APPENDIX O

Alameda County PCBs and Mercury Control Measure Plan and Reasonable Assurance Analysis Report

ALAMEDA COUNTY PCBS AND MERCURY TMDL CONTROL MEASURE PLAN AND REASONABLE ASSURANCE ANALYSIS REPORT

Report prepared by:

Alameda Countywide Clean Water Program

399 Elmhurst Street

Hayward, California 94544

Submitted to:

California Regional Water Quality Control Board, San Francisco Bay Region

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Protecting Alameda County Creeks, Wetlands & the Bay

Acknowledgements

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Preface

This *PCBs and Mercury TMDL Control Measure Plan and Reasonable Assurance Analysis Report* was prepared by the Alameda Countywide Clean Water Program (ACCWP) per the Municipal Regional Permit (MRP; NPDES Permit No. CAS612008; Order No. R2-2015-0049) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board. This report fulfills the requirements of MRP Provisions C.11.c.iii.(2), C.11.c.iii.(3), C.11.d.iii, C.12.c.iii.(2), C.12.b.iii.(2), and C.12.d.iii for providing a mercury and PCBs control measures implementation plan and corresponding reasonable assurance analysis (RAA).

This report is submitted by ACCWP on behalf of the following Permittees:

- The cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City;
- Alameda County;
- Alameda County Flood Control and Water Conservation District; and
- Zone 7 of the Alameda County Flood Control and Water Conservation District (Zone 7 Water Agency).

List of Acronyms

Acronym	Definition
ACCWP	Alameda Countywide Clean Water Program (also Program)
BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practices
EBMUD	East Bay Municipal Utility District
ESPS	Ettie Street Pump Station
g	gram
GSI	Green Stormwater Infrastructure
GIS	Geographic Information System
HRU	Hydrologic Response Unit
mg	milligram
mgd	million gallons per day
mg/kg	milligram per kilogram
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
ng	nanogram
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
PCBs	Polychlorinated Biphenyls
PG&E	Pacific Gas and Electric
POTW	Publicly Owned Treatment Works
RAA	Reasonable Assurance Analysis
ROW	Right-of-Way
RWSM	Regional Watershed Spreadsheet Model
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SSID	Stressor/Source Identification
SWMM	Stormwater Management Model
TMDL	Total Maximum Daily Load
WLA	Wasteload Allocation
WY	Water Year

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Executive Summary

This report presents the implementation plan for the Alameda Countywide Clean Water Program (ACCWP or Program) Permittees to meet mercury and polychlorinated biphenyls (PCBs) load reductions required by Total Maximum Daily Loads (TMDLs). The plan is required by the San Francisco Bay Regional Water Quality Control Board (Water Board) through the Municipal Regional Stormwater NPDES Permit (MRP). MRP Provisions C.11.c.iii.(2), C.11.c.iii.(3), C.11.d.iii, C.12.c.iii.(2), C.12.c.iii.(3), and C.12.d.iii specifically require a report providing a mercury and PCBs control measures implementation plan and corresponding reasonable assurance analysis (RAA).

ACCWP Permittees recommend a programmatic approach for reducing PCBs and mercury loads from urban stormwater discharges, whereby compliance is assessed based on implementing and documenting a regionally agreed-on program of control measures, which include:

- Source property identification and abatement,
- Management of PCBs in building materials during demolition,
- Management of PCBs in electrical utility equipment,
- Management of PCBs in bridge structures during replacement,
- Mercury load avoidance and reduction,
- Green stormwater infrastructure (GSI),
- Full trash capture devices, and
- Enhanced operation and maintenance, such as enhanced inlet cleaning.

As part of the process to implement MRP Provisions C.11.d and C.12.d, ACCWP Permittees have worked with peer stormwater programs through the Bay Area Stormwater Management Agency Association (BASMAA) to define the actions and quantifiable benefits of PCBs and mercury control measures. Lessons learned from over 15 years of monitoring, analysis, and reporting informed a series of technical work group meetings beginning in March 2019, with the active participation of Regional Water Board staff in four of those meetings. These workgroup meetings resulted in a programmatic approach agreed on regionally by all stormwater programs. The programmatic approach includes feasible implementation actions that will move the Permittees forward towards the TMDL load reduction goals. Commitment to the programmatic actions provide Permittees with planning certainty needed for compliance while addressing the public interest in measurable progress towards achieving water quality standards.

This TMDL Implementation Report presents an estimate of the load reductions resulting from PCBs and mercury control programs, along with an objective assessment of how inherent uncertainties affect forecast outcomes. It is important to emphasize that the projected pace of control measure implementation and the resultant predicted load reductions are based on current and projected business practices, which are subject to change. Economic or socio-economic impacts and political shifts may affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds available for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation.

PCBs Control Measures

Control measures discussed in Section 2 of this report focus on PCBs. Accounting methodologies are presented for both PCBs and mercury control measures in the RAA Report (Section 6) and the supporting BASMAA Source Control Loads Reduction Accounting for RAA Report (Appendix D).

Table ES-1 below summarizes the PCBs program of control measures and the estimated resulting load reductions over time that would result from the proposed control measures.

Table ES-1. Summary of PCBs Control Measures and Estimated Load Reductions

Control Measure	PCBs Load Reduction (kg/yr) by:			
	2020	2030	2040	2090
Source Property Identification and Abatement	0.29	0.49	0.55	0.55
PCBs in Building Materials Management	0.63	0.63	0.63	0.63
PCBs in Electrical Utilities Management	0.12	0.20	0.27	0.34
PCBs in Infrastructure	0	0.01	0.03	0.06
Green Stormwater Infrastructure	0.23	0.38	0.60	1.50
Full Trash Capture Treatment Control Measures	0.14	0.22	0.22	0.22
Enhanced Operations and Maintenance	0.0002	0.0002	0.0002	0.0002
Diversion to POTW	0.001	0.001	0.001	0.001
Total Load Reduced	**1.41**	**1.93**	**2.30**	**3.30**
Load Reduction Goal	**3.30**	**3.30**	**3.30**	**3.30**
Remaining Load to be Reduced	**1.89**	**1.37**	**1.00**	**0**

The analysis shows that, based on current assumptions, the load reduction needed to achieve the PCBs wasteload allocation assigned to Alameda County Permittees would not be achieved until well after 2030. The RAA estimates that the PCBs TMDL wasteload allocation would be achieved by 2090.

However, Provision C.12.d states that this report should show a path to compliance by 2030. Analysis provided in Appendix G shows that it is technically and economically infeasible to achieve the TMDL wasteload allocation by 2030.

Each of the control measure are described below.

Source Property Identification and Abatement

The Program will continue to assist Permittees with implementing source property investigations and referrals. Twenty-five percent of the remaining old industrial areas that drain to the MS4 will be investigated during the MRP 3 permit term, and the remaining area will be investigated within subsequent permit terms, but prior to 2040. Parcels that drain directly to the Bay may also be investigated if determined to be a high likelihood source property as feasible. If investigation does not identify a specific source for an area with observed elevated concentrations, then the source area may be considered for the application of other types of control measures, such as treatment controls or enhanced O&M.

The rate of discovering new source properties theoretically could be accelerated by increased monitoring effort; however, there is no assurance that new source properties would be discovered. Diminishing returns are expected from this investigation effort going forward, because early efforts targeted high likelihood areas. Therefore, there is low likelihood that progress shown in Table ES-1 above could be accelerated by increased effort on this control measure.

PCBs in Building Materials Management

Permittees will continue implementing adopted ordinances requiring inspection for and removal of PCBs-containing building materials prior to demolition, and reporting outcomes annually. Permittee effort applied to this control measure is expected to remain at its current level of implementation, which began in July 2019. Program costs could be impacted if there are requirements for additional studies, such as effectiveness assessments or refined methods for estimating loads reduced.

There is no way to accelerate the schedule of attaining TMDL goals by changes to this control measure. Future studies may provide information that helps better understand whether the PCBs load reduction achieved is greater or less than the 2 kg/yr allotted to this program in 2019 but would not likely lead to significant changes in the implementation of the program.

PCBs in Electrical Utilities Management

This control measure will improve procedures to document removal and disposal of PCBs in oil-filled electrical equipment (OFEE) as part of ongoing maintenance practices for municipally owned electrical utilities in the MRP area. Alameda Municipal Power is the only municipally owned electrical utility in Alameda County; the remainder of the county is served by East Bay Community Energy[1] and Pacific Gas and Electric Company (PG&E). Alameda Municipal Power will document the removal of PCBs-containing electrical equipment since 2005 and provide data to support calculations of the associated stormwater load reductions due to these efforts.[2]

The limiting factor on implementing this control measure, outside of municipally owned power companies, will likely continue to be the Water Board's ability to direct PG&E to provide the same data and documentation as the municipally owned electrical utilities.

PCBs in Infrastructure

Permittees will inventory bridges in their jurisdictions, including known information about past maintenance, expected maintenance needs, and useful life. The Permittees will then use the inventories to track bridge replacement or rehabilitation projects in their jurisdictions to ensure that contract standard specifications and special provisions addressing PCBs removal from bridge materials are included in any such work. This TMDL Implementation Plan includes the assumption that the responsibility for developing the contract standard specifications and special provisions will be assigned to Caltrans by the State Water Resources Control Board.

Permittees have no way of increasing the benefit from or accelerating the rate of implementing this control measure once it is implemented.

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[1] In 2018, the County of Alameda and 11 of its cities formed East Bay Community Energy (EBCE) to provide more renewable energy at competitive rates. EBCE is a not-for-profit public agency that governs the Community Choice Energy service. EBCE supplies electricity to all accounts (residential, business, and municipal) and PG&E delivers it.

[2] BASMAA conducted a regional Stressor/Source Identification (SSID) project that developed and implemented a regional SSID workplan to further understand the magnitude and extent of PCBs released by electrical utility equipment spills, and to identify controls that could be implemented to reduce the water quality impacts of this source. As a result of this project, BASMAA sent a letter to the SFBRWQCB requesting that the Regional Water Board use its authority under Section 13267 of the California Water Code to compel private electrical utilities operating in the Bay Region to provide technical information that is needed to support further investigation of electrical utility equipment and properties as potential sources of PCBs to MS4s in the Bay Region.

Green Stormwater Infrastructure

Permittees will implement their Green Stormwater Infrastructure plans. This will encumber municipal time and attention at current levels, or potentially increased levels, depending on the level of new development and redevelopment activity and ongoing Capital Improvement Project implementation. Permittees will continue tracking GSI implementation in an ArcGIS online (AGOL) database (or a suitable replacement system). The Program will continue to gather data annually to assess PCBs loads reduced. The rate of implementing this control measure is constrained by the rate of private new development, private redevelopment, and municipal capital project implementation.

The projected pace of GSI implementation and the resultant predicted load reductions are based on current and projected business practices, which are subject to change. Economic or socio-economic impacts and political shifts may affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds available for development and GSI implementation, and/or changes in the ability to provide services that are needed for implementation.

Full Trash Capture Treatment Control Measures

Permittees will continue tracking full trash capture devices in AGOL. The Program would continue to gather AGOL data annually to assess PCBs loads reduced. The opportunities to accelerate this or expand the benefit are limited, as there are a finite number of full trash capture opportunities available to Permittees.

Enhanced Operations and Maintenance (O&M)

Routine MS4 O&M activities conducted by Permittees include street sweeping and drain inlet cleaning. In addition, storm drains, culverts, and channels are maintained as needed (i.e., desilted when needed to remove excessive quantities of accumulated sediment that may be causing localized flooding issues). Infrequent capital improvement projects may also remove accumulated sediment from the MS4, such as storm drain repairs or channel stabilization projects. Each of these O&M activities removes PCBs and mercury that are present in the sediment that is removed. Permittees will continue to perform enhanced O&M at current levels and will consider expanding enhanced O&M in Old Industrial areas and / or near source property areas.

Diversion to POTW

The Alameda County Flood Control and Water Conservation District has an agreement with the East Bay Municipal Utility District (EBMUD) for operation of an urban runoff diversion at the Ettie Street Pump Station that directs dry weather discharge to EBMUD's main wastewater treatment plant for treatment. No other pump station diversion is planned for implementation.

Mercury Control Measures

Mercury control measures for source control (e.g., product collection for recycling) are well-established in the Bay Area. Because of the widespread nature of mercury in the urban environment, further progress on reducing mercury loads will most likely occur in tandem with stormwater management and treatment measures addressing PCBs (i.e., GSI implementation).

Schedule for Implementation

The RAA results predict that the PCBs TMDL wasteload allocation will be achieved in Alameda County by the year 2090. GSI implementation provides multiple benefits, addresses other urban pollutants, and is a requirement for new development and redevelopment projects, so would continue to be implemented as long as that requirement is in place. In addition, the Management of PCBs in Building Materials, Management of PCBs in Electrical Utilities, and Management of PCBs in Infrastructure programs will be implemented until these sources have been abated. As PCBs have been banned in the United States since 1979, it is likely that these programs will no longer be needed by 2080, 100 years later. The Source Property Identification and Abatement Program will be complete by 2040. Full trash capture device implementation is assumed to be complete no later than 2030. The source control measure Mercury Load Avoidance and Reduction, which began during MRP 1.0, is assumed to continue indefinitely.

Evaluation of Costs

The estimate of public agency costs for implementing the PCBs and mercury control measures ranges from $400,000,000 to $1,000,000,000 countywide. The estimated cost for implementing source control programs is negligible in comparison to the estimated costs for implementing GSI measures. An analysis of cost effectiveness demonstrates that source control measures are much more cost efficient than treatment control measures at reducing loads of PCBs in urban runoff.

Public project implementation will depend on funding availability. Funding for implementation of projects included in the Permittees' Green Infrastructure Plans would be obtained by the municipal agency, partnerships of agencies, or other stakeholder project sponsors working to implement the identified projects. Economic or socio-economic impacts and political shifts may affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds available for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation.

