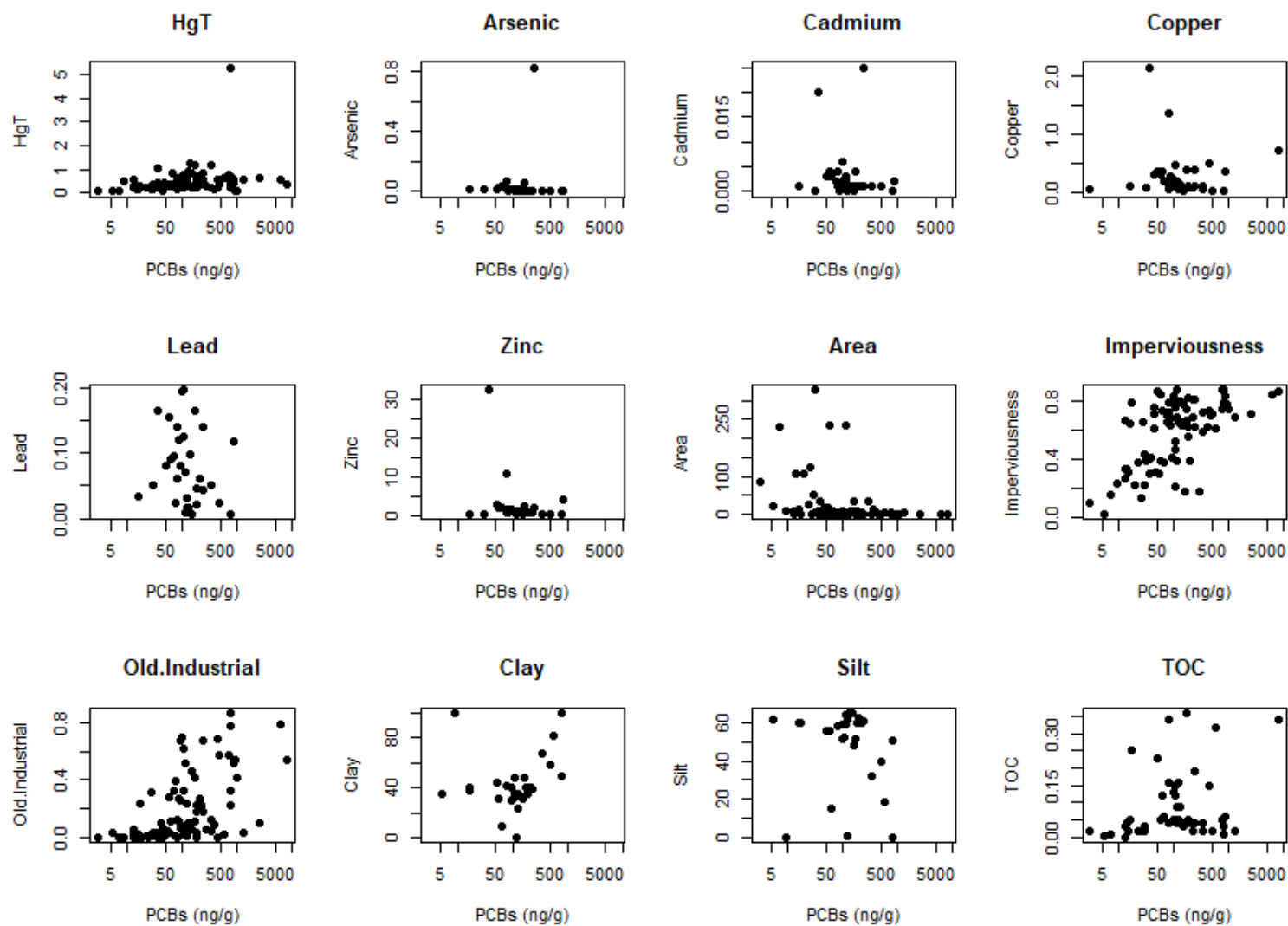
The remote sampler and the manual water composite data were first plotted against one another for a basic visual inspection of scatter about the 1:1 line, and then the differences between concentrations measured in samples collected by the two methods were plotted against the mean of the two measurements to evaluate symmetric grouping around zero and systematic variation of the differences with the mean (Bland and Altman, 1986; Dallal, 2012). Measurements of PCB EPCs measured by the remote and manual sampling methods (Figure 11A, B) agree better than those for HgT. The EPCs from remote samples were biased high relative to the manual samples. One outlier from the Hamlin remote sampler had an EPC (1767 ng/g) elevated well above the manual water composite EPC (783 ng/g); the Walling Tube also deployed at this location for this same storm had an EPC (956 ng/g) more similar to the manual water composite EPC but still elevated.

Results for Hg for Walling Tube and stormwater samples were in good agreement with no evident bias (Figure 11C, D; four samples are below the 1:1 line and two are above). The EPC in the Hamlin samples, however, were generally biased low relative to stormwater samples. The mean deviation of the paired sample differences (remote sample concentrations minus the water-composite sample concentrations) for the Walling Tube sampler was -25 ng/g with a standard deviation of 170, whereas for the Hamlin sampler the mean deviation was -241 ng/g with a standard deviation of 275 ng/g. The best agreement in Hg EPCs in remote and composite water samples was at Rodeo Creek at Seacliff Ct. Pedestrian Br using a Walling Tube (RPD 9%); a difference this low could be entirely attributed to subsampling and analytical variation. At other sites the differences were as much as 5-fold and cannot be easily explained by subsampling or analytical variation. A possible explanation for the differences is that the manual water composite sample is collected using 2 to 9 sub-samples whereas the remote sampler is a continuous time-integrated sample that reduces the influence of momentary spikes in concentrations. The low bias for the Hg EPCs is consistent with Yee and McKee (2010), who reported substantial proportions of Hg in dissolved and slower settling fractions. This is in agreement with measurements of 10-38% (mean 26%) of HgT in the dissolved form.

**Table 6.** Spearman Rank correlation matrix based on estimated particle concentrations (EPCs) of stormwater samples collected in the Bay Area since water year 2003 (see text for data sources and exclusions). Sample size in correlations ranged from 28 to 79. Correlation coefficients (r) shaded in light blue have a  $p$ -value <0.05.

|                               | PCBs (pg/mg) | HgT (ng/mg) | Arsenic (ug/mg) | Cadmium (ug/mg) | Copper (ug/mg) | Lead (ug/mg) | Zinc (ug/mg) | Area (sq km) | % Imperviousness | % Old Industrial | % Clay (<0.0039 mm) | % Silt (0.0039 to <0.0625 mm) | % Sands (0.0625 to <2.0 mm) |
|-------------------------------|--------------|-------------|-----------------|-----------------|----------------|--------------|--------------|--------------|------------------|------------------|---------------------|-------------------------------|-----------------------------|
| HgT (ng/mg)                   | 0.357        |             |                 |                 |                |              |              |              |                  |                  |                     |                               |                             |
| Arsenic (ug/mg)               | -0.61        | -0.07       |                 |                 |                |              |              |              |                  |                  |                     |                               |                             |
| Cadmium (ug/mg)               | -0.28        | 0.23        | 0.67            |                 |                |              |              |              |                  |                  |                     |                               |                             |
| Copper (ug/mg)                | -0.08        | 0.162       | 0.56            | 0.743           |                |              |              |              |                  |                  |                     |                               |                             |
| Lead (ug/mg)                  | -0.25        | 0.179       | 0.583           | 0.863           | 0.711          |              |              |              |                  |                  |                     |                               |                             |
| Zinc (ug/mg)                  | -0.25        | 0.266       | 0.497           | 0.801           | 0.894          | 0.691        |              |              |                  |                  |                     |                               |                             |
| Area (sq km)                  | -0.41        | -0.25       | 0.00            | -0.23           | -0.43          | -0.08        | -0.41        |              |                  |                  |                     |                               |                             |
| % Imperviousness              | 0.529        | 0.25        | -0.35           | 0.00            | 0.185          | -0.10        | 0.173        | -0.75        |                  |                  |                     |                               |                             |
| % Old Industrial              | 0.588        | 0.233       | -0.48           | -0.2            | -0.21          | -0.25        | -0.14        | -0.52        | 0.735            |                  |                     |                               |                             |
| % Clay (<0.0039 mm)           | 0.272        | 0.135       | -0.12           | 0.038           | -0.23          | -0.04        | -0.16        | -0.23        | 0.037            | 0.115            |                     |                               |                             |
| % Silt (0.0039 to <0.0625 mm) | -0.13        | 0.07        | -0.14           | -0.18           | 0.274          | 0.00         | 0.168        | 0.206        | -0.05            | -0.06            | -0.37               |                               |                             |
| % Sands (0.0625 to <2.0 mm)   | -0.19        | -0.24       | 0.094           | 0.008           | -0.02          | 0.086        | -0.02        | 0.285        | -0.14            | -0.11            | -0.84               | -0.05                         |                             |
| TOC (mg/mg)                   | 0.258        | 0.427       | 0.70            | 0.60            | 0.875          | 0.466        | 0.756        | -0.48        | 0.441            | 0.173            | -0.13               | 0.118                         | -0.06                       |

$p$  value <0.05



**Figure 8.** Relationships between observed estimated particle concentrations (EPCs) of PCBs and total mercury (HgT), trace elements, and impervious land cover and old industrial land use.



