INTEGRATED MONITORING REPORT

PART A: SAN FRANCISCO ESTUARY RECEIVING WATER MONITORING

Water Year 2014 through Water Year 2019

Submitted in compliance with Provision C.8.h.v of
NPDES Permit No. CAS612008 (Order No. R2-2015-0049)

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

March 31, 2020

LIST OF ACRONYMS

AFR	Alternative Flame Retardant
BAHM	Bay Area Hydrological Model
BASMAA	Bay Area Stormwater Management Agency Association
BOD	Board of Directors
C/CAG	City/County Association of Governments
CEC	Contaminant of Emerging Concern
ECWG	Emerging Contaminant Workgroup
IMR	Integrated Monitoring Report
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MS4	Municipal Separate Stormwater Sewer System
NPDES	National Pollution Discharge Elimination System
PBDE	Polybrominated Diphenyl Ether
PCBs	Polychlorinated Biphenyls
PFAS	Polyfluoroalkyl Sulfonate Substances
POC	Pollutant of Concern
RAA	Reasonable Assurance Analysis
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program for Water Quality in the San Francisco Bay
RWSM	Regional Watershed Spreadsheet Model
S&T	Status and Trends
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SFEI	San Francisco Estuary Institute
SFRWQCB	San Francisco Bay Regional Water Quality Control Board
SPLWG	Sources, Pathways and Loadings Workgroup
SSC	Suspended Sediment Concentration
STLS	Small Tributary Loading Strategy
TMDL	Total Maximum Daily Load
TRC	Technical Review Committee
USGS	United States Geological Survey
WMA	Watershed Management Area
WY	Water Year

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1.0 INTRODUCTION

This Integrated Monitoring Report (IMR) Part A: San Francisco Estuary Receiving Water Monitoring, Water Year[1] (WY) 2014 through WY 2019 was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP or Program). SMCWPPP is a program of the City/County Association of Governments (C/CAG) of San Mateo County. Each incorporated city and town in the county and the County of San Mateo share a common National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP). The MRP was first adopted by the San Francisco Regional Water Quality Control Board (SFRWQCB or Regional Water Board) on October 14, 2009 as Order R2-2009-0074 (SFRWQCB 2009; referred to as MRP 1.0). On November 19, 2015, the Regional Water Board updated and reissued the MRP as Order R2-2015-0049 (SFRWQCB 2015; referred to as MRP 2.0).

This report fulfills the requirements of provision C.8.h.v of MRP 2.0 for comprehensively interpreting and reporting all monitoring data collected since the previous IMR. As such, this report describes monitoring activities conducted during WY 2014 through WY 2019. The previous IMR described monitoring conducted during WY 2012 and WY 2013 (SMCWPPP 2014).

As described in provision C.8.c of MRP 2.0 and provision C.8.b of MRP 1.0, Permittees are required to provide annual financial contributions towards implementing an Estuary receiving water monitoring program that at a minimum is equivalent to the Regional Monitoring Program for Water Quality in the San Francisco Bay (RMP). Since the adoption of the 2009 MRP, SMCWPPP has complied with this provision by making financial contributions to the RMP. Additionally, SMCWPPP staff actively participates in RMP committees, workgroups, and strategy teams as described in the following sections.

The RMP is a long-term (1993 – present) monitoring program that is discharger-funded and shares direction and participation by regulatory agencies and the regulated community with the goal of assessing water quality in the San Francisco Bay. The regulated community includes municipal separate stormwater sewer systems (MS4s), publicly owned treatment works, dredgers, flood control districts, and industrial dischargers. The San Francisco Estuary Institute (SFEI) is the implementing entity for the RMP and the fiduciary agent for RMP stakeholder funds. SFEI does not provide direct oversight of the RMP but does help identify stakeholder information needs, develop workplans that address these needs, and implement the workplans.

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

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

[1] Most hydrologic monitoring occurs for a period defined as a Water Year, which begins on October 1 and ends on September 30 of the named year. For example, Water Year 2019 (WY 2019) began on October 1, 2018 and concluded on September 30, 2019.