Uncertainty Analysis

Components of uncertainty that cannot be addressed through the methods summarized in this document are pollutant degradation and changes in larger-scale processes that are difficult to predict. Degradation is the process of natural reduction in pollutant concentration, which is anticipated to occur over time as a result of numerous factors present in the watershed. A component of degradation which lends itself to uncertainty is the reduction of PCBs as a source. PCBs are a legacy pollutant in the environment, as they have not been in production for almost 40 years and the allowable uses have been mostly phased out and should be further reduced over time until they are eliminated. Therefore, the load of PCBs that is currently available for transport and conveyance in the MS4 can only be degraded and removed, not added to.

It is anticipated that PCBs as a source will diminish over time as a result of source control activities, as well as natural dispersion and degradation processes, which is not captured by the load reduction estimation methods. Little information is known about these processes, thus insufficient information is available to develop a methodology for accounting for degradation and source reduction in the watershed. Because of this, degradation overtime could account for a considerable amount of uncertainty in the future condition, particularly in the anticipated concentrations in urban runoff and land use-based pollutant load assumptions.

Additional uncertainty is associated with changes in large-scale processes. These include physical phenomena, such as effects of climate change, long-term meteorological patterns, and large seismic events. These can also include economic or socio-economic and political shifts, which may occur as a result of physical phenomena or other factors, such as that experienced in 2020, the COVID-19 pandemic.

Major changes in large-scale processes can impact the actuality of some of the assumptions in the pollutant loading model as well as the future implementation scenarios. These may include changes to total area contributing to loading, for example as a result of sea level rise; changes to annual loading due to increases or decreases in average annual stormwater runoff volume, as a result of precipitation or flooding changes caused by long-term meteorological patterns and/or climate change; or changes to loading and/or redevelopment rates as a result of a seismic event. Economic or socio-economic impacts and political shifts can also affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation.

The examples provided represent just a small fraction of the range of possibilities; many of these large-scale phenomena are very challenging to predict. As such, they are even more difficult to model and, in many cases, represent scenarios that may not happen and/or the timeframe for when they happen cannot be estimated.

1 Introduction

1.1 Purpose

This *PCBs and Mercury TMDL Control Measure Plan and Reasonable Assurance Analysis* report was prepared by the Alameda Countywide Clean Water Program (ACCWP) per the Municipal Regional Permit (MRP) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Order No. R2-2015-0049). This report fulfills the requirements of MRP Provisions C.11.c.iii.(2), C.11.c.iii.(3), C.11.d.iii, C.12.c.iii.(2), C.12.b.iii.(2), and C.12.d.iii for providing a mercury and PCBs control measures implementation plan and corresponding reasonable assurance analysis (RAA).

The following MRP reporting requirements are addressed within this report:

- An estimate of the amount and characteristics of land area that will be treated through green stormwater infrastructure (GSI) implementation by 2020, 2030, and 2040; the data used; and a full description of models and model inputs relied on to generate this estimate.
- A reasonable assurance analysis to demonstrate quantitatively that Alameda County's population-based portion of PCBs reductions of at least 3 kg/yr and mercury reductions of at least 10 kg/yr will be realized by 2040 through implementation of GSI projects; all data used; a full description of models and model inputs relied on to make the demonstration; and documentation of peer review of the reasonable assurance analysis.
- A PCBs and mercury control measure implementation plan and corresponding RAA that demonstrates quantitatively that the plan will result in mercury load reductions sufficient to attain the mercury TMDL wasteload allocations by 2028 and PCBs load reductions sufficient to attain the PCBs TMDL wasteload allocations by 2030. The plan must:
    1. Identify all technically and economically feasible PCBs control measures and mercury control measures (including GSI projects) to be implemented;
    2. Include a schedule according to which these technically and economically feasible control measures will be fully implemented; and
    3. Provide an evaluation and quantification of the PCBs load reduction and mercury load reduction of such measures as well as an evaluation of costs, control measure efficiency, and significant environmental impacts resulting from their implementation.

This report is organized into the following sections:

1. Introduction and Background – Section 1 describes requirements for managing mercury and PCBs per the TMDLs and the MRP.
2. PCBs Control Measure Plan – Section 2 describes the technically and economically feasible PCBs control measures that are currently being implemented or will be implemented by the Permittees during this and future permit terms.
3. Mercury Control Measure Plan – Section 3 describes the technically and economically feasible mercury control measures that are currently being implemented or will be implemented by the Permittees during this and future permit terms.
4. Schedule of Implementation – the schedule of implementation for the PCBs and mercury control measures is provided in Section 4.
5. Costs, Efficiency, and Environmental Impacts – Section 5 provides an evaluation of costs, control measure efficiency, and significant environmental impacts resulting from the implementation of the PCBs and mercury control measures.
6. Reasonable Assurance Analysis – This section presents estimates of the PCBs and mercury loads that will be reduced through implementation of the control measures described in the PCBs and Mercury Control Measure Plans presented in Section 2 and Section 3. This section summarizes the data used, describes the model and model inputs, and documents peer review.
7. Conclusion – the final section summarizes the findings of the report.

1.2 Background

1.2.1 PCBs and Mercury Total Maximum Daily Loads

Fish tissue monitoring in San Francisco Bay (Bay) has revealed bioaccumulation of PCBs, mercury, and other pollutants. The levels found are thought to pose a health risk to people consuming fish caught in the Bay. As a result of these findings, California has issued an interim advisory on the consumption of fish from the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act "Section 303(d) list" due to PCBs, mercury, and other pollutants. In response, the SFBRWQCB has developed Total Maximum Daily Load (TMDL) water quality restoration programs targeting PCBs and mercury in the Bay. The general goals of the TMDLs are to identify sources of PCBs and mercury to the Bay and implement actions to control the sources and restore water quality.

Municipal separate storm sewer systems (MS4s) are one of the PCBs and mercury source/pathways identified in the TMDL plans. Local public agencies (i.e., Permittees) subject to requirements via National Pollutant Discharge Elimination System (NPDES) permits are required to implement control measures in an attempt to reduce PCBs and mercury from entering stormwater runoff and the Bay. These control measures, also referred to as BMPs, are the tools that Permittees can use to assist in restoring water quality in the Bay.

PCBs TMDL

The PCBs TMDL was developed based on a fish tissue target of 10 nanograms (ng) of PCBs per gram (g) of fish tissue. This target is based on a cancer risk of one case per an exposed population of 100,000 for the 95th percentile San Francisco Bay Area sport and subsistence fisher consumer (32 g fish per day) (SFBRWQCB, 2008). A food web model was developed by San Francisco Estuary Institute (SFEI) to identify the sediment target concentration that would yield the fish tissue target; this sediment target was found to be 1 microgram (µg) of PCBs per kg of sediment. This is equivalent to reducing the total mass of PCBs in the active layer of the San Francisco Bay to 160 kg. The San Francisco Estuary Institute (Davis, 2003; SFEI, 2007a) developed a mass budget model that identified the total external load of PCBs to the Bay that would attain a long-term (i.e., equilibrated) PCBs mass in the bay of 160 kg within approximately 30 years. The mass budget model estimated that reduction of the external load to 10 kg of PCBs per year would achieve this goal, assuming a starting Bay-wide PCBs concentration in surface sediment of 4.65 micrograms per kilogram (µg/kg)[3] (SFEI, 2007a). Twenty percent of the estimated allowable external load was allocated to urban stormwater runoff.

The wasteload allocation (WLA) for PCBs for urban stormwater is 2 kg/yr by 2030. This load allocation was developed by applying the required sediment concentration (1 µg/kg) to the estimated annual sediment load discharged from local tributaries. The PCBs TMDL staff report (SFBRWQCB, 2008) estimated the annual sediment load originating from stormwater to be 2,000,000 metric tons (i.e., 2,000,000,000 kg/yr) based on a range of then available estimates and differing methods. This WLA was distributed among the counties on population in the year 2000. A summary of the allocations for each county is provided in Table 1-1.

[3] Bay-wide PCBs concentration in surface sediment estimated based on Regional Monitoring Program 2004 – 2006 data (SFEI, 2007a).

Table 1-1: PCBs Wasteload Allocations by County

County	Population (year 2000)	Wasteload Allocations (kg/yr)
Alameda	1,440,000	0.5
Contra Costa	790,000	0.3
Marin	240,000	0.1
Napa	120,000	0.05
San Francisco	630,000	0.2
San Mateo	600,000	0.2
Santa Clara	1,600,000	0.5
Solano	290,000	0.1
Sonoma	110,000	0.05
Total		2

The PCBs TMDL Staff Report estimates a total stormwater load of 20 kg/yr based on studies conducted by SFEI (SFEI, 2006; 2007b). SFEI calculated this baseline load using three different methods to scale monitoring data (grab sample concentration data from Water Year (WY) 2005[4], United States Geologic Survey [USGS] continuous discharge, and suspended sediment data) from Coyote Creek and the Guadalupe River by area and land use. Subtracting the WLA for urban stormwater from this estimate resulted in a required load reduction of 18 kg/yr (i.e., a 90% reduction) by 2030. Note that the MRP area[5] portion of the 2 kg/yr allocation is 1.6 kg/yr.

PCBs TMDL compliance can be demonstrated through two different approaches:

1. Meet the WLA (i.e., monitoring and/or modeling-based compliance demonstration); and
2. Demonstrate the required load reductions can be achieved (i.e., modeling-based compliance demonstration).

Mercury TMDL

The mercury TMDL addresses two water quality objectives. The first, established to protect people who consume Bay fish, applies to fish large enough to be consumed by humans. The objective is 0.2 milligrams (mg) of mercury per kilogram (kg) of fish tissue (average wet weight

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[4] Although the PCBs TMDL Staff Report states that PCBs loads estimates for the Guadalupe River were based on data collected between 2003 and 2005; SFEI, 2006 indicates that the baseline load estimate of 20 kg/yr was based on an extrapolation of monitoring data collected in WY 2005.

[5] Marin, Napa, San Francisco, and Sonoma are not within the MRP boundary.

concentration measured in the muscle tissue of fish large enough to be consumed by humans). The second objective, established to protect aquatic organisms and wildlife, applies to small fish (3-5 centimeters in length) commonly consumed by the California least tern, an endangered species. This objective is 0.03 mg mercury per kg fish (average wet weight concentration). To achieve the human health and wildlife fish tissue and bird egg monitoring targets and to attain water quality standards, the Bay-wide suspended sediment mercury concentration target is 0.2 mg mercury per kg dry sediment.

A roughly 50% decrease in sediment, fish tissue, and bird egg mercury concentrations is necessary for the Bay to meet water quality standards. Reductions in sediment mercury concentrations are assumed to result in a proportional reduction in the total amount of mercury in the system, which will result in the achievement of target fish tissue and bird egg concentrations (SFBRWQCB, 2004).

The urban stormwater runoff load to the San Francisco Bay is estimated to be equivalent to 116 kg/yr, as reported in the San Francisco Bay Regional Monitoring Program for Water Quality's Sources, Pathways, and Loadings Report (McKee et al., 2015), which is less than the Mercury TMDL Staff Report reported load of 160 kg/yr[6] (corresponding to "baseline year" of 2003). The WLA for urban stormwater is 82 kg/yr (SFBRWQCB, 2006). Based on the TMDL reported load of 160 kg/yr, this results in an estimated total required load reduction of 78 kg/yr, required to be achieved by 2028. A summary of the WLA and load reductions required for each urban stormwater entity subject to the TMDL is provided in Table 1-2 (SFBRWQCB, 2006).

[6] This loading assumes an annual sediment load of 410,000,000 kg/yr of sediment with a concentration of 0.38 mg/kg (ppm) (SFBRWQCB, 2006). Although the estimates were based on monitoring data collected in previous years, the TMDL states the baseline year as 2003.

Table 1-2: Mercury Wasteload Allocations by County

Entity	Wasteload Allocation (kg/yr)[1]
Santa Clara Valley Urban Runoff Pollution Prevention Program	23
Alameda Countywide Clean Water Program	20
Contra Costa Clean Water Program	11
San Mateo County Stormwater Pollution Prevention Program	8.4
Vallejo Sanitation and Flood Control District	1.6
Fairfield-Suisun Urban Runoff Management Program	1.6
American Canyon	0.14
Sonoma County area	1.6
Napa County area	1.6
Marin County area	3.3
Solano County area	0.81
San Francisco County area	8.8
Total	82

[1] Listed in Table 4-w of Appendix A in the Mercury TMDL Staff Report (SFBRWQCB, 2006).

Mercury TMDL compliance can be demonstrated through the following three approaches[7]:

1. Show mercury concentrations are below 0.2 milligrams per kilogram (mg/kg) on a countywide level (i.e., monitoring-based compliance demonstration);
2. Meet the WLA (i.e., monitoring and/or modeling-based compliance demonstration);[8] and
3. Demonstrate the required load reductions can be achieved (i.e., modeling-based compliance demonstration).

1.2.2 Municipal Regional Permit

NPDES permit requirements associated with Phase I municipal stormwater programs and Permittees in the Bay area are included in the MRP, which was issued to 76 cities, counties, and flood control districts in 2009 and revised in 2015.

MRP Provision C.3.j required the Permittees to develop a Green Infrastructure Plan for inclusion in the 2019 Annual Report. The Green Infrastructure Plans were developed using a mechanism

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[7] Detailed documentation requirements for demonstration of these approaches are summarized in the Mercury TMDL Staff Report (SFBRWQCB, 2006).

[8] Modeling-based compliance demonstration requires monitoring-based empirical inputs to conduct the analyses.

to prioritize and map areas for potential and planned green infrastructure projects, both public and private, on a drainage-area-specific basis, for implementation by 2020, 2030, and 2040.

MRP Provisions C.11.c and C.12.c require the Permittees to prepare an RAA for inclusion in the 2020 Annual Report. The RAA required in Provisions C.11.c and C.12.c should do the following:

1. Quantify the relationship between the areal extent of green infrastructure implementation and mercury and PCBs load reductions. This quantification should take into consideration the scale of contamination of the treated area as well as the pollutant removal effectiveness of green infrastructure strategies likely to be implemented.
2. Estimate the amount and characteristics of land area that will be treated by green infrastructure by 2020, 2030, and 2040.
3. Estimate the amount of mercury and PCBs load reductions that will result from green infrastructure implementation by 2020, 2030, and 2040.
4. Quantitatively demonstrate that mercury load reductions of at least 10 kg/yr and PCBs load reductions of at least 3 kg/yr will be realized by 2040 through implementation of green infrastructure projects.
5. Ensure that the calculation methods, models, model inputs, and modeling assumptions used have been validated through a peer review process.