Because the remote samplers capture primarily the solid phase, the agreement between remote and manual water samples is best when the amount of contaminant in the dissolved phase is small. The disparity between the manual water composite and remote sampling methods was well correlated with the percentage of contaminant in the dissolved phase in the manual water composite for each sampler (Figure 12).

While remote sampling methods can be used as an alternative for cost saving and in places where manual sampling is not feasible, interpreting the data from remote samples and comparing them to the composite water samples remains challenging. The remote methods collect primarily a concentrated, whole-storm-integrated suspended sediment sample, and the manually composited water samples include a proportion of dissolved concentration, which confounds the metric of comparison (EPC) between the methods. In addition, the data collected thus far from the Hamlin sampler has a different grain-size distribution than that for data collected by the Walling Tube and manual water composite methods. Further, the remote sampling data cannot be used to estimate loads without corresponding sediment load estimates.

In summary, although there are some drawbacks to using the remote samplers, they appear to be a defensible *screening* tool based on data collected to date. The SPLWG has decided that the pilot phase of this study is now complete and has recommended that the remote samplers be used as a low-cost screening tool to identify watersheds where greater investment in manual sampling and other methods of investigation may be needed. Reconnaissance characterization monitoring will continue into WY 2019, during which time remote samplers will be used for part of the effort, allowing the project to gather information at more sites for the same budget allocation. Other comparisons between the two methods are described below and presented in Table 8a and 8b.

**Cost:** Both manual and remote sampling involve many of the same costs, although manual sampling generally requires more staff labor related to deployment of field staff, and requires more labor during long storms. Remote sampling requires two trips to the site and slightly more for post-sample processing, but these additional costs are minimal. Laboratory analytical costs are equivalent. See additional details in Table 8b below.

**Sampling Feasibility:** Remote sampling has a number of feasibility advantages over manual sampling. With remote sampling, manpower is less of a constraint; there is little time spent on cleaning equipment and that cleaning can be done at the office; the samplers can be deployed for longer than a single storm event, if desired; the samplers composite more continuously over the hydrograph and therefore reduce the influence of momentary spikes; and remote samplers can conceivably be deployed in storm drains in logistically difficult locations such as the middle of streets. However, there is no advantage in deploying remote samplers in tidal locations as they must be deployed and retrieved during the same tidal cycle.

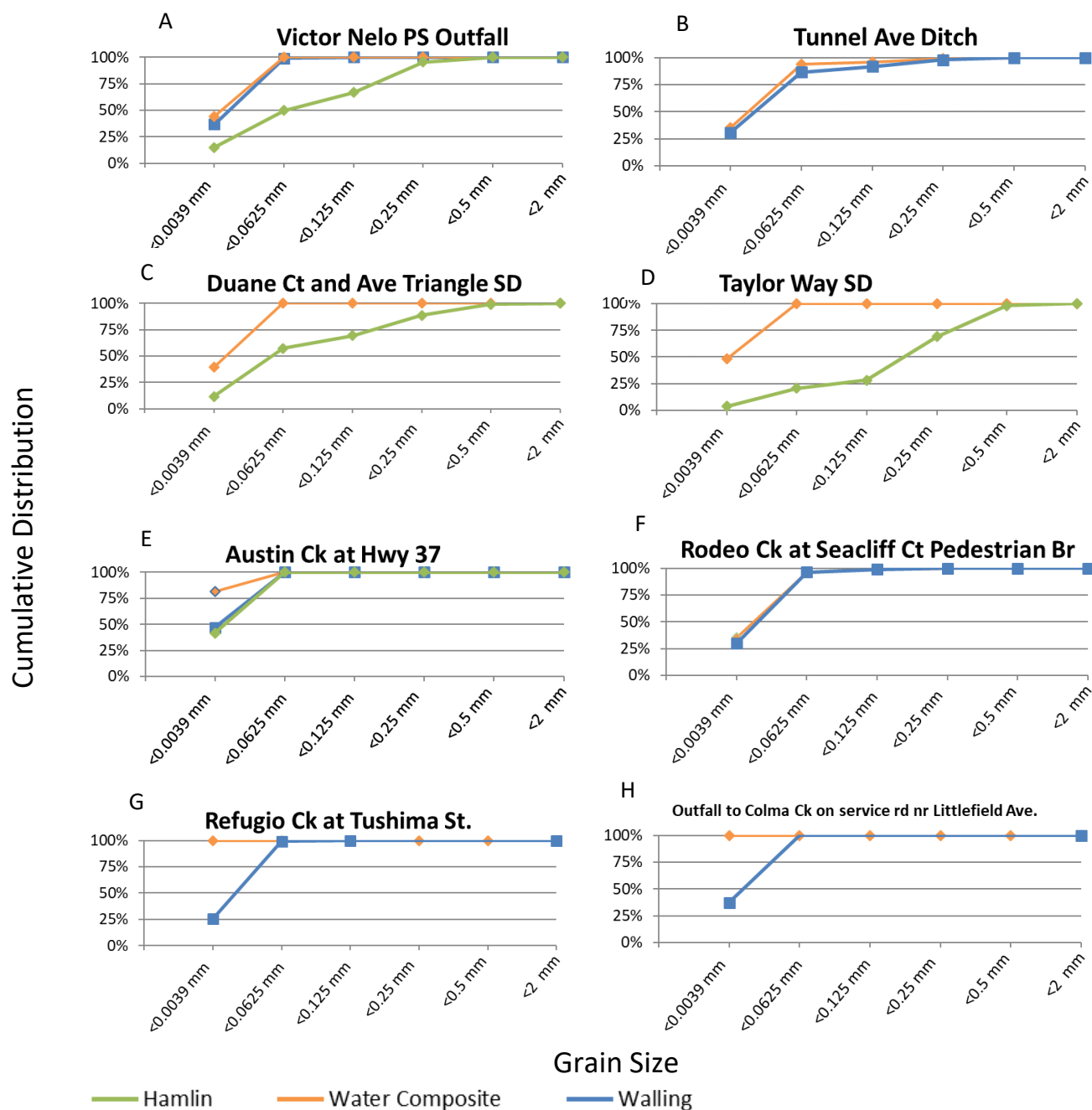
WYs 2015 through 2018 POC Reconnaissance Monitoring

**Table 7a.** Remote suspended-sediment sampler PCB data and comparison with manually collected composite water data. Note: EPC = estimated particle concentration.

| Site  | Remote Sampler Used | Manual Water Composite Data   |                   |                         |                       |             |  |                |                           | Remote Sampler Data     |  |
|---|---------------------|-------------------------------|-------------------|-------------------------|-----------------------|-------------|--|----------------|---------------------------|-------------------------|--|
|   |                     | SSC (manual composite) (mg/L) | PCBs Total (ng/L) | PCBs Particulate (ng/L) | PCBs Dissolved (ng/L) | % Dissolved | PCB particle concentration (lab measured on filter) (ng/g) | PCB EPC (ng/g) | Bias (EPC: lab measured ) | PCB EPC (remote) (ng/g) | Comparative Ratio between Remote Sampler and Manual Water Composites |
| Duane Ct and Ave Triangle SD (Jan 6)                        | Hamlin              | 48                            | 0.8               | 0.55                    | 0.28                  | 34%         | 11   | 17             | 151%                      | 43                      | 246%   |
| Victor Nelo PS Outfall                                      | Hamlin              | 45                            | 2.3               | 2.0                     | 0.28                  | 12%         | 45   | 51             | 114%                      | 70                      | 137%   |
| Taylor Way SD   | Hamlin              | 25                            | 4.2               | 3.5                     | 0.76                  | 18%         | 139  | 169            | 122%                      | 237                     | 140%   |
| Tunnel Ave Ditch  | Hamlin              | 96                            | 10                | 9.9                     | 0.60                  | 6%          | 103  | 109            | 106%                      | 150                     | 137%   |
| Forbes Blvd Outfall   | Hamlin              | 23                            | 1.8               | 1.8                     | 0.047                 | 3%          | 78   | 80             | 103%                      | 42                      | 53%  |
| Charcot Ave SD  | Hamlin              | 121                           | 15                | No data                 |                       |             |  | 123            | No data                   | 142                     | 115%   |
| Outfall to Lower Silver Ck                                  | Hamlin              | 57                            | 45                |                         |                       |             |  | 783            |                           | 1767                    | 226%   |
| SD near Cooley Landing                                      | Hamlin              | 82                            | 6.5               |                         |                       |             |  | 79             |                           | 68                      | 87%  |
| Austin Ck at Hwy 37   | Hamlin              | 20                            | 11                |                         |                       |             |  | 573            |                           | 700                     | 122%   |
| Outfall at Gilman St  | Hamlin              | 81                            | 8.6               |                         |                       |             |  | 107            |                           | 64                      | 60%  |
| Outfall at Gilman St  | Walling             | 81                            | 8.6               |                         |                       |             |  | 107            |                           | 144                     | 135%   |
| MeekerWest  | Walling             | 61                            | 28                |                         |                       |             |  | 458            |                           | 522                     | 114%   |
| Outfall to Lower Silver Ck                                  | Walling             | 57                            | 45                |                         |                       |             |  | 783            |                           | 956                     | 122%   |
| Austin Ck at Hwy 37   | Walling             | 20                            | 11                |                         |                       |             |  | 573            |                           | 362                     | 63%  |
| Rodeo Creek at Seacliff Ct. Pedestrian Br.                  | Walling             | 2626                          | 14                |                         |                       |             |  | 5              |                           | 10                      | 195%   |
| Victor Nelo PS Outfall                                      | Walling             | 45                            | 2.3               | 2.0                     | 0.28                  | 12%         | 45   | 51             | 114%                      | 100                     | 197%   |
| Tunnel Ave Ditch  | Walling             | 96                            | 10                | 10                      | 0.60                  | 6%          | 103  | 109            | 106%                      | 96                      | 88%  |
| Refugio Ck at Tsumisha St                                   | Walling             | 59                            | 0.5               | 0.53                    | <MDL                  | 0%          | 9  | 9              | 100%                      | 8                       | 86%  |
| Outfall to Colma Ck on service rd nr Littlefield Ave. (359) | Walling             | 43                            | 34                | 37                      | 1.0                   | 3%          | 871  | 788            | 90%                       | 1172                    | 149%   |
| Median  |                     |                               |                   |                         |                       | 6%          |  |                | 106%                      |                         | 122%   |
| Mean  |                     |                               |                   |                         |                       | 11%         |  |                | 112%                      |                         | 130%   |