4. *Have the concentrations, masses, and associated impacts of contaminants in the Estuary increased or decreased?*
5. *What are the projected concentrations, masses, and associated impacts of contaminants in the Estuary?*

The RMP budget is generally divided between two major program elements: Status and Trends and Pilot/Special Studies. The following sections provide a brief overview of these programs. The *2019 Annual Update to the RMP Multi-year Plan*[2] provides more details and establishes deliverables for each component of the current RMP budget. The RMP publishes annual summary reports. In odd years, the *Pulse of the Bay Report* focuses on Bay water quality and summarizes information from all sources. In even years, the *RMP Update Report* has a narrower and specific focus. The *2019 Pulse of the Bay*[3] includes: an overview of the various pollutant sources and pathways to the Bay with feature articles on four sources/pathways (municipal and industrial wastewater, stormwater, dredging and dredged sediment disposal) and updates on priority pollutants, such as nutrients, contaminants of emerging concern, mercury, Polychlorinated Biphenyls (PCBs), selenium, bacteria, and copper.

2.0 RMP STATUS AND TRENDS MONITORING PROGRAM

The Status and Trends Monitoring Program (S&T Program) is the long-term contaminant-monitoring component of the RMP. The S&T Program was initiated as a pilot study in 1989, implemented thereafter, and was redesigned in 2007 based on a more rigorous statistical design that enables the detection of trends. The RMP Technical Review Committee (TRC) continues to assess the efficacy and value of the various elements of the S&T Program and to recommend modifications to S&T Program activities based on ongoing findings. The current S&T sampling schedule, established in 2014, is listed in Table 2.1 with 2014 - 2019 accomplishments and 2020 goals. A redesign of the S&T Program is anticipated in 2020 reflecting on 20 years of monitoring, continued need for legacy contaminant monitoring, on-ramping of contaminants of emerging concern (CECs), and future collaboration with the United States Geological Survey (USGS).

Table 1.1. RMP Status and Trends Monitoring Schedule.

Program Element	Schedule	2014	2015	2016	2017	2018	2019	2020 (Plan)
Water	Every 2 years		X		X		X	
Bird Eggs	Every 3 years			X		X		
Sediment	Every 4 years	X				X		
Bay Margin Sediments	Random		X		X			X
Sport Fish	Every 5 years	X					X	
Bivalves	Every 2 years	X		X		X		X
Support to the USGS for suspended sediment, nutrients, and phytoplankton monitoring	Every year	X	X	X	X	X	X	X

[2] https://www.sfei.org/sites/default/files/biblio_files/2019%20Multi-Year%20Plan%20-%20SC%20Approved%2020190430%20-%20050119.pdf

[3] https://www.sfei.org/documents/2019-pulse-bay-pollutant-pathways

Additional information on the S&T Program and associated monitoring data are available for download via the RMP website at http://www.sfei.org/content/status-trends-monitoring.

3.0 RMP PILOT AND SPECIAL STUDIES

The RMP also conducts Pilot and Special Studies on an annual basis. Studies are typically designed to investigate and develop new monitoring measures related to anthropogenic contamination or contaminant effects on biota in the Estuary. Special Studies address specific scientific issues that RMP committees, workgroups, and strategy teams identify as priority for further study. These studies are developed through an open selection process at the workgroup level and selected for funding through the TRC and the Steering Committee. The amount of RMP budget allocated to Special Studies has increased over the years and is expected to continue this trend into the future.

In 2019, Pilot and Special Studies focused on the following topics:

- Small Tributary Loading Strategy (see Section 5.0 below and IMR Part D: Pollutants of Concern Monitoring for more details)
    - Watershed characterization reconnaissance monitoring for pollutants of concern
    - Advanced analysis of PCBs data
    - Development of a trends strategy
- Emerging Contaminant Strategy (see IMR Part D: Pollutants of Concern Monitoring for more information)
    - Ongoing review and update of the RMP's Tiered Risk and Management Action Framework
    - Contaminants of emerging concern monitoring (imidacloprid, fragrance ingredients, Polyfluoroalkyl Sulfonate Substances (PFAS), nonionic surfactants, pharmaceuticals) in water, sediment, and/or wastewater
    - Non-targeted analysis of Bay sediment to help identify new CECs
    - Increased focus on studying CECs in stormwater runoff
- Nutrients Management Strategy
    - Continued coordination with USGS for monitoring of nutrients, phytoplankton biomass, and dissolved oxygen at moored sensors in the Bay
    - Ship-based nutrient sampling
    - Study of harmful algae and toxin accumulation in small fish and mussels using Supplemental Environmental Project funds
- Microplastics
    - Review and update of the RMP's Microplastic Strategy
    - Monitoring of microplastics in sport fish
    - Development of several documents synthesizing microplastic research, including a factsheet and a draft manuscript on microplastics in urban stormwater runoff (Werbowski et al. in review)