Additionally, MRP Provisions C.11.d. and C.12.d. require the Permittees to prepare plans and schedules for mercury and PCBs control measure implementation and an RAA demonstrating that sufficient control measures will be implemented to attain the mercury TMDL wasteload allocations by 2028 and the PCBs TMDL wasteload allocations by 2030. The implementation plans must:

1. Identify all technically and economically feasible mercury or PCBs control measures (including green infrastructure projects, but also other control measures such as source property identification and abatement, managing PCBs in building materials during demolition, enhanced operations and maintenance, and other source controls) to be implemented;
2. Include a schedule according to which technically and economically feasible control measures will be fully implemented; and
3. Provide an evaluation and quantification of the mercury and PCBs load reduction of such measures as well as an evaluation of costs, control measure efficiency, and significant environmental impacts resulting from their implementation.

1.2.3 Bay Area RAA Guidance

From a regulatory perspective, reasonable assurance is defined as the demonstration that the implementation of control measures will, in combination with operation of existing or proposed storm drain system infrastructure and management programs, result in sufficient pollutant reductions over time to meet total maximum daily load (TMDL) wasteload allocations, water quality-based effluent limits (WQBELs), or other water quality targets specified in a municipal separate storm sewer system (MS4) permit (USEPA, 2017). From the perspective of a stakeholder in the watershed who is focused on the improvement of water quality or restoration of a beneficial use of a waterbody, reasonable assurance is the demonstration and a commitment that specific management practices are identified with sufficient detail (and with a schedule for implementation) to establish that necessary improvements in the receiving water quality will occur. From the perspective of an MS4 Permittee, reasonable assurance is a detailed analysis of TMDL WLAs, associated permit limitations, and the extent of stormwater management actions needed to achieve TMDL WLAs and address receiving water limitations. RAAs may also assist in evaluating the financial resources needed to meet pollutant reductions based on schedules identified in the permit, TMDL, or stormwater management plan, and in preparing associated capital improvement plans.

As defined in the *Bay Area RAA Guidance Document* (BASMAA, 2017), an RAA is a demonstration that the control measures proposed in Bay Area City and County Green Infrastructure Plans and PCBs and Mercury Control Measure Implementation Plans, as required by MRP Provisions C.3, C.11, and C.12, will meet the PCBs and mercury TMDL wasteload allocations for urban stormwater runoff over the defined period of time. Additionally, the RAA should provide a method for evaluating the type, size, number, location, and phasing of green infrastructure measures needed to comply with the green infrastructure load reduction goal (i.e., 10 kilograms per year [kg/yr] mercury load reductions and 3 kg/yr PCBs load reductions by 2040) stated in MRP Provisions C.11/C.12.c. As such, the green infrastructure planning and associated RAAs will require adaptive management. The RAA may also be used to justify extending the TMDL compliance schedules (SFBRWQCB, 2015). [9]

The MRP provides flexibility for Permittees to define what constitutes an acceptable RAA, however the RAAs developed in compliance with the MRP must be peer reviewed and must be approved by the SFBRWQCB. The RAA presented in this report is consistent with the guidance provided in the *Bay Area RAA Guidance Document* (BASMAA, 2017).

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[9] See MRP Attachment A: Fact Sheet page Attachment A-122.

2 PCBs Control Measure Plan

This section describes the control measures that are currently being implemented or will be implemented by the Permittees during this and future permit terms to control PCBs in urban runoff.

2.1 Source Control Measures

Source control measures include the following programs:

- Source area investigation and abatement,
- PCBs in building materials management,
- PCBs in electrical utilities management,
- PCBs in infrastructure management, and
- Mercury load avoidance and reduction.

Each of these source control programs are described below.

2.1.1 Source Property Identification and Abatement Program

Source property identification and abatement involves investigations of properties located in historically industrial land use or other land use areas where PCBs were used, released, and/or disposed of and/or where sediment concentrations are significantly elevated above urban background levels and are being transported to the MS4. The source property identification and abatement control measure begins with performing investigations in High Likelihood/Interest areas to identify PCBs sources. A detailed description of the investigation process is provided in Appendix A.

Once a source property is identified, the source of PCBs on the property may be abated or caused to be abated directly by the Permittee or the Permittee may choose to refer the source property to the SFBRWQCB for investigation and abatement. Source properties may include sites that were previously remediated but still have soils concentrations of PCBs that are elevated above urban background levels or may be newly identified source properties. Source properties may also include industrial facilities with ongoing industrial activities that are covered under the General Permit for Stormwater Discharges Associated with Industrial Activities (Industrial General Permit) or another NPDES permit.

The Permittees identify significantly elevated PCBs concentrations through surface soil/sediment sampling in the ROW or through water sampling where visual inspections and/or other information suggest that a specific property is a potential source of significantly elevated PCBs concentrations. Where data confirm significantly elevated concentrations (e.g., a sediment PCBs concentration equal to or greater than 1.0 mg/kg or a sediment concentration greater than 0.5 mg/kg and other lines of evidence) are present in soil/sediment from a potential source property or in stormwater samples, the Permittees may take actions to cause the property to be abated or may refer that property to the SFBRWQCB to facilitate the issuance of orders for further investigation and remediation of the subject property

For each referred source property, the applicable Permittee will implement or cause to be implemented one or a combination of interim enhanced O&M measures in the street or storm drain infrastructure adjacent to the source property during the source property abatement process, or will implement a stormwater treatment system downstream of the property to intercept historically deposited sediment. The intent is to prevent further contaminated sediment from being discharged from the storm drain system. These enhanced O&M measures and/or treatment systems are described in the source property referral form that is sent to the SFBRWQCB.

The selected enhanced O&M control measure(s) or stormwater treatment must be implemented and maintained during the source property abatement process and should be sufficient to intercept historically deposited sediment in the public ROW and prevent additional contaminated sediment from being discharged from the MS4. The Permittee should discuss the referral and achieve resolution with the SFBRWQCB prior to submitting the source property referral.

When a referred industrial facility is considered to be abated by the Permittee and the SFBRWQCB, the enhanced O&M measures may be discontinued, and ongoing facility inspections would be conducted as appropriate as part of the Permittee's routine industrial inspection program.

The properties that have been referred to the SFBRWQCB or self-abated through FY 2019/20 are listed in Table 2-1 below.

Table 2-1: ACCWP Contaminated Sites Referred to the SFBRWQCB and Self-Abated Properties

SITE NAME	LOCATION	PROPERTY SIZE (ACRES)	YEAR REFERRED	REFERRAL OR SELF-ABATEMENT
AMG	3438 Helen Street, Oakland	0.43	FY 2017/18[1]	Referral
Custom Alloy Scrap Sales	2601 Peralta St., Oakland	7.65	FY 2017/18[1]	Referral
Former Giampolini Facility	2838 Hannah St., Oakland	1.93	FY 2017/18[1]	Self-Abatement
General Electric – Oakland (Phase 1)	5441 East 14th St., Oakland	10.1	FY 2017/18	Self-Abatement
LBNL Old Town	One Cyclotron Rd., Berkeley	1.0	FY 2017/18	Self-Abatement
OAB Transformer Spill	10th and Maritime St., Oakland	0.02	FY 2017/18	Self-Abatement
Precision Cast Products	1549 32nd Street and 2868 Hannah Street, Oakland	0.79	FY 2017/18	Referral
South SPRR/Novartis	4560 Horton St., Emeryville	0.03	FY 2017/18	Self-Abatement
UPRR – Oakland Coliseum	700 73rd Avenue, Oakland	0.40	FY 2017/18	Referral
Schnitzer Steel	Schnitzer Steel, 1101 Embarcadero West, Oakland	33.7	FY2019/20	Referral
General Electric – Oakland (Phase 2)	5441 East 14th St., Oakland	13.9	FY 2019/20	Self-Abatement
Kaiser Medical Center	Kaiser Medical Center, 280 West MacArthur Blvd, Oakland	5.0	FY2019/20	Self-Abatement
OES-021	Wood Street and 15th Street, Oakland	6.2	FY2019/20	Self-Abatement
Brownfield Auto Auction (former Nor-Cal Rock)	768 46th Avenue, Oakland	1.8	FY2019/20	Referral
Economy Lumber	Economy Lumber, 750 High Street, Oakland	4.0	FY2019/20	Referral

The Permittees, with the support of the ACCWP, have estimated the remaining old industrial area to be investigated within Alameda County (Table 2-2). Twenty-five percent of the remaining old industrial areas that drain to the MS4 will be investigated during the MRP 3 permit term, and the remaining area will be investigated within subsequent permit terms, but prior to 2040. Parcels that drain directly to the Bay may also be investigated if determined to be a high likelihood source property as feasible. If investigation does not identify a specific source for an area with observed elevated concentrations, then the source area may be considered for the application of other types of control measures, such as treatment controls or enhanced O&M.

Table 2-2: Old Industrial Areas to be Investigated within Alameda County

Description		Total Area (acres)
Total urban area below dams and draining to the Bay		337,769
A.	All Old Industrial land use areas (2002)[1]	9,639
B.	Old Industrial land use areas that have redeveloped since 2002 and/or are currently treated by green stormwater infrastructure	821
C.	Old Industrial land use areas that have been previously determined to be low likelihood, investigated[2], referred, or abated.	3,847
D.	Old Industrial land use areas that do not drain to the MS4, rather drain directly to the Bay	337
E.	Old Industrial land use areas that will be investigated (A – (B + C + D))	4,634

Notes:

1. Does not include Old Industrial land use areas within the jurisdiction of the Port of Oakland.
2. Includes the Alameda Naval Air Station, Lawrence Livermore National Laboratory, and Old Industrial parcels associated with low (<0.5 mg/kg) sediment samples

2.1.2 Management of PCBs in Building Materials Program

The Permittees have developed and implemented, in cooperation with the Bay Area Stormwater Management Agencies Association (BASMAA), a protocol for managing materials with PCBs concentrations of 50 ppm or greater in applicable structures at the time such structures undergo demolition. PCBs from these structures can enter storm drains during and/or after demolition through vehicle track-out, airborne releases, soil erosion, stormwater runoff, or improper waste disposal. Applicable structures include, at a minimum, commercial, public, institutional, and industrial structures constructed between the years 1950 and 1980 and with building materials with PCBs concentrations of 50 ppm or greater. Single-family residential and wood frame structures are exempt.

The ACCWP and Permittees participated in a BASMAA Regional Project to address PCBs in building materials. This Regional Project developed an implementation framework, guidance materials, and tools for local agencies to ensure that PCBs-containing materials and wastes are properly managed during building demolition; these materials are provided in Appendix B. This Regional Project also provided training materials and a workshop for municipal staff and an outreach workshop for the industry on implementing the framework/protocols developed via the project. The tools and materials developed as part of the project build upon materials and outputs developed in 2010-2011 by the San Francisco Estuary Partnership with State Water Board grant funding, called the “PCBs in Caulk Project”, as well as subsequent and parallel activities by BASMAA.

Permittees have implemented the following process for this control measure:

- Municipalities inform applicable demolition permit applicants that their projects are subject to the program for managing materials with PCBs, necessitating, at a minimum, an initial screening for priority PCBs–containing materials.
- For every applicable demolition project, applicants implement the BASMAA protocol for identifying building materials with PCBs concentrations of 50 ppm and then complete and submit a version of BASMAA's model "PCBs Screening Assessment Form" (Screening Form) or equivalent to the municipality.
- The municipality reviews the Screening Form to make sure it is filled out correctly and is complete and works with the applicant to correct any deficiencies.
- The municipality then issues the demolition permit or equivalent, according to its procedures.
- The municipality sends each completed Screening Form for applicable structures and any supporting documents to its countywide program. The countywide program compiles the forms and works with the other MRP countywide programs to manage and evaluate the data, and to assist Permittees with associated MRP reporting requirements.

Data collection started with implementation of the new program on July 1, 2019. When sufficient amounts of new data have been collected, the data will support:

- Development of a revised estimate of the reduction in PCBs loading to stormwater runoff resulting from implementation of the new program, and
- Evaluation of various aspects of the PCBs management program and the effectiveness of potential future refinements.

2.1.3 Management of PCBs in Electrical Utilities Program

The Management of PCBs in Electrical Utilities Program includes the development and implementation of improved procedures for documenting removal and disposal of PCBs-containing electrical equipment as part of ongoing equipment maintenance practices.

For this control measure program, municipally owned electrical utilities will document the removal of PCBs-containing electrical equipment since the start of the TMDL and in the future until all PCBs-containing OFEE have been removed from active service and will provide data to support calculations of the associated stormwater load reductions due to these efforts.[10] Alameda Municipal Power is the only municipally owned electrical utility in Alameda County; the remainder of the county is served by East Bay Community Energy[11] and Pacific Gas and Electric Company (PG&E).

Electrical utility equipment and facilities in both the transmission and distribution systems are distributed across the MRP region. In the past, PCBs were routinely used in electrical utility equipment that contained dielectric fluid as an insulator. This is because prior to the 1979 PCBs ban, dielectric fluid was typically formulated with PCBs due to a number of desirable properties they have (e.g., high dielectric strength, thermal stability, chemical inertness, and non-flammability). Electrical equipment containing dielectric fluid is typically identified as Oil-Filled Electrical Equipment (OFEE). Any OFEE that contained PCBs in the past could still potentially contain PCBs today. The most common types of OFEE that may contain PCBs are transformers, capacitors, circuit breakers, reclosers, switches in vaults, substation insulators, voltage regulators, load tap changers, and synchronous condensers (PG&E, 2000).