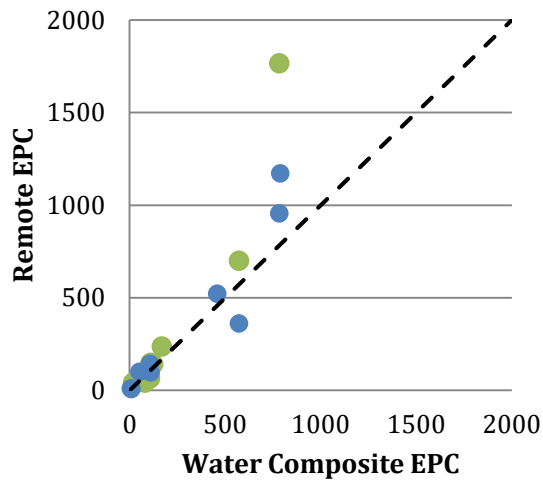
**Table 7b.** Remote suspended-sediment sampler Hg data and comparison with manually collected composite water data. Note: EPC = estimated particle concentration.

| Site  | Remote Sampler Used | Manual Water Composite Data |                 |                       |                     |             |   |               |                           | Remote Sampler Data    |  |
|---|---------------------|-----------------------------|-----------------|-----------------------|---------------------|-------------|---|---------------|---------------------------|------------------------|--|
|   |                     | SSC (manual composite)      | Hg Total (ng/L) | Hg Particulate (ng/L) | Hg Dissolved (ng/L) | % Dissolved | Hg particle concentration (lab measured on filter) (ng/g) | Hg EPC (ng/g) | Bias (EPC: lab measured ) | Hg EPC (remote) (ng/g) | Comparative Ratio between Remote Sampler and Manual Water Composites |
| Duane Ct and Ave Triangle SD (Jan 6)                        | Hamlin              | 48                          | 13              | 11                    | 1.9                 | 15%         | 229   | 268           | 117%                      | 99                     | 37%  |
| Victor Nelo PS Outfall                                      | Hamlin              | 45                          | 16              | 12                    | 3.7                 | 23%         | 269   | 351           | 131%                      | 447                    | 127%   |
| Taylor Way SD   | Hamlin              | 25                          | 29              | 18                    | 11                  | 38%         | 716   | 1156          | 161%                      | 386                    | 33%  |
| Tunnel Ave Ditch  | Hamlin              | 96                          | 73              | 66                    | 7.2                 | 10%         | 685   | 760           | 111%                      | 530                    | 70%  |
| Forbes Blvd Outfall   | Hamlin              | 23                          | 15              | 12                    | 2.5                 | 17%         | 530   | 637           | 120%                      | 125                    | 20%  |
| Charcot Ave SD  | Hamlin              | 121                         | 67              | No data               |                     |             |   | 557           | No data                   | 761                    | 137%   |
| Outfall to Lower Silver Ck                                  | Hamlin              | 57                          | 24              |                       |                     |             |   | 423           |                           | 150                    | 36%  |
| SD near Cooley Landing                                      | Hamlin              | 82                          | 35              |                       |                     |             |   | 427           |                           | 101                    | 24%  |
| Austin Ck at Hwy 37   | Hamlin              | 20                          | 13              |                       |                     |             |   | 640           |                           | 459                    | 72%  |
| Outfall at Gilman St  | Hamlin              | 81                          | 27              |                       |                     |             |   | 333           |                           | 82                     | 25%  |
| Outfall at Gilman St  | Walling             | 81                          | 27              |                       |                     |             |   | 333           |                           | 408                    | 123%   |
| MeekerWest  | Walling             | 61                          | 32              |                       |                     |             |   | 530           |                           | 772                    | 146%   |
| Outfall to Lower Silver Ck                                  | Walling             | 57                          | 24              |                       |                     |             |   | 423           |                           | 255                    | 60%  |
| Austin Ck at Hwy 37   | Walling             | 20                          | 13              |                       |                     |             |   | 640           |                           | 548                    | 86%  |
| Rodeo Creek at Seaciff Ct. Pedestrian B                     | Walling             | 2626                        | 119             |                       |                     |             |   | 45            |                           | 50                     | 110%   |
| Victor Nelo PS Outfall                                      | Walling             | 45                          | 16              | 12                    | 3.7                 | 23%         | 269   | 351           | 131%                      | 483                    | 138%   |
| Tunnel Ave Ditch  | Walling             | 96                          | 73              | 66                    | 7.2                 | 10%         | 685   | 760           | 111%                      | 577                    | 76%  |
| Refugio Ck at Tsushima St                                   | Walling             | 59                          | 30              | 22                    | 8.4                 | 28%         | 366   | 509           | 139%                      | 223                    | 44%  |
| Outfall to Colma Ck on service rd nr Littlefield Ave. (359) | Walling             | 43                          | 9               | 9.7                   | 4.9                 | 54%         | 225   | 210           | 93%                       | 264                    | 125%   |
| Median  |                     |                             |                 |                       |                     | 23%         |   |               | 120%                      |                        | 72%  |
| Mean  |                     |                             |                 |                       |                     | 26%         |   |               | 125%                      |                        | 78%  |

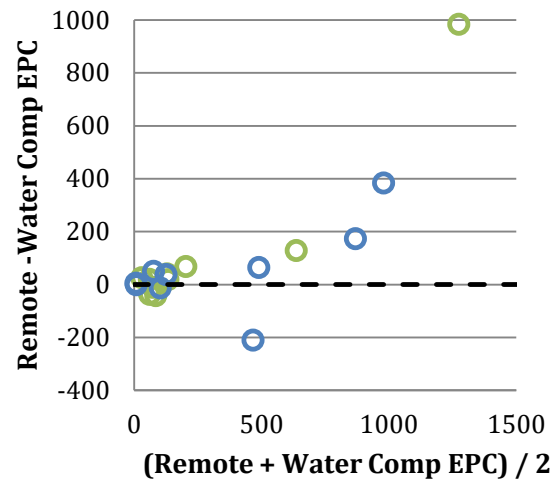


**Figure 10.** Cumulative grain size distribution in the Hamlin suspended-sediment sampler, Walling Tube suspended-sediment sampler, and water composite samples at eight of the sampling locations. The two samplers were deployed together at only two of these eight sites.