- Development of conceptual PCB models for prioritized Bay margin units
- Sediment
    - Development of the Sediment Monitoring Strategy
    - Review of beneficial reuse and strategic placement projects
    - Bathymetric change studies
    - Hosting and support for Dredged Material Management Office database
- Selenium monitoring in sturgeon plugs and North Bay clams and water

Results and summaries of the most pertinent Pilot and Special Studies can be found on the RMP website (http://www.sfei.org/rmp/rmp_pilot_specstudies).

During WY 2014 – WY 2019, a considerable amount of RMP and Stormwater Program staff time was spent overseeing and implementing Special Studies associated with the RMP's Small Tributary Loading Strategy (STLS). Pilot and Special Studies associated with the STLS are intended to fill data gaps associated with loadings of Pollutants of Concern (POC) from relatively small tributaries to the San Francisco Bay. Additional information on STLS-related studies is included in Section 5.0 of this report (IMR Part A) and in IMR Part D: POC Monitoring.

4.0 PARTICIPATION IN COMMITTEES, WORKGROUPS AND STRATEGY TEAMS

During WY 2014 - WY 2018, SMCWPPP and the BASMAA RMC partners actively participated in the following RMP committees, workgroups, and strategy teams:

- Steering Committee
- Technical Review Committee (TRC)
- Sources, Pathways and Loadings Workgroup (SPLWG)
- Emerging Contaminant Workgroup (ECWG)
- Nutrient Technical Workgroup
- Strategy Teams (e.g., Small Tributaries, PCBs, Microplastics, Dioxins, Selenium)

Committee, workgroup, and strategy team representation was provided by Permittee staff, Stormwater Program staff, and/or individuals designated by the Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition (RMC) participants and the BASMAA Board of Directors (BASMAA BOD). Representation included participating in meetings, reviewing technical reports and work products, co-authoring or reviewing articles and publications, and providing general program direction to RMP staff. Representatives of the RMC also provided timely summaries and updates to and received input from, Stormwater Program representatives (on behalf of Permittees) during BASMAA Monitoring and Pollutants of Concern Committee (MPC) and/or BASMAA BOD meetings to ensure that MRP Permittees' interests were represented.

5.0 SMALL TRIBUTARIES LOADING STRATEGY

The RMP Small Tributaries Loading Strategy was developed in 2009 by the STLS Team, which includes representatives from BASMAA, Regional Water Board staff, RMP staff, and technical advisors and is overseen by the Sources, Pathways, and Loadings Workgroup. The objective of the STLS is to develop a comprehensive planning framework to coordinate POC monitoring/modeling between the RMP and RMC participants. The following management policies and decisions guide the STLS:

- Refining pollutant loading estimates for future Total Maximum Daily Load (TMDL) updates,
- Informing provisions of the current and future versions of the MRP,
- Identifying small tributaries to prioritize for management actions, and
- Informing decisions on the best management practices for reducing concentrations and loads.

Work conducted by the STLS in 2014 - 2019 is framed by the same five priority POC management information needs identified in MRP 2.0.

1. **Source Identification** – identifying which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff;
2. **Contributions to Bay Impairment** – identifying which watershed source areas contribute most to the impairment of San Francisco Bay beneficial uses (due to source intensity and sensitivity of discharge location);
3. **Management Action Effectiveness –** providing support for planning future management actions or evaluating the effectiveness or impacts of existing management actions;
4. **Loads and Status** – providing information on POC loads, concentrations, and presence in local tributaries or urban stormwater discharges; and
5. **Trends** – evaluating trends in POC loading to the Bay and POC concentrations in urban stormwater discharges or local tributaries over time.

The sections below describe the tasks implemented by the RMP STLS in 2014 - 2019 to address the relevant management policies.