There are hundreds of thousands of pieces of OFEE in public rights-of-way and at hundreds of electrical sub-station facilities across the MRP region. Some portion of these OFEE that are older and/or refurbished may contain (or contained in the past) dielectric fluids with PCBs at concentrations that are of concern if released to MS4s. Due to their large quantity, dispersed nature, and the difficulty in tracking and monitoring discharges, Permittees are limited in their ability to implement and/or enforce consistent and appropriate control measures to reduce releases of PCBs from this source category. This creates a potential missed opportunity to account for past and ongoing removal of PCBs-containing OFEE which has been and continues to reduce loads of PCBs from MS4s to the Bay.

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[10] BASMAA conducted a regional Stressor/Source Identification (SSID) project that developed and implemented a regional SSID workplan to further understand the magnitude and extent of PCBs released by electrical utility equipment spills, and to identify controls that could be implemented to reduce the water quality impacts of this source. As a result of this project, BASMAA sent a letter to the SFBRWQCB requesting that the Regional Water Board use its authority under Section 13267 of the California Water Code to compel private electrical utilities operating in the Bay Region to provide technical information that is needed to support further investigation of electrical utility equipment and properties as potential sources of PCBs to MS4s in the Bay Region.

[11] In 2018, the County of Alameda and 11 of its cities formed East Bay Community Energy (EBCE) to provide more renewable energy at competitive rates. EBCE is a not-for-profit public agency that governs the Community Choice Energy service. EBCE supplies electricity to all accounts (residential, business, and municipal) and PG&E delivers it.

2.1.4 Management of PCBs in Infrastructure Program

The BASMAA study *Evaluation of PCBs in Caulk and Sealants in Public Roadway and Storm Drain Infrastructure* (BASMAA, 2018) sampled caulk and sealant materials from public roadway and storm drain infrastructure around the Bay Area. The sampling program was designed to specifically target roadway and storm drain structures that were constructed during the most recent time period when PCBs were potentially used in caulk and sealant materials (i.e., prior to 1980, with a focus on the 1960's and 1970's). A total of 54 caulk and sealant samples were collected from ten different types of roadway and storm drain structures in the ROW, including concrete bridges/overpasses, sidewalks, curbs and gutters, roadway surfaces, above and below ground storm drain structures (i.e., flood control channels and storm drains accessed from manholes), and electrical utility boxes or poles attached to concrete sidewalks. The individual samples were grouped by structure type and sample appearance (color and texture) and the groups were combined into 20 composites; 10 of these groups were collected from concrete bridges, overpasses, or roadways.

Total PCBs concentrations across the 20 composite samples ranged from non-detect to greater than 4,000 mg/kg. The majority of the composites had PCBs concentrations that were below 0.2 mg/kg. PCBs were not detected in ten of the composite samples, representing nearly 60% of the individual samples collected during this program. PCBs in twenty-five percent (5 of 20) of the composites were above 1 mg/kg. Of these, two composites had very high PCBs concentrations (greater than 1,000 ppm) that indicate PCBs were likely part of the original caulk or sealant formulations. Both composites were comprised of black, pliable joint filler materials that were collected from concrete bridges/overpasses.

This control measure has been developed as a result of the outcome of this study. For this control measure, Permittees will implement the following actions:

1. Maintain a list of applicable bridges that are scheduled for replacement or joint maintenance.
2. Implement or cause to be implemented the Caltrans specifications during applicable bridge projects that are under the direction of the Permittee.
3. Track and report on the use of the specifications for all applicable bridge projects within the Permittee's jurisdiction.

2.2 Treatment Control Measures

Treatment control measures include green stormwater infrastructure (GSI), full trash capture devices, enhanced operation and maintenance (O&M) practices, and diversion to publicly owned treatment works (POTW). Each of these treatment control measures are described below.

2.2.1 Green Stormwater Infrastructure

Green stormwater infrastructure (GSI) refers to constructing and retrofitting storm drainage systems to mimic natural processes by enabling stormwater to infiltrate into the soil rather than to runoff directly into storm drains. This control measure includes implementation of GSI in new development and redevelopment projects on private and public properties regulated by MRP Provision C.3, as well as retrofit of existing infrastructure in public right-of-way (ROW) areas and on public properties not subject to Provision C.3. GSI is being used to reduce runoff volumes, disperse runoff to vegetated areas, harvest and use runoff where feasible, promote infiltration and evapotranspiration, and use bioretention and other natural treatment control systems to detain and treat runoff before it reaches tributary creeks and, ultimately, San Francisco Bay. GSI treatment control measures include, for example, pervious pavement, infiltration basins, bioretention facilities, green roofs, and rainwater harvesting systems.

MRP Provision C.3 mandates implementation of a comprehensive program of stormwater control measures and actions designed to limit contributions of urban runoff pollutants to San Francisco Bay, including PCBs and mercury. GSI has been incorporated into new development and redevelopment projects in the County since the early 2000's. The first edition of the *C.3 Technical Guidance Manual* was published in 2005. The current 7th Edition of the *C.3 Technical Guidance Manual* was published in 2019. Many additional support documents are continually being developed by the ACCWP to assist the Permittees in C.3 implementation. All of these documents are available on the ACCWP website[12].

Permittees track C.3 project implementation in an ArcGIS Online (AGOL) database. ACCWP developed the countywide GIS database to assist with maintaining, analyzing, interpreting, displaying, and reporting relevant municipal stormwater program data and information related to MRP Provision C.3, Provision C.10 (i.e., trash load reduction activities), and Provisions C.11/C.12 (i.e., mercury and PCBs TMDL implementation activities).

[12] See: https://www.cleanwaterprogram.org/businesses/development.html.

MRP Provision C.3.j required each Permittee to develop a Green Infrastructure Plan for inclusion in the 2019 Annual Report. These Green Infrastructure Plans mapped and prioritized areas for potential and planned public and private GSI projects for implementation by 2020, 2030, and 2040. The RAA provided in Section 4 of this report estimates the PCBs and mercury load reductions that would be achieved through implementation of the Permittees' Green Infrastructure Plans.

The results of the RAA analysis (see Section 4) demonstrate that GSI projects that have the highest potential to reduce PCBs loads are concentrated within a small subset of the Alameda County Permittee area due to the pattern of pre-1980 industrial development within the region. Conversely, many Alameda County Permittees have no or very few opportunities to contribute significantly toward achievement of countywide PCBs loading reductions via implementation of GSI in their communities. Further, if PCBs load reductions are not achieved on a regional or countywide scale, and load reductions are allocated at a local level (by population), these Permittees would not be able to achieve those load reduction allocations due to a lack of opportunity.

Thus, given these findings, the Alameda County Permittees, collectively, believe that a countywide strategy would be the best way to achieve the PCBs load reduction goals in a more efficient and effective manner. For the purposes of creating their local GI Plans, Alameda County Permittees prioritized their GI projects based on achieving other multiple benefits. These other benefits include controlling other stormwater pollutants, preserving and enhancing local stream hydrology, reducing localized flooding, helping communities adapt to climate change by increasing the resiliency of water supply, ancillary benefits that derive from adding landscaped areas within the urbanized environment, and mitigating the urban heat island effect.

Additional actions that the Permittees have taken or will take to promote the implementation of GSI include:

- Incorporate GSI requirements into planning documents such as General Plans, Specific Plans, Complete Streets Plans, Active Transportation Plans, Storm Drain Master Plans, Pavement Work Plans, Urban Forestry Plans, Flood Control or Flood Management Plans, and other plans that may affect the future alignment, configuration, or design of impervious surfaces within the Permittee's jurisdiction;
- Evaluate funding options for GSI projects;
- Adopt policies, ordinances, and/or other appropriate legal mechanisms to ensure implementation of the Green Infrastructure Plan;

- Conduct public outreach, train Permittee staff, and educate elected officials on the MRP GSI requirements and methods of implementation; and
- Maintain a list of public infrastructure improvement projects that have a potential for incorporating GSI.

It is anticipated that the future iterations of the MRP will incorporate a required level of GSI implementation. The Permittees will continue to implement GSI in compliance with those provisions.

2.2.2 Full Trash Capture Treatment Control Measures

MRP Provision C.10 requires Permittees to implement trash prevention and control actions, including full trash capture systems, to reduce trash generation. Full trash capture systems capture sediment along with trash that may be contaminated with PCBs and mercury. Permittees have installed both large and inlet-based full trash capture devices in response Provision C.10. Large full trash capture devices, including hydrodynamic separators (HDS), gross solids removal devices (GSRDs), and baffle boxes, capture and treat urban runoff from large drainage areas, ranging from 10's to 100' of acres. Inlet-based devices in roadways enhance the capture of sediments that may be contaminated with PCBs and mercury from smaller, localized drainage areas. In addition, these inlets are typically cleaned more frequently as a result of the installation of the full trash capture device. Trash capture device implementation is described in each Permittee's Trash Load Reduction Plan.

2.2.3 Enhanced Operation and Maintenance

Routine MS4 O&M activities conducted by Permittees include street sweeping and drain inlet cleaning. In addition, storm drains, culverts, and channels are maintained as needed (i.e., desilted when needed to remove excessive quantities of accumulated sediment that may be causing localized flooding issues). Infrequent capital improvement projects may also remove accumulated sediment from the MS4, such as storm drain repairs or channel stabilization projects. Each of these O&M activities removes PCBs and mercury that are present in the sediment that is removed. The RAA provided in Section 4 of this report estimates the PCBs and mercury load reductions that are achieved through implementation of increased levels of O&M activities since 2003.

Enhanced O&M control measures are implemented as part of the Source Property Identification and Abatement Program (see Section 2.2.1 below) for referred source properties. Additional enhanced O&M measures may be implemented for Old Industrial source areas with observed elevated concentrations of PCBs if the source area investigation does not identify a specific source property and the source is suspected to be historically deposited sediment in the public ROW or the storm drain system.

PCBs and mercury load reductions achieved through implementation of enhanced O&M control measures, aside from enhanced O&M control measures associated with source property referrals, will be reported as part of the overall load reductions in future permit terms.

2.2.4 Diversion to POTW

This control measure consists of diverting dry weather and/or first flush events from MS4s to publicly owned treatment works (POTWs) as a method to reduce loads of PCBs and mercury in urban runoff. The Alameda County Flood Control and Water Conservation District (District) manages flood control infrastructure for flood protection of most of the urbanized portions of Western Alameda County. The District has an agreement with the East Bay Municipal Utility District (EBMUD) for operation of an urban runoff diversion at the Ettie Street Pump Station (ESPS) that directs dry weather discharge to EBMUD's main wastewater treatment plant for treatment. The project diverts up to 0.5 million gallons per day (mgd) of dry weather flow during the dry season (i.e., approximately April 16th through November 30th). EBMUD completed the installation of its pump and control system and a 6-inch diameter conveyance pipe in 2016 and the stormwater diversion is ongoing. District staff coordinates with and provides assistance to EBMUD staff to ensure proper operation and maintenance of the diversion pump.

No other pump station diversion is planned for implementation.

3 Mercury Control Measure Plan

3.1 Source Control Measures

3.1.1 Mercury Load Avoidance and Reduction

Mercury load avoidance and reduction includes several source control measures listed in the California Mercury Reduction Act adopted by the State of California in 2001. These source controls include material bans, reductions of the amount of mercury allowable for use in products, and mercury device recycling. The following source controls bans are included:

- Sale of cars that have light switches containing mercury;
- Sale or distribution of fever thermometers containing mercury without a prescription;
- Sale of mercury thermostats; and
- Manufacturing, sale, or distribution of mercury-added novelty items.

In addition, fluorescent lamps manufacturers continue to reduce the amount of mercury in lamps sold in the U.S. Manufacturers have significantly reduced the amount of mercury in fluorescent linear tube lamps.

Mercury device recycling programs resulting in mercury load reduction generally include three types of programs that promote and facilitate the collection and recycling of mercury–containing devices and products:

- Permittee-managed household hazardous waste (HHW) drop-off facilities and curbside or door-to-door pickup;
- Private business take-back and recycling programs (e.g., Home Depot); and,
- Private waste management services for small and large businesses.

The Permittees have been implementing these programs since 2005 and will continue to implement them as part of this control measure plan.

3.2 Treatment Control

Treatment control measures that address PCBs in stormwater will also reduce mercury. These treatment control measures, described in Section 2.2 above, include green stormwater infrastructure, full trash capture devices, and enhanced O&M.

Because of the widespread nature of mercury in the urban environment, further progress on reducing mercury loads will most likely occur in tandem with stormwater treatment control measures addressing PCBs (e.g., GSI implementation). The RAA provided in Section 6 of this report estimates the mercury load reductions that would be achieved through implementation of treatment control measures addressing PCBs.

4 Schedule of Implementation

4.1 Overall Schedule of Implementation

Table 4-1 below presents the schedule of implementation for each of the control measures described in the PCBs Control Measure Plan (Section 2) and the Mercury Control Measure Plan (Section 3). The schedule in Table 4-1 shows when implementation of each control measure began and will be complete with respect to TMDL implementation.

The RAA results provided in Section 6 predict that the PCBs TMDL WLA will be achieved in Alameda County by the year 2090, thus this date is listed for GSI and enhanced operations and maintenance (O&M). GSI implementation provides multiple benefits, addresses other urban pollutants, and is a requirement for new development and redevelopment projects, so would continue to be implemented as long as that requirement is in place. In addition, the Management of PCBs in Building Materials, Management of PCBs in Electrical Utilities, and Management of PCBs in Infrastructure programs will be implemented until these sources have been abated. As PCBs have been banned in the United States since 1979, it is likely that these programs will no longer be needed by 2080, 100 years later. The Source Property Identification and Abatement Program will be complete by 2040. Full trash capture device implementation is assumed to be complete no later than 2030. The source control measure Mercury Load Avoidance and Reduction, which began during MRP 1.0, is assumed to continue indefinitely.

Table 4-1: PCBs and Mercury Control Measure Plan Schedule of Implementation

Control Measure	Begin Implementation	Implementation Complete
Source Property Identification and Abatement	2012	2040
Management of PCBs in Building Materials	2019	2080
Management of PCBs in Electrical Utilities	2019	2080
Management of PCBs in Infrastructure	2021	2080
Green Stormwater Infrastructure	2003	2090
Full Trash Capture Treatment Control	2009	2030
Enhanced Operations and Maintenance	2003	2090
Mercury Load Avoidance and Reduction	2005	Ongoing

4.2 Green Stormwater Infrastructure Schedule of Implementation

Table 4-2 below provides an estimate of the area that will be treated through GSI implementation by 2020, 2030, and 2040 countywide. These areas are summarized from the Permittees' Green Infrastructure Plans, which were submitted to the SFBRWQCB in 2019. The data and models used to generate this estimate and schedules for GSI implementation for each Permittee are described in each Permittee's Green Infrastructure Plan and are summarized below. The RAA results for GSI implementation are based on these area predictions.