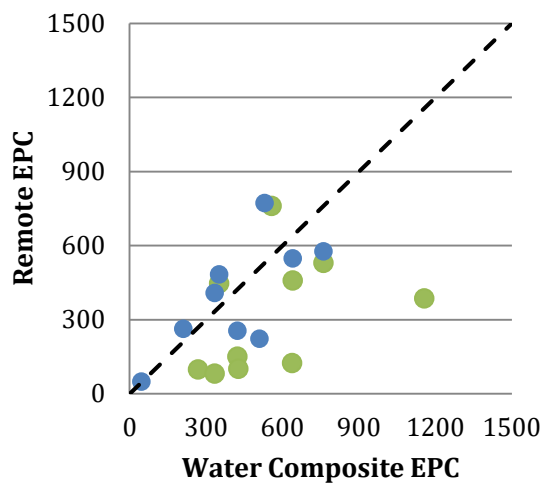
11A – PCB



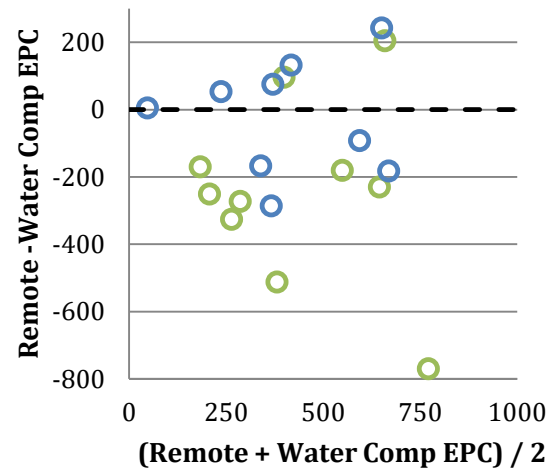
11B – PCBs



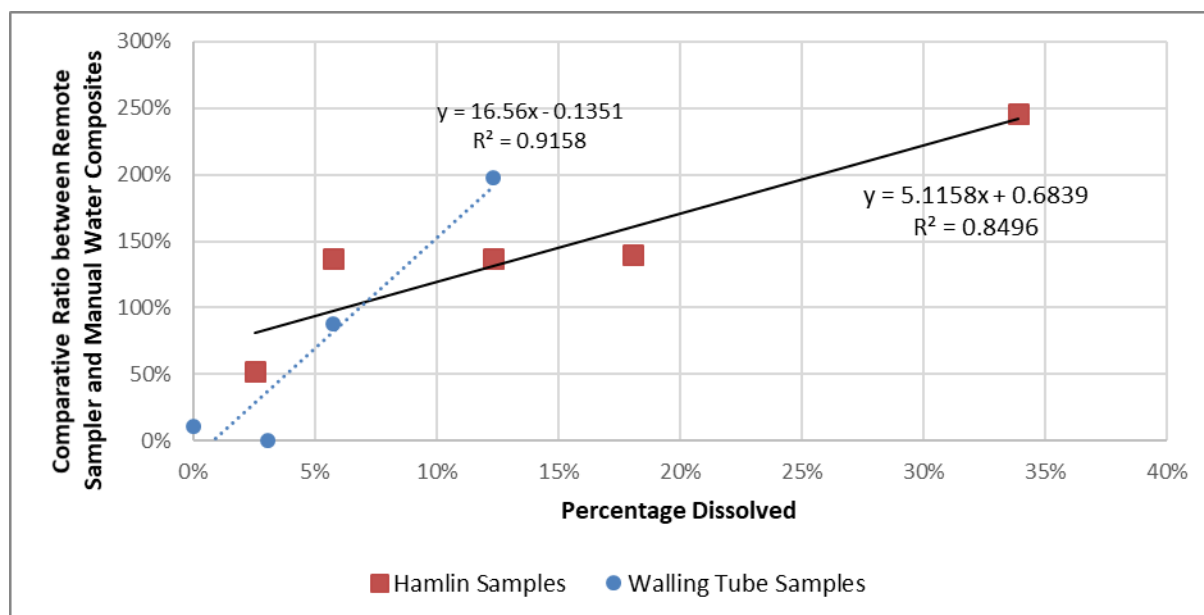
11C – Hg



11D – Hg



**Figure 11.** Comparison of estimated particle concentration (EPC) in remote suspended-sediment samples and manually collected composite samples. Figures 11A and 11C show the 1:1 line (dashed black line), and Figures 11B and 11D show the zero line as dashed. Hamlin sampler, green circles; Walling Tube, blue circles.



**Figure 12.** Comparative ratio for PCBs between remote sampler and manual water composites as a function of the percentage dissolved in the manual water composite.

**Data Quality:** Remote sampler and manual sampling results indicate similar trends – the highly polluted sites have high concentrations of pollutants using both methods. There is no evidence for consistent systematic bias between field protocols. On one hand, the remote samplers arguably miss the very finest fraction of sediments and dissolved phase portion, but on the other hand the remote samplers collect a sample continuously throughout the storm. Thus it is unclear whether that one approach produces data of quality superior to the other, but data quality for both methods are likely sufficient for site characterization.

**Data Uses:** Particle concentration data being collected using the remote sedimentation sampler methods will be used as a screening-only method to identify sites with elevated concentrations for further sampling. On the other hand, we will continue to use data collected by the manual composite water sampling techniques for comparing sites, and may also be used to estimate single storm loads if the volume is known or can be estimated (e.g., using the RWSM).

**Human Stresses and Risks Associated with Sampling Protocol:** Manual sampling involves a great deal of planning and logistical coordination to sample storms successfully; stresses include irregular schedules and having to cancel other plans; often working late and unpredictable hours; working in wet and often dark conditions after irregular or insufficient sleep and added risks under these cumulative stresses. Some approaches to remote sampling (e.g., not requiring exact coincidence with storm timing) could reduce many of these stresses (and attendant risks).

**Table 8a.** Comparison of the advantages and disadvantages of the remote sampling method for screening sites for further investigation by sampling versus the manual sampling method ranking sites relative to each other to support management decisions.

| Category   | Remote Sampling Relative to Manual Sampling                               | Notes  |
|--|---|--|
| Cost   | Less  | <ul style="list-style-type: none"> <li>Less labor during storms when labor is the limiting factor. (See table 8b. below for additional details.)</li> </ul>  |
| Sampling Feasibility                                       | Some advantages   | <ul style="list-style-type: none"> <li>Minimized cleaning time between storms</li> <li>Can be deployed over multiple storms</li> <li>Samplers composite more evenly over a storm</li> <li>Could be deployed by municipalities</li> <li>No advantage in tidal location</li> </ul>   |
| Data Quality   | Good for characterization; for absolute comparison, assessment incomplete | <ul style="list-style-type: none"> <li>Both methods appear to reproduce similar trends – the highly polluted sites have high concentrations using both methods, and the lesser polluted sites have low concentrations for both methods.</li> <li>May underrepresent the finest fractions, but sample continuously and do not miss any pulses.</li> </ul> |
| Data Uses  | Equivalent or slightly lower  | <ul style="list-style-type: none"> <li>Successful as a site screening tool.</li> <li>Unlike with manually collected samples, cannot be combined with volume (if known) to estimate loads.</li> </ul>   |
| Human stresses and risks associated with sampling protocol | Much less   | <ul style="list-style-type: none"> <li>Greatly reduced stress associated with storm planning and storm timing.</li> </ul>  |

**Table 8b.** Labor and cost comparison between the remote sampling method and the manual composite sampling method.

| Task                                  | Remote Sampling Labor Hours Relative to Manual Sampling | Manual Composite Sampling Task Description                                 | Remote Sampling Task Description   |
|---------------------------------------|---|--|--|
| Sampling Preparation in Office        | Equivalent  | Cleaning tubing/bottles; preparing bottles, field sampling basic materials | Cleaning sampler; preparing bottles, field sampling basic materials  |
| Watching Storms                       | Much less   | Many hours spent storm watching and deciding if/when to deploy             | Storm watching is minimized to only identifying appropriate events with less/little concern about exact timing |
| Sampling Preparation at Site          | Equivalent  | Set up field equipment   | Deploy sampler   |
| Driving                               | More (2x)   | Drive to and from site   | Drive to and from site twice   |
| Waiting on Site for Rainfall to Start | Less  | Up to a few hours  | No time since field crew can deploy equipment prior to rain arrival  |
| On Site Sampling                      | Much less   | 10-20 person hours for sampling and field equipment clean up               | 2 person hours to collect sampler after storm  |
| Sample Post-Processing                | Slightly more (~2 person hours)                         | NA   | Distribute composited sample into separate bottles; takes two people about 1 hour per sample                   |
| Data Management and Analysis          | Equivalent  | Same analytes and sample count (and usually same matrices)                 | Same analytes and sample count (and usually same matrices )  |

### 3.7 Sampling progress in relation to data uses

It has been argued that old industrial land use and the specific source areas found within or in association with older industrial areas are likely to have higher concentrations and loads of PCBs and HgT (McKee et al., 2012; McKee et al., 2015). RMP sampling for PCBs and HgT since WY 2003 has included 34% of the old industrial land use in the region. The best coverage to date has occurred in Santa Clara County (61% of old industrial land use in the county is in watersheds that have been sampled), followed by Alameda County (30%) and San Mateo County (27%). In Contra Costa County, only 9% of old industrial land use is in watersheds that have been sampled, and just 1% in Solano County. The disproportional coverage in Santa Clara County is a result of sampling several large watersheds (Lower Penitencia Creek, Lower Coyote Creek, Guadalupe River at Hwy 101, Sunnyvale East Channel, Stevens Creek and San Tomas Creek) that have relatively large proportions of older industrial land use upstream from their sampling points. Of the remaining older industrial land use yet to be sampled, 49% of it lies within 1 km and 63% within 2 km of the Bay. These areas are more likely to be tidal and are likely to include heavy industrial areas that were historically serviced by rail and ship-based transport and military areas, but are often very difficult to sample because of a lack of public rights-of-way and tidal conditions. A different sampling strategy may be required to effectively assess what pollution might be associated with these areas to better identify areas for potential management.

## 4. Summary and Recommendations

During WYs 2015-2018, composite water samples were collected at 65 sites during at least one storm event and analyzed for PCBs, HgT, and SSC, and, for a subset of samples, trace metals, organic carbon, and grain size. Sampling efficiency was increased, when possible, by sampling two nearby sites during a single storm. In parallel, a second sample was collected at 10 of the sampling sites using a Hamlin remote sedimentation sampler, and at 9 of the sites using a Walling Tube sedimentation sampler. Several sites with elevated PCB and HgT concentrations and EPCs were identified, in part because of an improved site selection process that focused on older industrial landscapes. The testing of the remote samplers had some success and, beginning in WY 2019, the remote samplers will be used as a low-cost screening tool unaccompanied by manual water composite sampling. Based on the WY 2015-2018 results, the following recommendations are made.

- Continue to select sites based on the four main selection objectives (Section 2.2). Most the sampling effort should be devoted to identifying potential high leverage areas with high unit area loads (yields) or concentrations/EPCs. Selecting sites by focusing on older industrial and highly impervious landscapes appears to be successful in identifying high leverage areas for PCBs.
- Continue to use the composite sampling field protocol as developed and applied during WYs 2015-2018 without further modifications. In the event of a higher rainfall wet season, when there is a greater likelihood that more storm events will fall within the required tidal windows, it may be possible to sample tidally influenced sites.
- Develop a procedure for identifying sites that return lower-than-expected concentrations or EPCs and consider re-sampling those sites. This method is being developed currently in an advanced data analysis project.