5.1 Wet Weather Reconnaissance Monitoring

With a goal of identifying watershed sources of PCBs and mercury, STLS field monitoring in WYs 2015 - 2019 focused on collection of storm composite samples in the downstream reaches of catchments located throughout the Bay Area. A total of 66 sites (21 in San Mateo County) were sampled during at least one storm event. The contributing areas for these sites range in size from 0.02 km^2 to 233 km^2 and typically represent small engineered MS4 drainage areas (75% were smaller than 5.2 km^2). Storm composite water samples were analyzed for concentrations of PCBs (i.e., RMP 40 congeners), total mercury, and suspended sediment concentration (SSC). In addition, a pilot study was continued at a subset of locations (two stations) to collect fine sediments using specialized settling chambers. A full description of the methods and results from WY 2015 through WY 2018 monitoring is included in Gilbreath et al. (in preparation) which is provided as Attachment D.3 to IMR Part D: POC Monitoring Report.

Data generated through STLS reconnaissance monitoring are used by SMCWPPP to prioritize Watershed Management Areas (WMAs) where PCB source investigations will be conducted. Reconnaissance monitoring by the STLS is planned to continue in WY 2020 and possibly into future years.

The RMP STLS has a growing database, now consisting of 88 stations regionwide that have been sampled during wet weather events for PCBs, mercury, and SSC since 2003. Some stations have also been sampled for a larger suite of constituents. Prior to WY 2015, most of the stations were located in natural creeks. Since that time, most of the stations were located in small MS4 catchments draining primarily old industrial land uses. At three of these sites, collection was conducted using a remote sediment sampler only – a method that was pilot tested during WYs 2015-2018 and approved by the SPLWG in spring 2018 for use in reconnaissance monitoring.

Acknowledging that dynamic climatic conditions and individual storm characteristics may affect data interpretation, the following broad conclusions and recommendations were identified as a result of wet weather reconnaissance monitoring conducted via the STLS (Gilbreat et al. in preparation):

- PCBs positively correlate with impervious cover, old industrial land use, and mercury. They inversely correlate with watershed area. Although mercury and PCBs positively correlate, the relationship is relatively weak, probably due to the larger role of atmospheric recirculation in the mercury cycle and the differences in use history of each POC.

- Neither PCBs nor mercury have strong correlations with other trace metals (As, Cu, Cd, Pb, and Zn). Therefore, there is no support for the use of trace metals as surrogate investigative tools for either PCBs or mercury sources.

- Continued focus on resampling of some stations (i.e., those that return lower than expected concentrations) is recommended to test for false negatives.

5.2 STLS Trends Strategy

The STLS Trends Strategy was initiated in 2015 at the recommendation of the SPLWG which advised the STLS to define where and how trends may be most effectively measured in relation to management effort so that data collection methods deployed over the next several years will support this management information need. The STLS Trends Strategy team is comprised of SFEI staff, RMC participants, and Regional Water Board staff. Invitations to key meetings are extended to additional interested parties (e.g., USEPA), and technical advisors (e.g., USGS) are consulted to review specific technical work products.

The Trends Strategy document (and Technical Appendix), initially drafted in WY 2016, serves as a foundation for this team. The main document summarizes the background, management questions, and guiding principles of the Trends Strategy. It also describes coordination between the RMP and BASMAA within the context of the MRP, proposed tasks to answer management questions, anticipated deliverables, and the overall timeline. The current priority POCs are PCBs and mercury and trend indicators under consideration (i.e., PCB concentrations and particle-ratios) were identified within the context of existing datasets (e.g., POC loading stations) and TMDL timelines. However, the Strategy recognizes that priorities can change in the future. The Technical Appendix (Melwani et al. 2016) presents an evaluation of variability and statistical power[4] for detecting trends based on POC loading station PCBs data. It presents sample size and revisit frequency scenarios needed to detect declining trends in PCBs in 25 years with > 80% statistical power. Due to high variability in baseline PCB concentrations, the modeled sampling scenarios would likely not be practical to implement. Therefore, the Technical Appendix recommends additional analyses and monitoring that should be considered prior to developing a trends monitoring design.