The projected pace of control measure implementation and the resultant predicted load reductions are based on current and projected business practices, which are subject to change. Economic or socio-economic impacts and political shifts may affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds available for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation.

Table 4-2: Estimate of Area Treated through GSI Implementation by 2020, 2030, and 2040 within Alameda County

Year	GSI Area Treated (acres)
2020	9,111
2030	11,568
2040	14,030

4.2.1 Private Redevelopment Area Projection

The ACCWP Permittees track GSI implemented as part of private development projects subject to MRP Provision C.3.d through the ACCWP's AGOL tracking tool. The combined area treated by GSI implemented for private development from 2003 through 2018 represents a portion of the 2020 total area included in Table 4-2; the remainder was projected private development.

To forecast private development for 2019/2020, 2021 through 2030, and 2031 through 2040, the ACCWP used the UrbanSim model developed by the Urban Analytics Lab at the University of California under contract to the Bay Area Metropolitan Transportation Commission (MTC). MTC forecasts growth in households and jobs and uses the UrbanSim model to predict new development and redevelopment to satisfy future demand. Model inputs include parcel-specific zoning and real estate data; model outputs show increases in households or jobs attributable to specific parcels. The methods and results of the Bay Area UrbanSim model have been approved for use in transportation projections and the regional Plan Bay Area development process.

ACCWP used outputs from the Bay Area UrbanSim model to map parcels predicted to undergo development or redevelopment in each Alameda jurisdiction at each time increment specified in the MRP (2020, 2030, and 2040). The resulting maps were reviewed by local staff for consistency with local knowledge and local planning and economic development initiatives, and the maps were revised as needed. Although the long-term projections based on UrbanSim are robust, there is a lot of uncertainty, much of it due to the unpredictability of future economic conditions.

4.2.2 Public GSI Project Area Projection

Publicly owned parcels and ROWs that could potentially be retrofit to include multi-benefit stormwater capture facilities were identified as part of the Alameda County Stormwater Resource Plan (SWRP) (ACCWP, 2019). These potential project locations were used as the basis for identifying potential public retrofit locations within each Permittee's jurisdiction based on local knowledge and priorities. Note that the public projects listed in the Permittees' GI Plans were based on desktop analysis and have not been field verified. The GI Plans described the process by which Permittees would move forward, when funding is available, to verify the feasibility of stormwater retrofit at the project locations.

5 Evaluation of Costs, Control Measure Efficiency, and Significant Environmental Impacts

5.1 Cost Analysis

5.1.1 Green Stormwater Infrastructure Cost Methodology

GSI project cost data were gathered from several sources within the Bay Area and Southern California to develop relationships between project size (tributary drainage area) and total capital cost (construction and design). Likewise, O&M cost data were gathered from these sources, as well as through literature review. A technical memorandum summarizing this cost analysis is provided in Appendix C. The results of this analysis for project capital costs, in 2018 dollars, are presented in Table 5-1 below. Actual GSI project implementation costs will vary and may be greater than those listed in Table 5-1.

Table 5-1: Statistical Summary of Unit Capital Cost for Green Street, Parcel-Based, and Regional GSI Project Types

Project Category	No. of Projects (n)	Unit Capital Cost ($/ac treated) in 2018 Dollars[1]					
		Minimum	25th-percentile	Median	75th-percentile	Maximum	Mean
Green Street	19	$25,000	$70,000	$137,000	$267,000	$1,290,000	$213,000
Distributed Green Infrastructure	21	$16,000	$90,000	$121,000	$176,000	$416,000	$153,000
Regional Stormwater Control	11	$15,000	$25,000	$61,000	$127,000	$427,000	$101,000

1 Units have been rounded to the nearest $1,000.

Annual O&M costs are intended to account for activities necessary to maintain the effectiveness of a project that recur on a regular basis, such as routine maintenance on an annual basis or repairs following a large storm event. For this cost analysis, annual O&M costs do not include replacement (of portions) or rehabilitation of GSI facilities, which occurs approximately every 20 to 30 years. For planning purposes, annual O&M costs are often assumed to be a percentage of the capital (design and construction) costs. Annual O&M costs range from approximately 1% to 6% of the capital costs, with an average of 4% of capital cost for the data sources reviewed.

The estimated capital cost, which includes both the design cost and the construction cost, for the estimated public GSI project area listed in Table 4-2 is provided in Table 5-2 below. This cost was estimated by applying the Green Street unit cost to right-of-way area and the Distributed Green Infrastructure unit cost to the parcel area within the total estimated public GSI project area for each year. The low, medium, and high cost estimates were calculated using the 25th percentile, median, and 75th percentile unit costs. The annual O&M cost was calculated by multiplying the capital cost by an estimated fixed O&M cost factor of 4%. The total project cost includes the capital costs and the annual O&M costs over the design life of the project. For the purposes of this analysis, a 20-year design life and a 3% inflation rate were used to calculate the total present value of the annualized O&M costs. The costs listed in Table 5-2 do not include replacement costs that would be expected to occur at the end of the useful life of the facility.

Table 5-2: Estimated Cost to Treat Public GSI Project Area by 2020, 2030, and 2040 within Alameda County

Year	Total Capital Cost ($1,000)			Annual O&M Cost ($1,000)			Total Project Cost ($1,000)		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
2020	$173,000	$249,000	$387,000	$6,920	$9,960	$15,480	$279,000	$402,000	$624,000
2030[1]	$216,000	$321,000	$515,000	$8,640	$12,840	$20,600	$348,000	$518,000	$831,000
2040[1]	$259,000	$392,000	$640,000	$10,360	$15,680	$25,600	$418,000	$632,000	$1,032,000

1. The cost estimates are cumulative from 2020 to 2030 and 2040.

Public project implementation will depend on funding availability. Funding for implementation of projects included in the Permittees' Green Infrastructure Plans would be obtained by the municipal agency, partnerships of agencies, or other stakeholder project sponsors working to implement the identified projects. Economic or socio-economic impacts and political shifts may affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds available for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation.

5.1.2 Source Control Measure Cost Analysis

A regionally consistent approach to estimating source control program implementation costs developed through collaboration with the other Bay Area stormwater programs is summarized in Table 5-3 below. These cost values represent average values based on a representative sample of implemented measures.

Table 5-3: Planning Level Cost Estimate Values for Source Control Measures

Control Measure Category	Control Measure	Unit of Implementation	Estimated Unit Costs[1]			
			Initial[2]		Ongoing[3]	
			Cost	Unit	Cost	Unit
Source Area Identification and Referral	Identify and Refer Source Properties	Acres of old industrial land use area investigated	$382	$/acre	NA	NA
Full Trash Capture (FTC)	FTC Implementation - Large Devices	Acres treated	$4,500	$/acre	$6,000	$ per year
	FTC Implementation - Small Devices	Acres treated	$1,000	$/acre	$400	$ per year
Enhanced Municipal Operation and Maintenance (O&M)	Enhanced Street Sweeping - mechanical broom	Acres addressed	$48 / curb-mile swept (lifecycle cost)			
	Enhanced Street Sweeping - Regenerative Air or Vacuum Assisted	Acres addressed	$80 / curb-mile swept (lifecycle cost)			
	Street Flushing	Linear mile of street flushed	$193,139	$ / linear mile of street flushed	NA	NA
	Enhanced Inlet Cleanout	Number of inlet cleaned out	NA	NA	$100	$ per cleanout
	Enhanced Pump Station Cleanout	Additional annual cleanouts	$82,200	$/cleanout	NA	NA
	Storm Drain Piping Cleanout	Annual cleanouts	$146,062	$/cleanout	NA	NA
Managing PCBs-containing Materials during Building Demolition		Annual cost	NA	NA	$400	$ per application
PCBs in Infrastructure Management Program		Annual cost	Minor municipal cost - just tracking and reporting. Some ongoing Program costs but also small.			
Management of PCBs in Electrical Utility Equipment		Annual cost	Minor municipal cost - just tracking and reporting. Some ongoing Program costs but also small.			

1. The unit costs are rough planning level estimates that do not consider net present worth cost adjustments or other complexities. These costs are not a true accounting of costs incurred to-date.
2. Initial costs generally include planning, design, capital, and other initial one-time costs.
3. Ongoing costs include operation & maintenance and other ongoing costs.

These planning level costs have been applied to an estimated level of implementation for each of the planned source control measures in Table 5-4 below.

Table 5-4: Planning Level Cost Estimate for Source Control Implementation – ACCWP

Control Measure	Unit Area Treated (acres) or Units Implemented			Estimated Implementation Cost		
	2020[1]	2030	2040	2020	2030	2040
Management of PCBs in Building Materials	30 applications	300 applications	600 applications	$12,000	$120,000	$240,000
Source Property Identification and Abatement	75 acres	87 acres	99 acres	$29,000	$33,000	$38,000
Full Trash Capture Treatment Control – Large Devices	7,100 acres	7,100 acres	7,100 acres	$1,554,000	$9,546,000	$18,426,000
Full Trash Capture Treatment Control – Inlet-Based Devices	17,660 acres	27,121 acres	27,121 acres	$9,286,000	$47,190,000	$87,936,000

1. The costs are rough planning level estimates that do not consider net present worth cost adjustments or other complexities. These costs are not a true accounting of costs incurred to-date.

As can be seen in Table 5-3 and Table 5-4, the estimated planning level cost for implementing source control programs, aside from full trash capture devices, is negligible in comparison to the estimated costs for implementing GSI measures. Although the estimated initial capital cost of the full trash capture devices is much less than the estimated costs of GSI implementation, the estimated full trash capture device cost is much higher than the programmatic source control program implementation costs, and over time, the ongoing O&M cost for the full trash capture devices contributes to the significant total implementation cost.

5.2 Control Measure Efficiency

In general, as discussed above, source control measures are much more cost efficient to implement than structural treatment control measures.

There are several factors that are considered when selecting control measures to address PCBs and mercury for a specific area. Cost efficiency (i.e., the cost per mass of pollutant reduced), while an important factor, is not sufficient when considering which type of control measure to implement at the management area or site scale. Different types of control measures may be more appropriate in some situations than others. Additionally, the potential load reduction available for each type of control measure varies; some control measures may be more effective but not have as much opportunity for implementation (such as source property identification and abatement), while others may be less effective but have much more opportunity (such as full trash capture devices).

Factors that help identify optimal implementation for a given location are listed below; site- or catchment-specific characteristics may increase or decrease the importance of any of these factors at a given location:

- *Costs*: includes all lifecycle (i.e., including maintenance) costs associated with planning and implementing a given control measure.
- *Load Reduction Potential*: includes the load reduction potential at the site, catchment, or municipal scale.
- *Opportunity*: includes the current and future opportunities and feasibility to implement a given control measure successfully.
- *Safety*: includes consideration of the potential to cause a safety hazard and the need for any additional measures to avoid creating a safety hazard. Safety hazards may include slip, trip, or fall hazards; drowning hazards; visual impairments (i.e., overgrowth into a roadway); vector concerns; chemical hazards; or flooding concerns.
- *Implementation Challenges*: includes consideration of potential implementation challenges due to local ordinances or regulations, resistance from the local community, or ability to obtain adequate funding.

5.2.1 Clean Watersheds for a Clean Bay

The Clean Watersheds for a Clean Bay (CW4CB) project was a collaboration among the BASMAA member agencies funded by a San Francisco Bay Water Quality Improvement Fund grant from the United States Environmental Protection Agency and matching funds from Bay Area countywide stormwater management programs and member agencies. The CW4CB project was designed to evaluate the effectiveness of stormwater controls for PCBs and mercury in response to the PCBs and mercury TMDLs. The CW4CB project pilot-tested methods to control discharges of PCBs and mercury in urban stormwater runoff and developed and implemented a regional risk reduction program that focused on targeted education on the health risks of consuming certain species of Bay fish that contain relatively high levels of mercury and PCBs. The results of the CW4CB project are available on the CW4CB website (http://basmaa.org/Clean-Watersheds-for-a-Clean-Bay-Project).

A significant finding from the project was that source control measures, such as source area identification and abatement, are much more cost effective for controlling PCBs and mercury than treatment control measures.

Table 5-5 lists the estimated cost per unit pollutant load reduced by the source property identification and referral and the treatment control retrofit pilot projects. The source property identification and referral cost per unit load reductions represent the cost of pollutant loads reduced per acre of watershed investigated. Costs are in 2016 dollars.

Table 5-5: Estimated Cost Effectiveness for the CW4CB Source Property Identification and Abatement and Treatment Control Retrofit Pilot Projects

Pilot Project Type	Average Cost per PCBs Unit Load Reduced[1] ($/(mg/year))	Estimated Cost per Mercury Unit Load Reduced[1] ($/(mg/year))
Source Area Identification and Abatement[2]	$16	$53
Treatment Control Retrofit		
Tree Well Filter[3]	$4,400	$9,800
Bioretention[4]	$22,000	$372,500
Catch Basin Media Filter[5]	$53,100	$7,800
Vegetated Swale[6]	$47,600	$1,100
HDS Unit[7]	$700	$3,000

1. Assigns the pilot project total design and construction costs to each pollutant independently. Treatment control retrofit project costs are not annualized.
2. Average for all five pilot watersheds of cost of loads reduced per acre of watershed area investigated ($/acre) divided by the unit load reduced ((mg/yr)/acre).
3. Average of cost per acre treated ($/acre) divided by unit load reductions ((mg/yr)/acre) for the West Oakland Industrial Area Tree Wells.
4. Average of cost per acre treated ($/acre) divided by unit load reductions ((mg/yr)/acre) for the El Cerrito Green Streets, Bransten Road, and PGE 1st and Cutting projects.
5. Average of cost per acre treated ($/acre) divided by unit load reductions ((mg/yr)/acre) for the Vallejo PG&E Substation.
6. Average of cost per acre treated ($/acre) divided by unit load reductions ((mg/yr)/acre) for the Broadway and Redwood Swale.
7. Average of cost per acre treated ($/acre) divided by unit load reductions ((mg/yr)/acre) for the Leo Avenue HDS Unit only, pollutant reduction values are not available for the Alameda and High project.