## WYs 2015 through 2018 POC Reconnaissance Monitoring

- Results from the remote sampler study indicate reasonable comparability to manually collected sample concentrations. It is recommended that future sampling include the use of remote samplers as a low-cost screening tool to identify sites for further sampling using the reconnaissance characterization monitoring protocol.
- Develop an advanced data analysis method for identifying and ranking watersheds of management interest for further characterization or investigation. This recommendation will be implemented during the 2018 calendar year and possibly be ready to contribute to site selection in WY 2019.

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## **6. Appendices**

## Appendix A: Characteristics of Larger Watersheds

Characteristics of larger watersheds to be monitored, proposed sampling location, and proposed sampling trigger criteria. In WY 2017, the sampling trigger criteria for flow and rainfall were met but large watershed sampling was focused on the Guadalupe River rather than the watersheds on this list due to a piggybacking opportunity associated with Hg.

| Proposed sampling location   |                                   |                        |                |                    |  |   | Relevant USGS gauge for 1st order loads computations |                                       |
|--|-----------------------------------|------------------------|----------------|--------------------|--|---|--|---------------------------------------|
| Watershed system   | Watershed Area (km <sup>2</sup> ) | Impervious Surface (%) | Industrial (%) | Sampling Objective | Commentary   | Proposed Sampling Triggers  | Gauge number   | Area at USGS Gauge (sq <sup>2</sup> ) |
| Alameda Creek at EBRPD Bridge at Quarry Lakes  | 913                               | 8.5                    | 2.3            | 2, 4               | Operating flow and sediment gauge at Niles just upstream will allow the computation of 1st order loads to support the calibration of the RWSM for a large, urbanizing type watershed.                        | 7" of antecedent rainfall in Livermore (reliable web published rain gauge), after at least an annual storm has already occurred (~2000 cfs at the Niles gauge), and a forecast for the East Bay interior valleys of 2-3" over 12 hrs.   | 11179000   | 906                                   |
| Dry Creek at Arizona Street (purposely downstream from historic industrial influences)   | 25.3                              | 3.5                    | 0.3            | 2, 4               | Operating flow gauge at Union City just upstream will allow the computation of 1st order loads to support the calibration of the RWSM for mostly undeveloped land use type watersheds.                       | 7" of antecedent rainfall in Union City, after at least a common annual storm has already occurred (~200 cfs at the Union City gauge), and a forecast for the East Bay Hills of 2-3" over 12 hrs.   | 11180500   | 24.3                                  |
| San Francisquito Creek at University Avenue (as far down as possible to capture urban influence upstream from tide)                          | 81.8                              | 11.9                   | 0.5            | 2, 4               | Operating flow gauge at Stanford upstream will allow the computation of 1st order loads to support the calibration of the RWSM for larger mixed land use type watersheds. Sample pair with Matadero Ck.      | 7" of antecedent rainfall in Palo Alto, after at least a common annual storm has already occurred (~1000 cfs at the Stanford gauge), and a forecast for the Peninsula Hills of 3-4" over 12 hrs.  | 11164500   | 61.1                                  |
| Matadero Creek at Waverly Street (purposely downstream from the railroad)  | 25.3                              | 22.4                   | 3.7            | 2, 4               | Operating flow gauge at Palo Alto upstream will allow the computation of 1st order loads to support the calibration of the RWSM for mixed land use type watersheds. Sample pair with San Francisquito Ck.    | 7" of antecedent rainfall in Palo Alto, after at least a common annual storm has already occurred (~200 cfs at the Palo Alto gauge), and a forecast for the Peninsula Hills of 3-4" over 12 hrs.  | 11166000   | 18.8                                  |
| Colma Creek at West Orange Avenue or further downstream (as far down as possible to capture urban and historic influence upstream from tide) | 27.5                              | 38                     | 0.8            | 2, 4 (possibly 1)  | Historic flow gauge (ending 1996) in the park a few hundred feet upstream will allow the computation of 1st order loads estimates to support the calibration of the RWSM for mixed land use type watersheds. | Since this is a very urban watershed, precursor conditions are more relaxed: 4" of antecedent rainfall, and a forecast for South San Francisco of 2-3" over 12 hrs. Measurement of discharge and manual staff plate readings during sampling will verify the historic rating. | 11162720   | 27.5                                  |



## Appendix B – Sampling Method Development

The monitoring protocol implemented in WYs 2015-2018 was based on a previous monitoring design that was trialed in WY 2011 when multiple sites were visited during one or two storm events. In that study, multiple discrete stormwater samples were collected at each site and analyzed for a number of POCs (McKee et al., 2012). At the 2014 SPLWG meeting, an analysis of previously collected stormwater sample data from both reconnaissance and fixed station monitoring was presented (SPLWG et al. 2014). A comparison of three sampling designs for Guadalupe River at Hwy 101 (sampling 1, 2, or 4 storms, respectively: functionally 4, 8, and 16 discrete samples) showed that PCB estimated particle concentrations (EPC) at this site can vary from 45-287 ng/g (1 storm design), 59-257 ng/g (2 storm design), and 74-183 ng/g (4 storm design) between designs, suggesting that the number of storms sampled for a given watershed has big impacts on the EPCs and therefore the potential relative ranking among sites. A similar analysis that explores the relative ranking based on a random 1-storm composite or 2-storm composite design was also presented for other monitoring sites (Pulgas Pump Station-South, Sunnyvale East Channel, North Richmond Pump Station, San Leandro Creek, Zone 4 Line A, and Lower Marsh Creek). This analysis showed that the potential for a false negative could occur due to a low number of sampled storms, especially in smaller and more urbanized watersheds where transport events can be more acute due to lack of channel storage. The analysis further highlighted the trade-off between gathering information at fewer sites with more certainty versus at more sites with less certainty. Based on these analyses, the SPLWG recommended a 1-storm composite per site design with allowances that a site could be revisited if the measured concentrations were lower than expected, either because a low-intensity storm was sampled or other information suggested that potential sources exist.

In addition to composite sampling, a pilot study was designed and implemented to test remote suspended sediment samplers based on enhanced water column settling. Four sampler types were considered: the single-stage siphon sampler, the CLAM sampler, the Hamlin sampler, and the Walling Tube. The SPLWG recommended the single-stage siphon sampler be dropped because it allowed for collection of only a single stormwater sample at a single time point, and therefore offers no advantage over manual sampling but requires more effort and expense to deploy. The CLAM sampler was also dropped as it had limitations affecting the interpretation of the data; primarily its inability to estimate the volume of water passing through the filters and the lack of performance tests in high turbidity environments. As a result, the remaining two samplers (Hamlin sampler and Walling Tube) were selected for the pilot study as previous studies showed the promise of using these devices in similar systems (Phillips et al., 2000; Lubliner, 2012). The SPLWG recommended piloting these samplers at 12 locations<sup>15</sup> where manual water composites would be collected in parallel to test the comparability between sampling methods.

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<sup>15</sup> Note that so far due to climatic constraints, only 9 and 7 locations have been sampled with the Hamlin and Walling samplers, respectively. Additional samples using the Walling sampler are planned for WY 2018.

## Appendix C – Quality assurance

The sections below report quality assurance reviews on WYs 2015-18 data only. The data were reviewed using the quality assurance program plan (QAPP) developed for the San Francisco Bay Regional Monitoring Program for Water Quality (Yee et al., 2017). That QAPP describes how RMP data are reviewed for possible issues with hold times, sensitivity, blank contamination, precision, accuracy, comparison of dissolved and total phases, magnitude of concentrations versus concentrations from previous years, other similar local studies or studies described from elsewhere in peer-reviewed literature and PCB (or other organics) fingerprinting. Data handling procedures and acceptance criteria can differ among monitoring protocols, however, for the RMP the underlying data were never discarded. Because the results for “censored” data were maintained, the effects of applying different QA protocols can be assessed by a future analyst if desired.

### *Suspended Sediment Concentration and Particle Size Distribution*

In WY 2015, the SSC and particle size distribution (PSD)<sup>16</sup> data from USGS-PCMSC were acceptable, aside from failing hold-time targets. SSC samples were all analyzed outside of hold time (between 9 and 93 days after collection, exceeding the 7-day hold time specified in the RMP QAPP); hold times are not specified in the RMP QAPP for PSD. Minimum detection limits (MDLs) were generally sufficient, with <20% non-detects (NDs) reported for SSC and the more abundant Clay and Silt fractions. Extensive NDs (>50%) were generally reported for the sand fractions starting as fine as 0.125 mm and larger, with 100% NDs for the coarsest (Granule + Pebble/2.0 to <64 mm) fraction. Method blanks and spiked samples are not typically reported for SSC and PSD. Blind field replicates were used to evaluate precision in the absence of any other replicates. The relative standard deviation (RSD) for two field blind replicates of SSC were well below the 10% target. Particle size fractions had average RSDs ranging from 12% for Silt to 62% for Fine Sand. Although some individual fractions had average relative percent difference (RPD) or RSDs >40%, suspended sediments in runoff (and particle size distributions within that SSC) can be highly variable, even when collected by minutes, so results were flagged as estimated concentrations rather than rejected. Fines (clay and silt) represented the largest proportion (~89% average) of the mass.

In 2016 samples, SSC and PSD was analyzed beyond the specified 7-day hold time (between 20 and 93 days after collection) and qualified for holding-time violation but not censored. No hold time is specified for grain-size analysis. Method detection limits were sufficient to have some reportable results for nearly all the finer fractions, with extensive NDs (> 50%) for many of the coarser fractions. No method blanks or spiked samples were analyzed/reported, common with SSC and PSD. Precision for PSD could not be evaluated as no replicates were analyzed for 2016. Precision of the SSC analysis was evaluated using the field blind replicates and the average RSD of 2.12% was well within the 10% target Method Quality Objective (MQO). PSD results were similar to other years, dominated by around 80% Fines.