In 2018, the STLS Trends Strategy team followed up on some of the recommendations from the Technical Appendix. A statistical model for trends in PCB loads in the Guadalupe River (as a case study) was finalized. The model incorporates the significant turbidity-PCB relationships that exist and evaluates climatic, seasonal, and inter-annual factors as potential drivers of PCB loads. More intensive review of the Guadalupe River dataset resulted in two main findings: 1) No trends in PCB loads were apparent for the period of 2003 through 2014: 2) A monitoring design that includes sampling at least two storms in 13 out of 20 years (with 4 to 6 grab samples per storm) would detect inter-annual trends of 25% or more over 20 years with > 80% power (Melwani et al. 2018). Results of the statistical analyses were presented at key stages in the analysis to USGS technical advisors with expertise in trends analysis of water data. It is uncertain how the Guadalupe River model and analysis could be applied to other watersheds which have distinct characteristics.

In 2018, the Trends Strategy team updated the Trends Strategy document to include an evaluation of how various tasks to date have and could be used to address the five POC information needs from the MRP (Wu et al. 2018). This review included empirical data collection (i.e., loading stations, wet weather reconnaissance monitoring, BASMAA source identification and BMP effectiveness monitoring, SPoT monitoring) and modeling approaches (i.e., RWSM, the Guadalupe River statistical analysis, Reasonable Assurance Analysis). The 2018 Trends Strategy describes the pros and cons of various methods available to identify and predict trends. Due to concerns about the limitations of extrapolating monitoring results from a relatively small number of watersheds to the entire region, regional modeling was proposed as the most efficient tool to estimate POC loading over time and space for trends evaluation at the desired spatial scales. The 2018 Trends Strategy reviews and compares currently available models and modeling platforms relative to their ability to answer key management questions, including Countywide Reasonable Assurance Analysis (RAA) modeling efforts, the Bay Area Hydrological Model (BAHM), the Regional Watershed Spreadsheet Model (RWSM), and HSPF and SWMM platforms. Based on the goals of the STLS Trends Strategy team, the BAHM, which is based on the HSPF platform, was recommended as the most suitable starting point to develop a regional POC trends model. This recommendation was documented in the Modeling Implementation Plan (Wu and McKee 2019).

Beyond questions about PCBs and mercury, the new regional model will also be used to support other RMP workgroups that have similar management questions. For example, the model could be used to estimate sediment and CEC loads to the Bay.

In 2020, the STLS plans to develop a regional model for hydrology following procedures outlined in the Modeling Implementation. The hydrology model, once established, will be used as a basis for modeling sediment, PCBs, CECs, and other POCs in subsequent years.

[4] Power is defined as the probability of detecting a trend of a certain magnitude during a specified monitoring period (years), where a Type I error rate is set at 5%.

5.3 Advanced Data Analysis

In 2018, the STLS began a new task to provide a deeper analysis of the growing set of PCBs data collected by BASMAA and the RMP. The Advanced Data Analysis task includes two parallel lines of investigation: site inter-comparison methodologies and PCB congener profile comparisons.

5.3.1 Site Inter-Comparison Methodologies

Most of the wet weather characterization data used by the Program and other BASMAA RMC partners to identify and prioritize WMAs where PCB source investigations will be conducted are based on composite samples collected during a single storm event. See IMR Part D for more information on the wet weather sampling programs implemented by the Program and the WMA characterization process. The data collected through these sampling techniques is valuable, but some aspects of its interpretation have been challenging. Since only one storm was sampled at most sites, differing storm characteristics (intensity, duration, antecedent rainfall conditions) interplay with differing PCBs source characteristics to confound comparisons among watersheds. For example, if the targeted storm was relatively small, it is possible that measured PCBs concentrations (and/or PCBs particle ratios) will be lower than they would be in a sample collected at the same station during a larger storm, when larger amounts of sediments and attached pollutants may be mobilized. The main goal of this investigation was to develop a method to account for the differences in targeted storm characteristics at the various sampled stations.

In 2019, the STLS developed a method to generate comparable yield estimates for small industrial watersheds where only a single storm has been sampled. The method includes four steps:

1. Estimate storm runoff volume in the sampled watershed.
2. Compute estimates of storm load for the sampled storm.
3. Adjust estimates of storm load to a standard sized storm.
4. Normalize standardized storm loads to the watershed area of interest to generate storm yields.

This stepwise method was developed using Santa Clara County as a case study and pilot tested with a focus on nested sites within the Guadalupe River watershed. McKee et al. (2019) describes the loads-based site inter-comparison method. Further development and testing in a great number of areas with a wider range of conditions was recommended for 2020.