5.2.2 PCBs and Mercury Control Measure Plan Cost Effectiveness

A comparison of the estimated cost for GSI implementation in Section 5.1.1 to the source control measure analysis in Section 5.2.2 demonstrates that the programmatic source control measures (i.e., Source Property Identification and Abatement, Management of PCBs in Building Materials, Management of PCBs in Electrical Utilities, and Management of PCBs in Infrastructure) are much more cost efficient than treatment control measures (GSI and full trash capture devices) at reducing loads of PCBs in urban runoff.

5.3 Significant Environmental Impacts

The California Environmental Quality Act (CEQA) establishes requirements and procedures for state and local agency review of the environmental effects of projects proposed within their jurisdictions. It further requires that agencies, when feasible, avoid or reduce the significant environmental impacts of their decisions. The applicable statutes are contained in California

Public Resources Code, Sections 21000 - 21189, and Title 14 CCR, Division 6, Chapter 3, Sections 15000 – 15387.

CEQA applies to all California public agencies that carry out or approve projects. CEQA compliance is only required if a lead agency is considering approval of a proposed "project." The distinction between the normal and the specific CEQA meaning of "project" is very important, as it can determine whether an action is subject to CEQA compliance or not. Section 15378 of the State CEQA Guidelines provides the following definition of a project:

1. "Project" means the whole of an action, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and that is any of the following:

    a. An activity directly undertaken by a public agency including but not limited to public works construction and related activities clearing or grading of land, improvement to existing public structures, enactment and amendment of zoning ordinances, and the adoption and amendment of local General Plans or elements thereof pursuant to Government Code Sections 65100-65700.

    b. An activity undertaken by a person which is supported in whole or in part through public agency contacts, grants subsidies, or other forms of assistance from one or more public agencies.

    c. An activity involving the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies.

CEQA requires the preparation of an Initial Study to determine if a project may result in significant effects on the environment. If there is substantial evidence in the record that supports a fair argument that significant effects may occur, an Environmental Impact Report will be prepared. A Negative Declaration or Mitigated Negative Declaration must be prepared if there is no substantial evidence that the project may have a significant effect on the environment, or if revisions to the project would avoid or mitigate the effects that would result in no significant effects.

The CEQA Guidelines stipulate that a public agency shall prepare or have prepared a proposed Negative Declaration or Mitigated Negative Declaration for a project subject to CEQA when:

- The initial study shows that there is no substantial evidence, in light of the whole record before the agency, that the project may have a significant effect on the environment, or

- The initial study identifies potentially significant effects, but:

- Revisions in the project plans or proposals made by, or agreed to by the applicant before a proposed mitigated negative declaration and initial study are released for public review would avoid the effects or mitigate the effects to a point where clearly no significant effects would occur; and
- There is no substantial evidence, in light of the whole record before the agency, that the project as revised may have a significant effect on the environment.

CEQA requires that reasonable alternatives to implement a proposed project should be considered during the planning process and potential environmental effects should be included in the evaluation of the project. CEQA also requires state and local agencies to disclose and consider the environmental impacts of their actions. It further requires that agencies, when feasible, avoid or reduce the significant environmental impacts of the implementation of their action.

This TMDL Control Measure Plan is statutorily exempted under Public Resources Code (California Administrative Code Sec. 15262 et seq.) because it involves feasibility or planning studies for possible future actions that the Permittees have not approved or adopted. Any future projects that are to be constructed as recommended by this Plan will either be determined to be exempt from CEQA or an initial study to determine potential environmental impacts will be prepared. In general, this TMDL Control Measure Plan has been determined to have no potential to generate significant adverse impacts to the environment, but instead will lessen adverse water quality impacts through reducing loads of PCBs and mercury into the Bay.

6 Reasonable Assurance Analysis

This section presents the results of the RAA required by MRP Provisions C.11.c, C.11.d, C.12.c, and C.12.d for the control measures that are described in the preceding sections of this report (Section 2 – the PCBs Control Measure Plan and Section 3 – the Mercury Control Measure Plan). The methodologies for estimating load reductions are introduced herein; additional details on the RAA methodology are provided in Appendix D and Appendix E.

6.1 Methodology

The approach used to estimate the load reductions resulting from implementation of the PCBs Control Measure Plan and the Mercury Control Measure Plan includes several different model components. The methodology is consistent with the *Bay Area RAA Guidance Document* (BASMAA, 2017). The model components include:

- Baseline Pollutant Loading Model – the baseline pollutant loading model is a continuous simulation[13] hydrology model combined with pollutant loading inputs to obtain the average annual loading of mercury and PCBs across Alameda County during the TMDL baseline period (i.e., 2003 – 2005, see BASMAA, 2017). See Section 4.1 for a summary of the baseline model results.
    - Hydrology – this model component produces average annual runoff across Alameda County for the period of record using a hydrologic response unit (HRU) approach. The HRU approach involves modeling various combinations of land surface features (i.e., imperviousness, underlying soil characteristics, slope, etc.) present within each county for a unit area drainage catchment.
    - Water Quality – the hydrology output is combined with average annual concentrations estimated by the Regional Monitoring Program's Regional Watershed Spreadsheet Model (RWSM; SFEI, 2018) developed by SFEI to produce average annual PCBs and mercury loading for the period of record.
- GSI Performance Models – GSI performance models were developed to represent load reductions resulting from implementation of GSI.

[13] Continuous simulation models calculate outputs (e.g., runoff) "continuously", i.e., for many time steps over a long-term period of record (e.g., every 10 minutes for 10 years). Long-term "continuous" input data (e.g., hourly rainfall) is required. This is contrasted with design-event simulations which model a single rainfall event, e.g., a 24-hour storm with a 10-year recurrence frequency.

- Source Control Measure Calculations – Calculation methods for estimating load reduction associated with implementation of the source control measures identified in the PCBs Control Measure Plan and the Mercury Control Measure Plan, as established in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020, provided in Appendix D).
- Future Condition (RAA Scenario) Models – the RAA scenario models represent future land use changes and control measure implementation that would result in pollutant load reduction. These include the following (see Section 4.2):
    - Future Land Use – changes to land use as a result of new development and redevelopment and the associated reduction in pollutant loading (i.e., with newer building materials and practices) is represented.
    - Future GSI Performance – the GSI performance model output is applied to areas to be treated by GSI in the future based on the Permittees' Green Infrastructure Plans (see Section 2.1).
    - Source Control Measure Performance – Performance of the source control measures that have been or will be implemented is modeled based on the incidence and location of these control measures.

These components are introduced in the following sections and described in further detail in the Peer Review Package (Appendix E). Third party peer review was undertaken for the baseline model and GSI performance models; documentation of this peer review is provided in Appendix E.

6.1.1 Baseline

The baseline pollutant loading model is a representation of the loading of PCBs and mercury across the County during the TMDL baseline period (i.e., 2003 – 2005, see BASMAA, 2017). The baseline model utilizes an HRU approach to estimate runoff across the County. Generic HRUs, characterized by varying the values of specific identified parameters within a defined representative range, were modeled using USEPA's Stormwater Management Model (SWMM). HRU parameters varied included precipitation and evaporation, slope, underlying soil type (i.e., subsurface infiltration rate) and compaction (i.e., developed versus undeveloped areas), and imperviousness. Continuous simulation HRU models were run on an hourly timestep for the identified baseline period of record (water years [WYs] 2000 – 2009).

An average annual runoff volume per acre was obtained for each HRU through the continuous simulation runs. The average annual runoff volume per acre associated with each specific HRU was multiplied by the area represented by that HRU within the entire area of analysis (i.e., across the county, estimated using geospatial data). Watershed-based drainage routing was accounted for through calibration efforts. Calibration of the generic HRU models was conducted on the average annual discharge volume for WYs 2000-2009, utilizing available stream flow records. The objective of the calibration was to reasonably match the average annual runoff volume for this 10-year period (i.e., within the bounds included in BASMAA (2017). Additional details regarding the calibration efforts are provided in Appendix E.

To obtain pollutant loading, average annual concentrations estimated by the RWSM (SFEI, 2018), for each land use category (i.e., Old Industrial, Old Urban Commercial/Transportation, Old Urban Residential, New Urban, and Open Space) are multiplied by the calibrated average annual runoff volume estimated using the HRU approach. The average annual PCBs and mercury loading for the baseline period of record was validated using available in-stream concentration data, as described in Appendix E.

A flow chart representing the baseline loading model is provided in Figure 6-1 below.

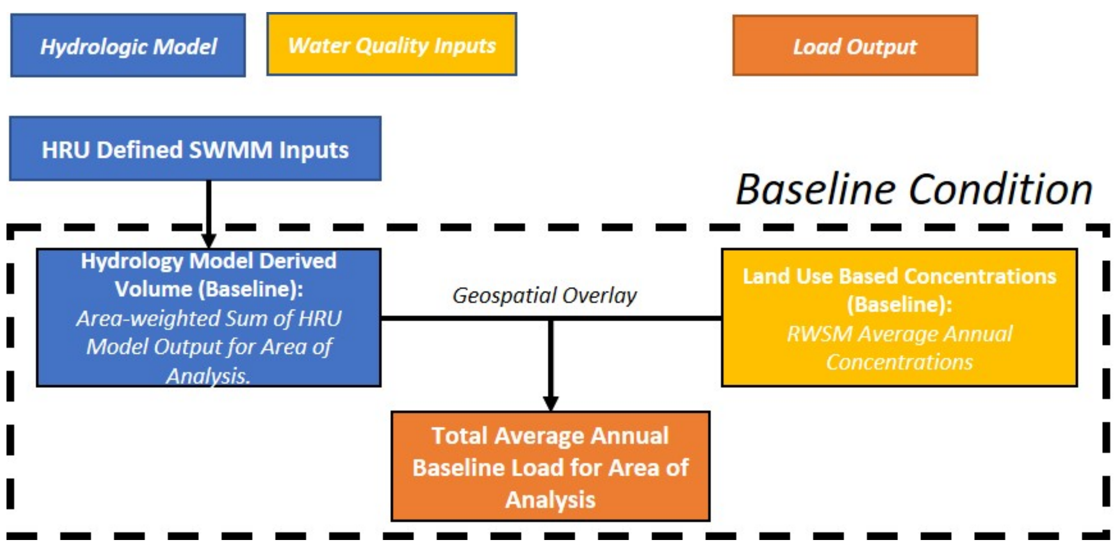

Figure 4-1: Baseline Condition Model Flow Chart

6.1.2 Loads Reduced

Loads reduced from baseline are estimated based on projected land use changes and control measure implementation. To calculate pollutant load reductions associated with land use changes and GSI and source control implementation for future scenarios, the difference between the pollutant loading in the baseline scenario and the total pollutant loading associated with each future implementation scenario were calculated. Future scenarios included implementation in years 2030, 2040, and beyond 2040. Loads reduced resulting from implementation of control measures are estimated through different methods depending on control measure type. Details relating to load reductions resulting from land use changes versus those from control measures are provided in the following sections.

Load Reduction Resulting from Land Use Changes

Land use-based pollutant loading was based on changes to the land use through new development and redevelopment that has occurred or is projected to occur since the 2003-2005 baseline. To forecast future private development area, ACCWP used the output of UrbanSim,[14] a model developed by the Urban Analytics Lab at the University of California under contract to the Bay Area Metropolitan Transportation Commission (MTC). The UrbanSim modeling system was developed to support the need for analyzing the potential effects of land use policies and infrastructure investments on the development and character of cities and regions. The Bay Area's application of UrbanSim was developed specifically to support the development of Plan Bay Area, the Bay Area's Sustainable Communities planning effort.

MTC forecasts growth in households and jobs and uses the UrbanSim model to identify development and redevelopment sites to satisfy future demand. Model inputs include parcel-specific zoning and real estate data; model outputs show increases in households or jobs attributable to specific parcels. The methods and results of the Bay Area UrbanSim model have been approved by both MTC and Association of Bay Area Governments Committees for use in transportation projections and the regional Plan Bay Area development process.

The ACCWP process used outputs from the Bay Area UrbanSim model to map parcels predicted to undergo development or redevelopment in each jurisdiction within Alameda County at the time increments specified in the MRP (2020, 2030, and 2040). The resulting maps were reviewed by Permittee staff for consistency with local knowledge and local planning and economic development initiatives and revised as needed.

If projected new development and redevelopment is assumed to alter the imperviousness of parcels identified for development, the HRU assigned at the parcel scale was revised from the baseline condition to represent the new imperviousness (no other HRU variables would be anticipated to change) in the future condition. Similarly, the overlying RWSM land use category designation was updated from the baseline condition to reflect new land uses from new

[14] http://www.urbansim.com/

development and redevelopment. Updated land use-based pollutant loading was then calculated for the future conditions, using the applicable updated HRU and RWSM land use category assignments.

Load Reductions Resulting from GSI Implementation

Load reduction through implementation of GSI facilities was estimated through the methods described as part of the *Quantitative Relationship between GSI Implementation and PCBs/Mercury Load Reductions Report* (ACCWP, 2018; provided in Appendix E). The POC load reductions through GSI were developed through a combination of hydraulic modeling of GSI facilities combined with empirically derived effluent concentration estimates. The annual estimate of pollutant load reduction from the modeled drainage area is equivalent to the difference between the influent load and the sum of the pollutant load that bypasses the GSI facility and the effluent load. The effluent load is calculated as the proportion of runoff that is treated by the GSI facility multiplied by an effluent concentration. Water quality performance data from selected, representative studies were used to determine a method to predict effluent concentrations in stormwater following treatment through a biofiltration (bioretention or tree well filters) GSI facility. A flow chart representing the GSI load reduction modeling is provided in Appendix E.