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<sup>16</sup> Particle size data were captured for % Clay (<0.0039 mm), % Silt (0.0039 to <0.0625 mm), % V. Fine Sand (0.0625 to <0.125 mm), % Fine Sand (0.125 to <0.25 mm), % Medium Sand (0.25 to <0.5 mm), % Coarse Sand (0.5 to <1.0 mm), % V. Coarse Sand (1.0 to <2.0 mm), and % Granule + Pebble (>2.0 mm).

Average SSC for whole-water samples (excluding those from passive samplers) was in a reasonable range of a few hundred mg/L.

In 2017, method detection limits were sufficient to have at least one reportable result for all analyte/fraction combinations. Extensive non-detects (NDs > 50%) were reported for only Granule + Pebble/2.0 to <64 mm (90%). The analyte/fraction combinations Silt/0.0039 to <0.0625 mm; Sand/Medium 0.25 to <0.5 mm; Sand/Coarse 0.5 to <1.0 mm; Sand/V. Coarse 1.0 to <2.0 mm all had 20% (2 out of 10) non-detects. No method blanks were analyzed for grain size analysis. SSC was found in one of the five method blanks at a concentration of 1 mg/L. The average SSC concentration for the 3 method blanks in that batch was 0.33 mg/L < than the average method blank method detection limit of 0.5 mg/L. No blank contamination qualifiers were added. No spiked samples were analyzed/reported. Precision for grain size could not be evaluated as there was insufficient amount of sample for analysis of the field blind replicate. Precision of the SSC analysis was examined using the field blind replicates with the average RSD of 29.24% being well above the 10% target MQO, therefore they were flagged with the non-censoring qualifier "VIL" as an indication of possible uncertainty in precision.

In WY 2015, the SSC and particle size distribution (PSD)<sup>17</sup> data from USGS-PCMSC were acceptable, aside from failing hold-time targets. SSC samples were all analyzed outside of hold time (between 25 and 62 days after collection, exceeding the 7-day hold time specified in the RMP QAPP); hold times are not specified in the RMP QAPP for PSD. Minimum detection limits (MDLs) were generally sufficient, with zero non-detects (NDs) reported for SSC and the more abundant Clay and Silt fractions. Extensive NDs (>50%) were generally reported for the sand fractions starting as fine as 0.125 mm and larger, with 100% NDs for the coarsest (Granule + Pebble/2.0 to <64 mm) fraction. Method blanks and spiked samples are not typically reported for SSC and PSD. Blind field replicates were used to evaluate precision in the absence of any other replicates. The relative standard deviation (RSD) for the field blind replicate of SSC was 8.22%, below the 10% target. Particle size fractions had average RSDs ranging from 10.6% - 10.7% for Fine, Clay and Silt fractions.

### *Organic Carbon in Water*

Reported TOC and DOC data from EBMUD and ALS were acceptable. In 2015, TOC samples were field acidified on collection, DOC samples were field or lab filtered as soon as practical (usually within a day) and acidified after, so were generally within the recommended 24-hour holding time. MDLs were sufficient with no NDs reported for any field samples. TOC was detected in only one method blank (0.026 mg/L), just above the MDL (0.024 mg/L), but the average blank concentration (0.013 mg/L) was still below the MDL, so results were not flagged. Matrix spike samples were used to evaluate accuracy, although many samples were not spiked high enough for adequate evaluation (must be at least two times the parent sample concentration). Recovery errors in the remaining DOC matrix spikes were all below the 10% target MQO. TOC errors in WY 2015 averaged 14%, above the 10% MQO, and TOC was therefore qualified but not censored. Laboratory replicate samples evaluated for precision had an

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<sup>17</sup> Particle size data were captured for % Clay (<0.0039 mm), % Silt (0.0039 to <0.0625 mm), % V. Fine Sand (0.0625 to <0.125 mm), % Fine Sand (0.125 to <0.25 mm), % Medium Sand (0.25 to <0.5 mm), % Coarse Sand (0.5 to <1.0 mm), % V. Coarse Sand (1.0 to <2.0 mm), and % Granule + Pebble (>2.0 mm).

average RSD of <2% for DOC and TOC, and 5.5% for POC, within the 10% target MQO. RSDs for field replicates were also within the target MQO of 10% (3% for DOC and 9% for TOC), so no precision qualifiers were needed.

POC and DOC were also analyzed by ALS in 2016. One POC sample was flagged for a holding time of 104 days (past the specified 100 days). All OC analytes were detected in all field samples and were not detected in method blanks, but DOC was detected in filter blanks at 1.6% of the average field sample and 5% of the lowest field sample. The average recovery error was 4% for POC evaluated in LCS samples, and 2% for DOC and TOC in matrix spikes, within the target MQO of 10%. Precision on POC LCS replicates averaged 5.5% RSD, and 2% for DOC and TOC field sample lab replicates, well within the 10% target MQO. No recovery or precision qualifiers were needed. The average 2016 POC was about three times higher than 2014 results. DOC and TOC were 55% and 117% of 2016 results, respectively.

In 2017, method detection limits were sufficient with no non-detects (NDs) reported except for method blanks. DOC and TOC were found in one method blank in one lab batch for both analytes. Four DOC and 8 TOC results were flagged with the non-censoring qualifier “VIP”. TOC was found in the field blank and its three lab replicates at an average concentration of 0.5375 mg/L which is 8.6% of the average concentration found in the field and lab replicate samples (6.24 mg/L). Accuracy was evaluated using the matrix spikes except for POC which was evaluated using the laboratory control samples. The average %error was less than the target MQO of 10% for all three analytes; DOC (5.2%), POC (1.96%), and TOC (6.5%). The laboratory control samples were also examined for DOC and TOC and the average %error was once again less than the 10% target MQO. No qualifying flags were needed. Precision was evaluated using the lab replicates with the average RSD being well below the 10% target MQO for all three analytes; DOC (1.85%), POC (0.97%), and TOC (1.89%). The average RSD for TOC including the blind field replicate and its lab replicates was 2.32% less than the target MQO of 10%. The laboratory control sample replicates were examined and the average RSD was once again well below the 10% target MQO. No qualifying flags were added.

In WY 2018, all TOC samples were censored. Accuracy was evaluated using the matrix spikes. The average %error for TOC in the matrix spikes of 47.68% (average recovery 147.68%) was above the 10% target MQO.

### ***PCBs in Water and Sediment***

PCBs samples were analyzed for 40 PCB congeners (PCB-8, PCB-18, PCB-28, PCB-31, PCB-33, PCB-44, PCB-49, PCB-52, PCB-56, PCB-60, PCB-66, PCB-70, PCB-74, PCB-87, PCB-95, PCB-97, PCB-99, PCB-101, PCB-105, PCB-110, PCB-118, PCB-128, PCB-132, PCB-138, PCB-141, PCB-149, PCB-151, PCB-153, PCB-156, PCB-158, PCB-170, PCB-174, PCB-177, PCB-180, PCB-183, PCB-187, PCB-194, PCB-195, PCB-201, PCB-203). Water (whole water and dissolved) and sediment (separately analyzed particulate) PCB data from AXYS were acceptable. EPA 1668 methods for PCBs recommend analysis within a year, and all samples were analyzed well within that time (maximum 64 days). MDLs were sufficient with no NDs reported for any of the PCB congeners measured. Some blank contamination was detected in method

blanks for about 20 of the more abundant congeners, with only two PCB 008 field sample results censored for blank contamination exceeding one-third the concentration of PCB 008 in those field samples. Many of the same congeners detected in the method blank also were detected in the field blank, but at concentrations <1% the average measured in the field samples and (per RMP data quality guidelines) always less than one-third the lowest measured field concentration in the batch. Three target analytes (part of the “RMP 40 congeners”), PCBs 105, 118, and 156, and numerous other congeners were reported in laboratory control samples (LCS) to evaluate accuracy, with good recovery (average error on target compounds always <16%, well within the target MQO of 35%). A laboratory control material (modified NIST 1493) was also reported, with average error 22% or better for all congeners. Average RSDs for congeners in the field replicate were all <18%, within the MQO target of 35%, and LCS RSDs were ~2% or better. PCB concentrations have not been analyzed in remote sediment sampler sediments for previous POC studies, so no inter-annual comparisons could be made. PCBs in water samples were similar to those measured in previous years (2012-2014), ranging from 0.25 to 3 times previous averages, depending on the congener. Ratios of congeners generally followed expected abundances in the environment.

AXYS analyzed PCBs in dissolved, particulate, and total fraction water samples for 2016. Numerous congeners had several NDs, but extensive NDs (>50%) were reported for only PCBs 099 and 201 (both 60% NDs). Some blank contamination was detected in method blanks, with results for some congeners in field samples censored due to concentrations that were less than 3 times higher than the highest concentration measured in a blank. This was especially true for dissolved-fraction field samples with low concentrations. Accuracy was evaluated using the laboratory control samples. Again, only three of the PCBs (PCB 105, PCB 118, and PCB 156) reported in the field samples were included in LCS samples (most being non-target congeners), with average recovery errors for those of <10%, well below the target MQO of 35%. Precision on LCS and blind field replicates was also good, with average RSDs <5% and <15%, respectively, well below the 35% target MQO. Average PCB concentrations in total fraction water samples were similar to those measured to previous years, but total fraction samples were around 1% of those measured in 2015, possibly due to differences in the stations sampled.