5.3.2 PCB Congener Profile Comparisons

PCBs samples collected by BASMAA and the STLS are routinely analyzed for 40 individual PCBs congeners (i.e., the “RMP 40”). Although most data analyses are conducted using the sum of those congeners, BASMAA and the STLS recognize the value of generating the more robust RMP 40-based dataset with individual congener results and the potential for future data exploration possibilities. For example, PCBs congener profiles can inform efforts to identify source areas that contribute most to the PCBs mass exported from the watershed via stormwater, and to help illustrate variability in PCBs mobilization from source areas over time.

In 2018, the STLS began development of a method to estimate the contributions of different Aroclor[5] mixtures to the congener profiles of samples of stormwater and sediment. The method is based on the use of indicator congeners that are representative of each of the four most commonly used Aroclors. Data from the Pulgas Pump Station watershed in the City of San Carlos were used to pilot test the method. At this station, stormwater and sediment had high concentrations with a relatively unique pattern, dominated by congeners indicative of a combination of Aroclors 1242 and 1260. The concentrations and congener profiles in sediment suggest that there are two distinct source areas in the watershed that combine to create the mix of 1242 and 1260 that is dominant in stormwater at the Pump Station (Figure 5.1). The data suggest that if PCB flux from one of these areas could be eliminated, loads from the watershed would be reduced by 50% or more. For the Coyote Creek watershed in Santa Clara County, the similarity in congener profiles between the highest concentration sediment samples and the stormwater samples suggest that the important source areas in the watershed have been identified, and that reduction of loading from an area at the south end of the Charcot Avenue Storm Drain watershed would yield the greatest reduction in export at the Coyote Creek station. The concentrations and congener profiles in stormwater and sediment from the Guadalupe River watershed indicate the presence of one source area that is likely a significant contributor to PCBs export from the watershed, but suggest that all of the significant sources areas may not yet have been identified.

A report describing the PCBs congener profile comparison method was published in 2019 (Davis and Gilbreath 2019).

[5] PCBs were manufactured and used as complex mixtures of individual PCBs (referred to as PCB congeners). In North America, the only producer was the Monsanto Company, which marketed PCBs under the trade name Aroclor from 1930 to 1977. A series of different Aroclor mixtures was produced, with varying degrees of overall chlorine content, and these different mixtures were used for different purposes. The congener composition of the various Aroclor mixtures has been reported in the literature (e.g., Schulz et al. 1989, Frame et al. 1996a,b). As a consequence of the use of Aroclor mixtures, PCBs are also present in the environment as complex mixtures of congeners.