GSI implementation levels corresponding to each future implementation scenario were estimated based on GSI Plan projections. The pollutant loading resulting from each of the GSI implementation scenarios was calculated by first applying the updated land use loading. Then, pollutant load reductions resulting from implementation of GSI were applied to identified GSI drainage areas (i.e., both development areas, where land uses are assumed to change, and GSI retrofit areas, where land uses are not assumed to change) to obtain a revised total pollutant loading for those land surfaces. Resulting pollutant loading for areas identified as draining to GSI and areas not draining to GSI were combined geospatially to obtain the pollutant loading associated with each GSI implementation scenario.

Load Reductions Resulting from Implementation of Source Controls

Pollutant load reductions from the source controls described in the implementation plans are incorporated into the RAA scenarios for the TMDL attainment date (i.e., 2030) along with future scenarios for 2040 and beyond 2040. The calculation methods used to estimate load reduction are those described in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* (BASMAA, 2020, provided in Appendix D). The resulting load reductions from source controls are combined with the land use and GSI load reduction estimations to get the total estimated load reduction for each future implementation scenario.

6.2 Baseline PCBs and Mercury Loads and Load Reduction Goals

6.2.1 PCBs

Refined PCBs Baseline Load

The results of the RAA baseline modeling for PCBs are presented for Alameda County in Table 6-1 below.

Table 6-1: RAA Model Baseline Loading Estimates – PCBs

RWQCB Region	Above/Below Dam	Permit	Baseline Load Alameda County (kg/yr)
Region 2	**Below Dam**	**MRP[1]**	**3.74**
		NPDES[2]	0.04
		Phase II[3]	0.45
	TMDL Baseline		***4.23***
	Above Dam	MRP[1]	0.03
		NPDES[2]	0
		Phase II[3]	<0.01
		Total	4.27

[1] Municipal Regional Permit permitted areas, along with IGP facilities and facilities with individual NPDES Stormwater Industrial permits.
[2] Major and Non-Major dischargers with individual NPDES permits. See Appendix F.
[3] Phase II General Permit permittees. See Appendix F.

The countywide baseline load estimated using the RAA model is 4.23 kg/yr. The baseline load estimated for the Permittees after deducting the estimated baseline load for the NPDES dischargers within the County is 3.74 kg/yr. This baseline load is used to establish the PCBs TMDL load reduction goal described below.

TMDL Attainment Load Reduction Goal (2030)

Calculations were conducted to develop the PCBs load reduction goals as described in the *Bay Area RAA Guidance Document* (BASMAA, 2017). The calculation methodology is summarized below.

LR_{goal} = Baseline – WLA (kg/yr)

Where:

LR_{goal} = The load reduction goal (kg/yr)

Baseline = The baseline pollutant loading as calculated through the RAA

WLA = The population-based wasteload allocation for Alameda County

The TMDL population-based wasteload allocation for Alameda County is 0.5 kg/yr. This wasteload allocation must be distributed between the MRP permittees and other permitted stormwater dischargers (i.e., individual NPDES permittees and Phase II permittees). The wasteload allocations calculated to reflect the relative percentage of the estimated baseline loads are provided in Table 6-2.

Table 6-2: TMDL Wasteload Allocations for Alameda County

Stormwater Discharger within TMDL Baseline Area[1]	Percentage of Baseline Load (%)	PCBs WLA (kg/yr)
MRP Permittees	88%	0.44
NPDES Permittees	1%	0.01
Phase 2 Permittees	11%	0.05
Alameda County	100%	0.5

[1] All SFBRWQCB Region 2, above dams.

Using the calculated Permittee proportion of the WLA and RAA-calculated baseline load, the load reduction goal is estimated to be 3.30 kg/yr (i.e., 3.74 kg/yr – 0.44 kg/yr).

MRP Load Reduction Goal through GI by 2040

The PCBs load reduction required to be achieved through GI by 2040 per MRP Provision C.3.j (i.e., 3 kg/yr MRP area-wide or 0.5 kg/yr for Alameda County) must be adjusted to reflect the RAA-calculated load reduction goal (i.e., 3.30 kg/yr). The MRP load reduction requirement for GI for all Permittees (3 kg/yr) represents 20.8% of the overall load reduction required in the TMDL. Therefore, the adjusted countywide load reduction through GI can be calculated as:

$$LR_{MRP,\ GI,\ 2040} = LR_{goal} * 20.8\%$$

The adjusted countywide MRP PCBs load reduction goal through GSI by 2040 is presented in Table 6-3.

Table 6-3: Adjusted Countywide PCBs Load Reduction Goal through GI by 2040

County	PCBs Load Reduction Goal through GI (kg/yr)
Alameda County	0.69

6.2.2 Mercury

Refined Mercury Baseline Load

The results of the RAA baseline modeling for mercury are presented for Alameda County in Table 6-4 below. The countywide TMDL baseline load estimated with the RAA model is 8.73 kg/yr

Table 6-4: RAA Model Baseline Loading Estimates – Mercury

RWQCB Region	Above/Below Dam	Permit	Baseline Load Alameda County (kg/yr)
Region 2	Below Dam	**MRP[1]**	**8.51**
		NPDES[2]	0.02
		Phase 2[3]	0.20
	TMDL Baseline		***8.73***
	Above Dam	MRP[1]	1.68
		NPDES[2]	0.00
		Phase 2[3]	<0.01
		Total	10.41

[1] Municipal Regional Permit permitted areas, along with IGP facilities and facilities with individual NPDES Stormwater Industrial permits.

[2] Major and Non-Major dischargers with individual NPDES permits. See Appendix F.

[3] Phase II General Permit permittees. See Appendix F.

TMDL Attainment Load Reduction Goal (2028)

The mercury WLA for Alameda County is 20 kg/yr, while the estimated baseline load for the entire county below dams is only 8.73 kg/yr. Thus, the results of the RAA indicate that the TMDL wasteload allocation has been achieved.

MRP Load Reduction Goal through GI by 2040

The mercury load reduction required to be achieved through GSI by 2040 per MRP Provision C.3.j is 10 kg/yr MRP area-wide (3.13 kg/yr for Alameda County). This represents 2.5% of the TMDL baseline load of 127.7 kg/yr for the Alameda County MRP area. Applying this percentage to the adjusted baseline from the RAA model, an adjusted GSI goal would be 0.21 kg/yr for Alameda County (i.e., 8.51 kg/yr x 0.025 = 0.21 kg/yr).

6.3 Estimate of Loads Reduced

6.3.1 Loads Reduced – PCBs

The total estimated annual PCBs loads reduced through implementation of control measures by 2020, 2030, 2040, and beyond 2040 is provided in Table 6-5.

Table 6-5: Summary of PCBs Load Reductions Achieved through Control Measure Implementation

Control Measure	PCBs Load Reduction (kg/yr) by:			
	2020	2030	2040	2090
Source Property Identification and Abatement	0.29	0.49	0.55	0.55
PCBs in Building Materials Management	0.63	0.63	0.63	0.63
PCBs in Electrical Utilities Management	0.12	0.20	0.27	0.34
PCBs in Infrastructure	0	0.01	0.03	0.06
Green Stormwater Infrastructure	0.23	0.38	0.60	1.50
Full Trash Capture Treatment Control Measures	0.14	0.22	0.22	0.22
Enhanced Operations and Maintenance	0.0002	0.0002	0.0002	0.0002
Diversion to POTW	0.001	0.001	0.001	0.001
Total Load Reduced	**1.41**	**1.93**	**2.30**	**3.30**
Load Reduction Goal	**3.30**	**3.30**	**3.30**	**3.30**
Remaining Load to be Reduced	**1.89**	**1.37**	**1.00**	**0**

PCBs TMDL Attainment (2030)

As can be seen in Table 6-5, the required load reduction to achieve the TMDL (3.30 kg/yr) is not met by the TMDL compliance date of 2030. Assuming the annual average load reduction estimated between 2020 and 2040 for GSI is extended past 2040, the PCBs TMDL load reduction goal would be achieved by 2090.

An analysis of scenarios to achieve the TMDL wasteload allocation by 2030 is provided in Appendix G. The results of these analyses show that it is technically and economically infeasible to achieve the TMDL wasteload allocation by 2030.

MRP GSI Load Reduction Goal (2040)

The estimated PCBs load reduced through implementation of GSI by 2040 is 0.60 kg/yr (Table 6-5). As discussed in Section 6.1.3, the RAA-adjusted goal is 0.69 kg/yr, thus there is a predicted 0.09 kg/yr deficit. Extrapolating the average annual increase in load reduction through GSI predicted to occur from 2020 – 2040, the MRP PCBs GSI load reduction goal would be achieved by 2045.

Public GSI retrofit opportunities that have the highest potential to reduce PCBs loads are concentrated within a small subset of Alameda Permittee area due to the pattern of pre-1980 industrial development within the region. Conversely, many Alameda Permittees have no or very few opportunities to contribute significantly toward achievement of countywide PCBs loading reductions via implementation of GSI in their communities. Further, if load reductions are not achieved on a regional or countywide scale, and load reductions are allocated at a local level (by population), these Permittees would not be able to achieve those load reduction allocations due to a lack of opportunity.

Thus, given these findings, the Alameda Permittees, collectively, believe that a countywide strategy would be the best way to achieve the PCBs load reduction goals in a more efficient and effective manner. For the purposes of creating their local GI Plans, Alameda Permittees have prioritized their GSI projects based on achieving other multiple benefits. These other benefits include controlling other stormwater pollutants, preserving and enhancing local stream hydrology, reducing localized flooding, helping communities adapt to climate change by increasing the resiliency of water supply, ancillary benefits that derive from adding landscaped areas within the urbanized environment, and mitigating the urban heat island effect.

6.3.2 Loads Reduced – Mercury

The total estimated mercury loads reduced through implementation of control measures by 2020, 2030, 2040, and 2080 is provided in Table 6-7. Note that these estimated load reductions do not account for loads reduced by the Mercury Load Avoidance and Reduction source control measure. ACCWP will continue to annually compile and report the number of mercury-containing products collected at household hazardous waste facilities. Translation of that collection information to loads reduced from urban stormwater discharges is challenging and may not be necessary to show attainment of the mercury TMDL.

Table 6-6: Summary of Mercury Load Reductions Achieved through Control Measure Implementation

Control Measure	Hg Load Reduction (kg/yr) by:			
	2020	2030	2040	2080
Green Stormwater Infrastructure	0.18	0.25	0.33	0.41
Full Trash Capture Treatment Control Measures	0.22	0.31	0.31	0.31
Enhanced Operations and Maintenance	0.00	0.00	0.00	0.00
Diversion to POTW	0.003	0.003	0.003	0.003
Total	**0.40**	**0.56**	**0.65**	**0.72**
Load Reduction Goal via GI in MRP 2	**3.13**	**3.13**	**3.13**	**3.13**
Remaining Load to be Reduced via GI	**2.73**	**2.57**	**2.48**	**2.41**

Mercury TMDL Attainment (2028)

As is stated in Section 6.2.2 above, mercury WLA for Alameda County is 20 kg/yr, while the estimated baseline load for the entire county below dams is only 8.73 kg/yr. Thus, the results of the RAA indicate that the TMDL wasteload allocation has been achieved.

MRP Load Reduction Goal through GSI (2040)

The estimated mercury load reduction by 2040 through GSI (0.33 kg/yr) is predicted to achieve the adjusted MRP load reduction goal for GSI by 2040 (0.21 kg/yr).

6.3.3 Uncertainty Analysis

As summarized in the RAA Guidance Document (BASMAA, 2017), according to USEPA's Guidance on the Development, Evaluation, and Application of Environmental Models (USEPA, 2009), model uncertainty describes the lack of knowledge about models, parameters, constants, data, and beliefs. The USEPA Model Guidance identifies two types of uncertainty related to models: model framework uncertainty, related to the scientific soundness of the model, and data uncertainty, arising from measurement errors, analytical imprecision, and limited data sample sizes. The methods and assumptions used for the analysis and described in detail in the appendices were developed with consideration of available data. The methods for developing baseline loading and GSI load reduction estimates went through a rigorous third-party peer review process. The source control load reduction calculations methods presented in Appendix D have been accepted by the SFBRWQCB. Therefore, the methods are reasonably rigorous given the data and resources available, and the primary source of uncertainty for these computational methods is expected to be data uncertainty.

The USEPA Model Guidance (USEPA, 2009) describes the three components that affect data uncertainty:

- Accuracy – the closeness of a measured or computed value to its "true" value.
- Variability – data differences arising from true heterogeneity or diversity in model parameters and their underlying input datasets.
- Precision – the quality of being reproducible in outcome or performance.

Due to natural variability, data limitations affect both accuracy and precision, resulting in higher data uncertainty. Because of this, data limitations will also inform the complexity of the model.

In addition, as indicated in the USEPA RAA Guide (USEPA, 2017), calibration and validation can be used to manage model uncertainty, though data limitations will still cause uncertainty in model output. Because of this, the USEPA RAA Guide suggests that it is important to update RAA modeling tools over time as additional data become available.

Other components of uncertainty that cannot be addressed through the methods summarized in this document are pollutant degradation and changes in larger-scale processes that are difficult to predict. Degradation is the process of natural reduction in pollutant concentration, which is anticipated to occur over time as a result of numerous factors present in the watershed. A component of degradation which lends itself to uncertainty is the reduction of PCBs as a source. PCBs are a legacy pollutant in the environment, as they have not been in production for almost 40 years and the allowable uses have been mostly phased out and should be further reduced over time until they are eliminated. Therefore, the load of PCBs that is currently available for transport and conveyance in the MS4 can only be degraded and removed, not added to.

It is anticipated that PCBs as a source will diminish over time as a result of source control activities, as well as natural dispersion and degradation processes, which is not captured by the load reduction estimation methods. Little information is known about these processes, thus insufficient information is available to develop a methodology for accounting for degradation and source reduction in the watershed. Because of this, degradation overtime could account for a considerable amount of uncertainty in the future condition, particularly in the anticipated concentrations in urban runoff and land use-based pollutant load assumptions. The Permittees may consider degradation and source reduction in the future as more information becomes available.