AXYS also analyzed PCBs in dissolved, particulate, and total fraction water samples for 2017. Numerous congeners had several NDs but none extensively. Some blank contamination was detected in method blanks, with results for some congeners in field samples censored due to concentrations that were less than 3 times higher than the highest concentration measured in a blank. This was especially true for dissolved-fraction field samples with low concentrations. Accuracy was evaluated using the laboratory control samples. Again, only three of the PCBs (PCB 105, PCB 118, and PCB 156) reported in the field samples were included in LCS samples (most being non-target congeners), with average recovery errors for those of <10%, well below the target MQO of 35%. Precision on LCS replicates was also good, with average RSDs <5%, well below the 35% target MQO.

In WY 2018, AXYS analyzed total water samples for PCBs (no samples for dissolved or particulate fractions were submitted for analysis). Method detection limits were acceptable with non-detects (NDs) reported for a single PCB 170 result (7.14%; 1 out of 14 PCB 170 results). PCB 008, PCB 018, PCB 028, PCB 031, PCB 033, PCB 044, PCB 049, PCB 052, PCB 056, PCB 066, PCB 070, PCB 087, PCB 095, PCB 099,

PCB 101, PCB 105, PCB 110, PCB 118, PCB 138, PCB 149, PCB 151, and PCB 174 were found in at least one and often both method blanks at concentrations above the method detection limits. Two PCB 008 results (14.29%; 2 out of 14 results) were flagged with the censoring qualifier VRIP; other blank contaminated results were flagged by the laboratory and did not need to be censored. Contamination was found in the field blank for PCB 008, PCB 018, PCB 028, PCB 031, PCB 033, PCB 044, PCB 049, PCB 052, PCB 056, PCB 060, PCB 066, PCB 070, PCB 087, PCB 095, PCB 099, PCB 101, PCB 110, PCB 118, PCB 138, PCB 151, PCB 153, and PCB187 at concentrations generally less than 1% of the average concentrations found in the field samples (the only exception was PCB 008 which was found in the field blank at a concentration representing ~2% of the average field sample concentration). Accuracy was evaluated using the laboratory control samples (LCSs); the only spiked samples reported. PCB 105, PCB 118, and PCB 156 were the only target congeners included in the LCS samples with an average %error of 8.35%, 9.25%, and 13.63%, respectively, all well below the 35% target MQO. No qualifiers were needed. Precision was evaluated using the blind field replicates. The average RSD ranged from 0.10% to 17.99% for the 40 target PCB congeners; all below the target MQO of 35% target. Laboratory control sample replicates were examined, but not used in the evaluation. The respective RSD's for PCB 105, PCB 118, and PCB 156 were 11.07%, 12.25%, and 3.27%, respectively. No qualification was necessary.

#### *Trace Elements in Water*

Overall the 2015 water trace elements (As, Cd, Pb, Cu, Zn, Hg) data from Brooks Rand Labs (BRL) were acceptable. MDLs were sufficient with no NDs reported for any field samples. Arsenic was detected in one method blank, and mercury in four method blanks; the results were blank corrected, and blank variation was <MDL. No analytes were detected in the field blank. Recoveries in certified reference materials (CRMs) were good, averaging 2% error for mercury to 5% for zinc, all well below the target MQOs (35% for arsenic and mercury; 25% for all others). Matrix spike and LCS recovery errors all averaged below 10%, well within the accuracy MQOs. Precision was evaluated in laboratory replicates, except for mercury, which was evaluated in certified reference material replicates (no mercury lab replicates were analyzed). RSDs on lab replicates ranged from <1% for zinc to 4% for arsenic, well within target MQOs (35% for arsenic and mercury; 25% for all the other analytes). Mercury CRM replicate RSD was 1%, also well within the target MQO. Matrix spike and laboratory control sample replicates similarly had average RSDs well within their respective target MQOs. Even including the field heterogeneity from blind field replicates, precision MQOs were easily met. Average concentrations were up to 12 times higher than the average concentrations of 2012-2014 POC water samples, but whole water composite samples were in a similar range those measured in as previous years.

For 2016 the quality assurance for trace elements in water reported by Brooks Applied Lab (BRL's name post-merger) was good. Blank corrected results were reported for all elements (As, Cd, Ca, Cu, Hardness (as CaCO<sub>3</sub>), Pb, Mg, Hg, Se, and Zn). MDLs were sufficient for the water samples with no NDs reported for Cd, Cu, Pb, Hg, and Zn. Around 20% NDs were reported for As, Ca, Hardness, and Mg, and 56% for Se. Mercury was detected in a filter blank, and in one of the three field blanks, but at concentrations <4% of the average in field samples and (per RMP data quality guidelines) always less than one-third the lowest measured field concentration in the batch. Accuracy on certified reference materials was good, with



average %error for the CRMs ranging from 2 to 18%, well within target MQOs (25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se). Recovery errors on matrix spike and LCS results on these compounds was also good, with the average errors all below 9%, well within target MQOs. The average error of 4.8% on a Hardness LCS was within the target MQO of 5%. Precision was evaluated for field sample replicates, except for Hg, where matrix spike replicates were used. Average RSDs were all < 8%, and all below their relevant target MQOs (5% for Hardness; 25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se). Blind field replicates were also consistent, with average RSDs ranging from 1% to 17%, all within target MQOs. Precision on matrix spike and LCS replicates was also good. No qualifiers were added. Average concentrations in the 2016 water samples were in a similar range of POC samples from previous years (2003-2015), with averages ranging 0.1x to 2x previous years' averages.

In 2017, the data was overall good and all field samples were usable. Blank corrected results were reported for all elements (As, Cd, Ca, Cu, Hardness (as  $\text{CaCO}_3$ ), Pb, Mg, Hg, Se, and Zn). MDLs were sufficient for the water samples with no NDs reported. The Hg was also not detected. Accuracy on certified reference materials was good, with average %error for the CRMs within 12%, well within target MQOs (25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se). Recovery errors on matrix spike and LCS results on these compounds were also all within target MQOs. Precision was evaluated for field sample replicates. Average RSDs were all < 8%, and all below their relevant target MQOs (5% for Hardness; 25% for Cd, Ca, Cu, Pb, Mg, Zn; 35% for As, Hg, and Se).

In WY 2018, samples were only analyzed for mercury. Samples were all measured well within hold time. Method detection limits were acceptable as no non-detects (NDs) were reported for mercury. Mercury was not found in the method blanks at concentrations above the method detection limits. All method blank results were NDs. The single field blank contained mercury at a low concentration (0.00015 ug/L) equal to ~0.1% of the average mercury concentration measured in the field samples. Accuracy was evaluated using the matrix spikes. The average %error for mercury in the matrix spikes of 4% was well below the 35% target MQO. Laboratory control material samples were examined, but not used in the evaluation. The average %error of 6% was also well below the target MQO of 35%. No qualifiers were needed. Precision was evaluated using the lab replicates. The average RSD for Mercury was 3% well below the target MQO of 35% target (average RSD for lab replicates and field replicates combined was 6%). Matrix spike replicates were examined, but not used in the evaluation. The average RSD of 2% was also below the 35% target MQO. The laboratory control materials were not used because they had different though similar target concentrations. No additional qualifiers were added.

### *Trace Elements in Sediment*

A single sediment sample was obtained in 2015 from fractionating one Hamlin sampler and analyzing for As, Cd, Pb, Cu, Zn, and Hg concentration on sediment. Overall the data were acceptable. MDLs were sufficient with no NDs for any analytes in field samples. Arsenic was detected in one method blank (0.08 mg/kg dw) just above the MDL (0.06 mg/kg dw), but results were blank corrected and the blank standard deviation was less than the MDL so results were not blank flagged. All other analytes were not detected in method blanks. CRM recoveries showed average errors ranging from 1% for copper to 24%

for mercury, all within their target MQOs (35% for arsenic and mercury; 25% for others). Matrix spike and LCS average recoveries were also within target MQOs when spiked at least 2 times the native concentrations. Laboratory replicate RSDs were good, averaging from <1% for zinc to 5% for arsenic, all well within the target MQOs (35% for arsenic and mercury; 25% for others). Matrix spike RSDs were all 5% or less, also well within target MQOs. Average results ranged from 1 to 14 times higher than the average concentrations for the RMP Status and Trend sediment samples (2009-2014). Results were reported for Mercury and Total Solids in one sediment sample analyzed in two laboratory batches. Other client samples (including lab replicates and Matrix Spike/Matrix Spike replicates), a certified reference material (CRM), and method blanks were also analyzed. Mercury results were reported blank corrected.

In 2016, a single sediment sample was obtained from a Hamlin sampler, which was analyzed for total Hg by BAL. MDLs were sufficient with no NDs reported, and no target analytes were detected in the method blanks. Accuracy for mercury was evaluated in a CRM sample (NRC MESS-4). The average recovery error for mercury was 13%, well within the target MQO of 35%. Precision was evaluated using the laboratory replicates of the other client samples concurrently analyzed by BAL. Average RSDs for Hg and Total Solids were 3% and 0.14%, respectively, well below the 35% target MQO. Other client sample matrix spike replicates also had RSDs well below the target MQO, so no qualifiers were needed for recovery or precision issues. The Hg concentration was 30% lower than the 2015 POC sediment sample.