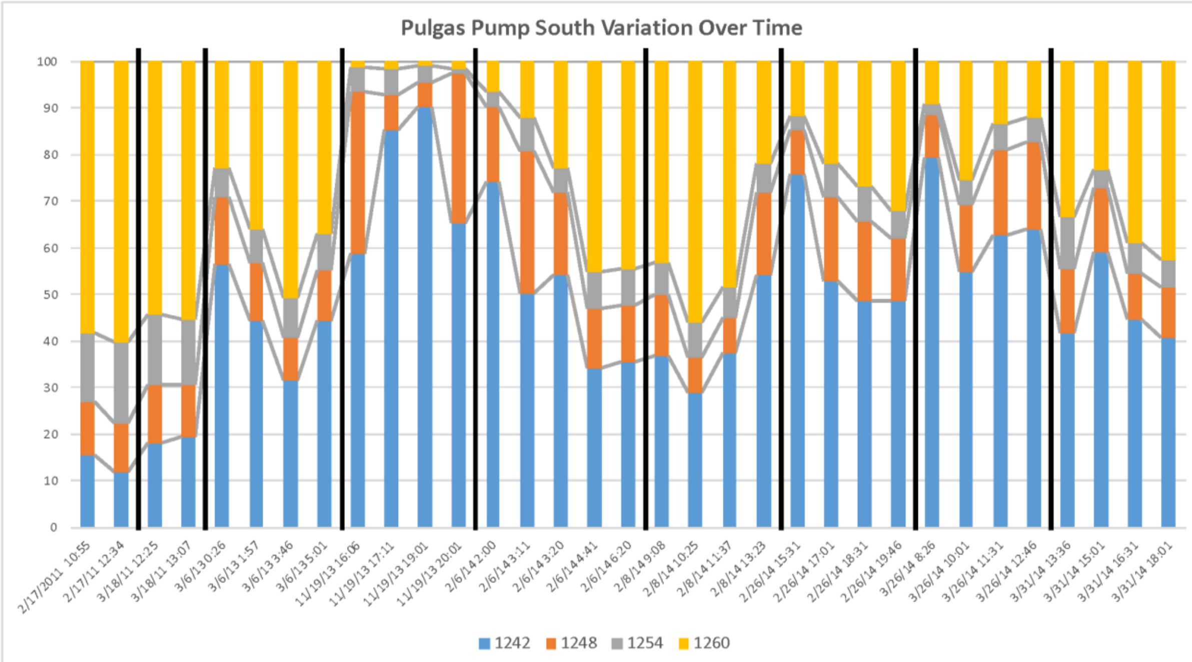

Figure 5.1. Aroclor fractions in stormwater at the outlet of Pulgas Pump Station South over time (figure produced by SFEI, 2018).

5.4 Alternative Flame Retardant Conceptual Model

Alternative flame retardants (AFRs) came into use following state bans and nationwide phase-outs of polybrominated diphenyl ether (PBDE) flame retardants in the early 2000's. They include many categories of compounds, including organophosphate esters. In 2018 the RMP STLS and the Emerging Contaminant Workgroup worked together to conduct a special study to inform ECWG's planning activities related to AFRs. The special study compiled and reviewed available data and previously developed conceptual models for PBDE to support a stormwater-related AFR conceptual model being developed by the ECWG. Organophosphate esters were prioritized for further investigation due to their increasing use, persistent character, and ubiquitous detections at concentrations exceeding PBDE concentrations in the Bay. Limited stormwater data from two watersheds in Richmond and Sunnyvale suggest that urban runoff may be an important source of these compounds. Additional monitoring and modeling were recommended in the AFR Technical Report (Lin and Sutton 2018).

5.5 Regional Watershed Spreadsheet Model

The Regional Watershed Spreadsheet Model is a land use based planning tool for estimation of annual POC loads from small tributaries to San Francisco Bay at a regional scale. Development of the RWSM began in 2010 and the RWSM tool-kit that was published in 2017.

The RWSM is based on the idea that to accurately assess total contaminant loads entering San Francisco Bay, it is necessary to estimate loads from local watersheds. "Spreadsheet models" of stormwater quality provide a useful and relatively inexpensive means of estimating regional scale watershed loads. Spreadsheet models have advantages over mechanistic models because the data for many of the input parameters required by mechanistic models may not currently exist, and also require large calibration datasets which take money and time to collect.

The RWSM is based on the assumption that an estimate of mean annual stormwater runoff **volume** for each land use type within a watershed can be combined with an estimate of mean annual pollutant **concentration** for that same land use type to derive a pollutant **load** which can be aggregated for a watershed or many watersheds within a region of interest. It may be used to provide hypotheses about which sub-regions or watersheds export relatively higher or lower loads to the Bay relative to area. It can also serve as a baseline for analyzing changes in loadings due to large scale changes in land use (e.g., associated with redevelopment and new development) and runoff (e.g., associated with climate change and changes in impoundment). However, the RWSM is less reliable for predicting loadings from individual watersheds and for estimating load changes in relation to implementation of stormwater runoff treatment BMPs.

The RWSM beta tool-kit, published in June 2017 includes:

- Hydrology Model coded using ArcPy and drawing on a user interface accessible through ArcGIS;
- Pollutant Model Spreadsheet for taking the outputs from the Hydrology Model and inputting land use coefficients to estimate pollutant loads;
- Two optional calibration tools – a spreadsheet for manual calibration, and an R script for an optimized automated calibration; and
- User Manual

As described in Section 5.2, a more sophisticated dynamic simulation model (i.e., SWMM, HSPF) is currently under development.

6.0 RECOMMENDATIONS

Overall, SMCWPPP has found that the RMP's work helps support certain aspects of San Mateo County Permittee efforts to comply with MRP requirements. SMCWPPP recommends that RMP funding continues to be directed towards the following high priority topics:

- Bay status and trends monitoring focused on current and emerging pollutants;
- Wet weather monitoring in small tributaries for high priority pollutants; and
- Conceptual and quantative modeling to further understand the sources, transport, and fates of current and emerging pollutants.

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