**Appendix D – Figures 7 and 10 Supplementary Info**

Sample counts for data displayed in Figures 7 and 10 bar graphs. For samples with a count of 2 or more, the central tendency was used which was calculated as the sum of the pollutant water concentrations divided by the sum of the SSC data.

| Catchment  | Year Sampled    | Discrete Grabs  | Composite Samples | Number of Aliquots per composite sample |
|--|-----------------|-----------------|-------------------|---|
| Belmont Creek  | Prior to WY2015 | 4               | 0                 | NA                                      |
| Borel Creek  | Prior to WY2015 | 5               | 0                 | NA                                      |
| Calabazas Creek  | Prior to WY2015 | 5               | 0                 | NA                                      |
| Ettie Street Pump Station                                | Prior to WY2015 | 4               | 0                 | NA                                      |
| Glen Echo Creek  | Prior to WY2015 | 4               | 0                 | NA                                      |
| Guadalupe River at Foxworthy Road/<br>Almaden Expressway | Prior to WY2015 | 14 PCB; 46 Hg   | 0                 | NA                                      |
| Guadalupe River at Hwy 101                               | Prior to WY2015 | 119 PCB; 261 Hg | 0                 | NA                                      |
| Lower Coyote Creek                                       | Prior to WY2015 | 5 PCB; 6 Hg     | 0                 | NA                                      |
| Lower Marsh Creek  | Prior to WY2015 | 28 PCB; 31 Hg   | 0                 | NA                                      |
| Lower Penitencia Creek                                   | Prior to WY2015 | 4               | 0                 | NA                                      |
| North Richmond Pump Station                              | Prior to WY2015 | 38              | 0                 | NA                                      |
| Pulgas Pump Station-North                                | Prior to WY2015 | 4               | 0                 | NA                                      |
| Pulgas Pump Station-South                                | Prior to WY2015 | 29 PCB; 26 Hg   | 0                 | NA                                      |
| San Leandro Creek  | Prior to WY2015 | 39 PCB; 38 Hg   | 0                 | NA                                      |
| San Lorenzo Creek  | Prior to WY2015 | 5 PCB; 6 Hg     | 0                 | NA                                      |
| San Pedro Storm Drain                                    | Prior to WY2015 | 0 PCB; 3 Hg     | 0                 | NA                                      |
| San Tomas Creek  | Prior to WY2015 | 5               | 0                 | NA                                      |
| Santa Fe Channel   | Prior to WY2015 | 5               | 0                 | NA                                      |
| Stevens Creek  | Prior to WY2015 | 6               | 0                 | NA                                      |
| Sunnyvale East Channel                                   | Prior to WY2015 | 42 PCB; 41 Hg   | 0                 | NA                                      |
| Walnut Creek   | Prior to WY2015 | 6 PCB; 5 Hg     | 0                 | NA                                      |
| Zone 4 Line A  | Prior to WY2015 | 69 PCB; 94 Hg   | 0                 | NA                                      |
| Zone 5 Line M  | Prior to WY2015 | 4               | 0                 | NA                                      |
| Charcot Ave Storm Drain                                  | WY2015          | 0               | 1                 | 6                                       |
| E. Gish Rd Storm Drain                                   | WY2015          | 0               | 1                 | 5                                       |
| Gateway Ave Storm Drain                                  | WY2015          | 0               | 1                 | 6                                       |
| Line 3A-M-1 at Industrial Pump Station                   | WY2015          | 0               | 1                 | 6                                       |
| Line 4-B-1   | WY2015          | 0               | 1                 | 5                                       |
| Line 9-D   | WY2015          | 0               | 1                 | 8                                       |
| Line-3A-M at 3A-D  | WY2015          | 0               | 1                 | 5                                       |
| Line4-E  | WY2015          | 0               | 1                 | 6                                       |
| Lower Penitencia Creek                                   | WY2015          | 0               | 1                 | 7                                       |
| Meeker Slough  | WY2015          | 0               | 1                 | 6                                       |
| Oddstad Pump Station                                     | WY2015          | 0               | 1                 | 6                                       |
| Outfall to Lower Silver Creek                            | WY2015          | 0               | 1                 | 5                                       |
| Ridder Park Dr Storm Drain                               | WY2015          | 0               | 1                 | 5                                       |
| Rock Springs Dr Storm Drain                              | WY2015          | 0               | 1                 | 5                                       |
| Runnymede Ditch  | WY2015          | 0               | 1                 | 6                                       |
| Seaboard Ave Storm Drain SC-050GAC580                    | WY2015          | 0               | 1                 | 5                                       |
| Seaboard Ave Storm Drain SC-050GAC600                    | WY2015          | 0               | 1                 | 5                                       |
| South Linden Pump Station                                | WY2015          | 0               | 1                 | 5                                       |
| Storm Drain near Cooley Landing                          | WY2015          | 0               | 1                 | 6                                       |

## WYs 2015 through 2018 POC Reconnaissance Monitoring

| Catchment   | Year Sampled | Discrete Grabs | Composite Samples | Number of Aliquots per composite sample |
|---|--------------|----------------|-------------------|---|
| Veterans Pump Station                                       | WY2015       | 0              | 1                 | 5                                       |
| Condensa St SD  | WY2016       | 0              | 1                 | 6                                       |
| Duane Ct and Ave Triangle SD                                | WY2016       | 0              | 1                 | 5                                       |
| Duane Ct and Ave Triangle SD                                | WY2016       | 0              | 1                 | 3                                       |
| E Outfall to San Tomas at Scott Blvd                        | WY2016       | 0              | 1                 | 6                                       |
| Forbes Blvd Outfall   | WY2016       | 0              | 1                 | 5                                       |
| Gull Dr Outfall   | WY2016       | 0              | 1                 | 5                                       |
| Gull Dr SD  | WY2016       | 0              | 1                 | 5                                       |
| Haig St SD  | WY2016       | 0              | 1                 | 6                                       |
| Industrial Rd Ditch   | WY2016       | 0              | 1                 | 4                                       |
| Lawrence & Central Expwys SD                                | WY2016       | 0              | 1                 | 3                                       |
| Line 13A at end of slough                                   | WY2016       | 0              | 1                 | 7                                       |
| Line 9D1 PS at outfall to Line 9D                           | WY2016       | 0              | 1                 | 8                                       |
| Outfall at Gilman St.                                       | WY2016       | 0              | 1                 | 9                                       |
| Taylor Way SD   | WY2016       | 0              | 1                 | 5                                       |
| Tunnel Ave Ditch  | WY2016       | 0              | 1                 | 6                                       |
| Valley Dr SD  | WY2016       | 0              | 1                 | 6                                       |
| Victor Nelo PS Outfall                                      | WY2016       | 0              | 1                 | 9                                       |
| Zone 12 Line A under Temescal Ck Park                       | WY2016       | 0              | 1                 | 8                                       |
| Line 12H at Coliseum Way                                    | WY2017       | 0              | 1                 | 3                                       |
| Outfall to Colma Ck on service rd nr Littlefield Ave. (359) | WY2017       | 0              | 1                 | 2                                       |
| S Linden Ave SD (291)                                       | WY2017       | 0              | 1                 | 7                                       |
| Austin Ck at Hwy 37   | WY2017       | 0              | 1                 | 6                                       |
| Line 12I at Coliseum Way                                    | WY2017       | 0              | 1                 | 3                                       |
| Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir    | WY2017       | 0              | 1                 | 4                                       |
| Line 12M at Coliseum Way                                    | WY2017       | 0              | 1                 | 4                                       |
| Line 12F below PG&E station                                 | WY2017       | 0              | 1                 | 3                                       |
| Rosemary St SD 066GAC550C                                   | WY2017       | 0              | 1                 | 5                                       |
| North Fourth St SD 066GAC550B                               | WY2017       | 0              | 1                 | 5                                       |
| Line 12K at Coliseum Entrance                               | WY2017       | 0              | 1                 | 4                                       |
| Colma Ck at S. Linden Blvd                                  | WY2017       | 0              | 1                 | 5                                       |
| Line 12J at mouth to 12K                                    | WY2017       | 0              | 1                 | 3                                       |
| S Spruce Ave SD at Mayfair Ave (296)                        | WY2017       | 0              | 1                 | 8                                       |
| Guadalupe River at Hwy 101                                  | WY2017       | 0              | 0                 | 7                                       |
| Refugio Ck at Tsushima St                                   | WY2017       | 0              | 1                 | 6                                       |
| Rodeo Creek at Seacliff Ct. Pedestrian Br.                  | WY2017       | 0              | 1                 | 7                                       |
| East Antioch nr Trembath                                    | WY2017       | 0              | 1                 | 6                                       |
| Outfall at Gilman St.                                       | WY2018       | 0              | 1                 | 5                                       |
| Zone 12 Line A at Shellmound                                | WY2018       | 0              | 1                 | 6                                       |
| Meeker Slough   | WY2018       | 0              | 1                 | 5                                       |
| MeekerWest  | WY2018       | 0              | 1                 | 5                                       |
| Little Bull Valley  | WY2018       | 0              | 1                 | 2                                       |
| Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir    | WY2018       | 0              | 1                 | 5                                       |
| Gull Dr Outfall   | WY2018       | 0              | 1                 | 6                                       |
| Gull Dr SD  | WY2018       | 0              | 1                 | 5                                       |
| GR outfall 066GAC850  | WY2018       | 0              | 1                 | 4                                       |
| GR outfall 066GAC900  | WY2018       | 0              | 1                 | 4                                       |