Additional uncertainty is associated with changes in large-scale processes. These include physical phenomena, such as effects of climate change, long-term meteorological patterns, and large seismic events. These can also include economic or socio-economic and political shifts, which may occur as a result of physical phenomena or other factors, such as that experienced in 2020, the COVID-19 pandemic.

Major changes in large-scale processes can impact the actuality of some of the assumptions in the pollutant loading model as well as the future implementation scenarios. These may include changes to total area contributing to loading, for example as a result of sea level rise; changes to annual loading due to increases or decreases in average annual stormwater runoff volume, as a result of precipitation or flooding changes caused by long-term meteorological patterns and/or climate change; or changes to loading and/or redevelopment rates as a result of a seismic event. Economic or socio-economic impacts and political shifts can also affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation. The examples provided represent just a small fraction of the range of possibilities; many of these large-scale phenomena are very challenging to predict. As such, they are even more difficult to model and, in many cases, represent scenarios that may not happen and/or the timeframe for when they happen cannot be estimated. These types of large-scale phenomena can be considered for incorporation into periodic RAA updates when they occur.

7 Conclusions

7.1 PCBs and Mercury Control Measures

ACCWP Permittees recommend a programmatic approach for reducing PCBs and mercury loads from urban stormwater discharges, whereby compliance is assessed based on implementing and documenting a regionally agreed-on program of control measures, which include:

- Source property identification and abatement,
- Management of PCBs in building materials during demolition,
- Management of PCBs in electrical utility equipment,
- Management of PCBs in bridge structures during replacement,
- Mercury load avoidance and reduction,
- Green stormwater infrastructure (GSI),
- Full trash capture devices, and
- Enhanced operation and maintenance, such as enhanced inlet cleaning.

7.2 Implementation Schedule

The RAA results predict that the PCBs TMDL wasteload allocation will be achieved in Alameda County by the year 2090.

7.3 Evaluation of Costs

The estimate of public agency costs for implementing the PCBs and mercury control measures ranges from $400,000,000 to $1,000,000,000 countywide. The estimated cost for implementing source control programs is negligible in comparison to the estimated costs for implementing GSI measures. An analysis of cost effectiveness demonstrates that source control measures are much more cost efficient than treatment control measures at reducing loads of PCBs in urban runoff.

7.4 Reasonable Assurance Analysis

This TMDL Implementation Report presents an estimate of the load reductions resulting from PCBs and mercury control programs, along with an objective assessment of how inherent uncertainties affect forecast outcomes. It is important to emphasize that the projected pace of control measure implementation and the resultant predicted load reductions are based on current and projected business practices, which are subject to change. Economic or socio-economic impacts and political shifts may affect future implementation scenarios, causing increases or decreases in the amount of private investment and public funds available for development and control measure implementation, and/or changes in the ability to provide services that are needed for implementation.

7.4.1 PCBs

The reasonable assurance analysis shows that, based on current assumptions, the load reduction needed to achieve the PCBs wasteload allocation assigned to Alameda County Permittees would not be achieved until well after 2030. The RAA estimates that the PCBs TMDL wasteload allocation would be achieved by 2090. Analysis provided in Appendix G shows that it is technically and economically infeasible to achieve the TMDL wasteload allocation by 2030.

The reasonable assurance analysis predicts that the MRP PCBs GSI load reduction goal would be achieved by 2045. Public GSI retrofit opportunities that have the highest potential to reduce PCBs loads are concentrated within a small subset of Alameda Permittee area due to the pattern of pre-1980 industrial development within the region. Conversely, many Alameda Permittees have no or very few opportunities to contribute significantly toward achievement of countywide PCBs loading reductions via implementation of GSI in their communities. Further, if load reductions are not achieved on a regional or countywide scale, and load reductions are allocated at a local level (by population), these Permittees would not be able to achieve those load reduction allocations due to a lack of opportunity. Given these findings, the Alameda Permittees, collectively, believe that a countywide strategy would be the best way to achieve the PCBs load reduction goals in a more efficient and effective manner.

7.4.2 Mercury

The results of the RAA indicate that the TMDL wasteload allocation has been achieved and the estimated mercury load reduction by 2040 through GSI is predicted to achieve the adjusted MRP load reduction goal for GSI.

7.4.3 Uncertainty

Uncertainty in the reasonable assurance analysis include factors related to pollutant degradation and changes in larger-scale processes that are difficult to predict. PCBs are a legacy pollutant in the environment, as they have not been in production for almost 40 years and the allowable uses have been mostly phased out and should be further reduced over time until they are eliminated. Therefore, the load of PCBs that is currently available for transport and conveyance in the MS4 can only be degraded and removed, not added to. The load reduction estimation methods do not capture the diminishing of PCBs over time as a result of source control activities, as well as natural dispersion and degradation processes.

Large-scale processes, such as climate change, long-term meteorological patterns, large seismic events, economic or socio-economic and political shifts, which may occur as a result of physical phenomena or other factors, such as that experienced in 2020, the COVID-19 pandemic also introduce uncertainty into the analysis.

The examples provided represent just a small fraction of the range of possibilities; many of these phenomena are very challenging to predict. As such, they are even more difficult to model and, in many cases, represent scenarios that may not happen and/or the timeframe for when they happen cannot be estimated.

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APPENDIX A

Source Area Investigation Guidance

Source Area Investigation and Abatement Guidance

Process to Conduct Source Area Investigations during MRP 3.0

Background

Since 2000, Bay Area stormwater programs have conducted investigations on behalf of MRP Permittees to identify land areas or properties that contribute substantial amounts of PCBs to Bay Area municipal separate storm sewer systems (MS4s). These investigations have largely focused on land areas where industrial land use activities occurred prior to 1980 and continue today (i.e., old industrial land use areas). The *Interim Accounting Methodology for TMDL Loads Reduced Report* (BASMAA, March 2017) described this control measure and defined the methodology that was used for PCBs load reduction accounting during the MRP 2.0 permit term.

The pollutant reduction benefits and costs of conducting source property investigations were examined, along with other stormwater control measures, via the *Clean Watersheds for Clean Bay* (CW4CB) project. The CW4CB project concluded that PCBs source property investigations are much more cost-effective at reducing loads of PCBs than retrofitting old industrial areas with green stormwater infrastructure (GSI). This finding and the pollutant reductions achieved during the MRP 2.0 permit term via this control measure provide an impetus for MRP Permittees to continue source property investigations as a viable control measure for PCBs during MRP 3.0.

The process for conducting source area investigations that would be followed by each stormwater program during MRP 3.0 is presented below.

Source Area Investigation Process

The source area investigation process consists of the four steps outlined below:

1. Identify areas that should be considered for source area investigations;
2. Conduct screening-level investigations in the areas identified in (1) to prioritize these areas as high, moderate, or low-likelihood source areas;
3. Conduct targeted source area investigations in areas prioritized as high or moderate-likelihood source areas in (2) to identify and confirm source areas; and
4. Determine next steps for confirmed source areas.

Each of these steps is described in more detail below.

Step 1: Identify Areas Considered for Source Area Investigations

Identify areas that should be considered for source area investigations as follows:

A. Identify the extent of old industrial land use areas that were present in 2002, the starting date for accounting for POC load reductions;

B. Remove those old industrial land use areas that have already been investigated, referred, and/or abated since 2002;

C. Remove those old industrial land use areas that have undergone redevelopment or GSI retrofit since 2002;

D. Remove those old industrial land use areas that do not drain to an MS4, rather drain directly to the Bay shoreline; and

E. Identify the remaining old industrial land use areas that should be considered for source property investigations by subtracting B, C, and D from A above.

Each countywide stormwater program has implemented this process to identify the total area that will be considered for investigation within each of the five MRP counties.

Step 2: Conduct Screening-level Source Area Investigations

The purpose of screening-level source area investigations is to identify both (1) areas that are likely to contain sources of PCBs, and (2) areas that are unlikely to contain sources of PCBs. This effort will assist Permittees in narrowing the focus for more in-depth, targeted source investigations to those areas that are most likely to contain sources. The screening methods described below are designed to categorize areas at the watershed, MS4 catchment, or individual parcel-scale as high-, moderate-, or low-likelihood source areas according to the following criteria:

- Low-likelihood source areas:
    - No evidence of current or historical use of PCBs; and,
    - all MS4 sediment concentrations and stormwater particle ratios are below 0.5 mg/kg.
- Moderate-likelihood source areas
    - There may be evidence of current or historical use of PCBs; and/or
    - At least one MS4 sediment or stormwater particle ratio between 0.5 and 1.0 mg/kg.
- High-likelihood source areas:
    - There is evidence of current or historical use of PCBs; and/or
    - At least one MS4 sediment or stormwater particle ratio is greater than 1.0 mg/kg.

Screening-level investigation methods may involve any of the following:

- Desktop Analysis. Desktop analysis conducted to gather available information on potential sources of PCBs in a given area or on a specific parcel can also be used to screen areas for further investigation or to remove them from further consideration. This type of screening may include review of current and historic land uses, historical parcel records, contaminated properties databases (e.g., Geotracker and EnviroStor), and aerial photography to identify past and current activities that may be associated with PCBs (e.g., recycling facilities, parcels with large electrical equipment, PCBs manufacturing sites, industrial activities that used PCBs, etc.). Any stormwater or MS4 sediment data collected in the past may also be used as an indicator of likely PCBs sources that warrant further investigation.
- Stormwater Monitoring. Stormwater samples collected at the outlet of a defined drainage area (watershed, MS4 catchment, or individual parcel scale) can be used to screen the entire area that drains to the sampling location; if the PCBs particle ratio in all stormwater samples is less

than 500 ng/g[1], then the entire area draining to that sampling location can be identified as a low-likelihood source area.

- Sediment Monitoring. Suspended sediment samples collected from storm drain infrastructure or a channel that drains a defined area (e.g., a watershed, MS4 catchment, or one or more individual parcels) can be also be used to screen potential source areas. If the PCBs particle ratio in samples collected are less than 0.5 mg/kg, then the area or parcels that drain to the sampling location can be identified as low-likelihood area/parcels.

Step 3: Conduct Targeted Source Area Investigations

Select parcels or smaller areas within areas that are identified in Step 2 as high- and moderate-likelihood source areas may be targeted for more in-depth source investigation. The purpose of a targeted source area investigation is to identify and confirm specific source properties that contribute elevated PCBs to MS4s. Once a source property has been confirmed, Permittees may refer the property to the Regional Water Board for abatement, or the Permittee can oversee property abatement directly. The targeted source area investigation steps are modeled after the CW4CB Source Property Identification and Referral Pilot Projects (BASMAA, 2017). The targeted source area investigation process proceeds through the following four tasks:

1. Records Review. The purpose of the records review is to evaluate available information on specific parcels of interest within an investigation area to identify sources of PCBs. The types of information reviewed may include the following:

   - Site history, cleanup records, or monitoring data available through online databases (i.e., Geotracker and EnviroStor);
   - Cal OES records of PCBs releases from electrical utility equipment;
   - Changes in aerial photos from prior to 1980 and present condition;
   - Outdoor storage, suspected waste areas or ponds;
   - Available stormwater inspection history, including occurrence of PCBs, spills, and stormwater violations on prior inspection reports; and
   - Industrial General Permit (IGP) facility data.

2. Public ROW Surveys / Facility Site Visits. The purpose of public ROW surveys / facility site visits is to verify information obtained during records review, document possible sources, observe sediment migration and flow patterns from parcels of interest to the public ROW, document existing stormwater control measures, and identify potential sample locations. Information documented during public ROW surveys / site visits may include the following:

   - Electrical equipment associated with PCBs (e.g., transformers and capacitors);
   - Old equipment with hydraulic fluids;
   - Outdoor hazardous material/waste storage areas (e.g., tanks, drums), especially with poor housekeeping;

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[1] This value may be adjusted in the future based on the results of the Advanced Data Analysis under development by the Regional Monitoring Program Sources, Pathways, and Loadings workgroup or equivalent analyses conducted by the Permittees.

- Signs related to hazardous materials and wastes;
- Recycling/scrap yards (e.g., for automobiles);
- Building demolition activities;
- Unidentified puddles or stains;
- Flow patterns and storm drain structures;
- Existing and potential stormwater control measures;
- Sediment erosion from a property and migration to the street or storm drains;
- Properties that have been redeveloped or are in the process of redevelopment; and
- Redeveloped areas where older exposed soils are available for tracking off site.

The combined results of the records reviews, public ROW surveys / facility site visits are then used to prioritize sampling and develop the sampling plan.

3. Sampling. The purpose of sampling is to confirm if the suspected source area is an actual source of elevated PCBs to the MS4 or is not. Sampling methods may include the collection of sediment in the ROW, and inlet, or the storm drain; and/or stormwater sampling.
4. Identification of Source Areas. This task will review the information gathered throughout the investigation process in order to identify and confirm any source areas. Pollutant concentrations provide the primary means of confirming the identification of source areas. Elevated soil/sediment or stormwater concentrations from samples collected onsite, at the border of a parcel, or at the junction of an onsite underground drainage pipe (lateral) and the MS4 provide the best definitive evidence of whether a property is a source of PCBs to the MS4 or is not. Parcels or areas with PCBs concentrations ≥ 1.0 mg/kg are considered *confirmed source areas* and need no further investigation.

Step 4: Determine Next Steps for Confirmed Source Areas

The options Permittees may pursue for confirmed source areas include the following:

- Submit a referral to the Regional Water Board (and/or other regulatory agency) for follow-up investigation and abatement. The referral process and standard referral form are more fully described in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020).
- Abate or cause the area to be abated directly, without referral to a regulatory agency. For this option, the City will work directly with the property owner to ensure the property is fully abated and a self-abatement report will be submitted to the Regional Water Board according to the process outlined in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020).
- If the investigation conducted in Step 3 does not identify a specific source area for the observed elevated concentrations, then the source area will be considered for the application of other types of control measures.

APPENDIX B

PCBs in Priority Building Materials: Model Screening Assessment Applicant Package

PCBs in Priority Building Materials: Model Screening Assessment Applicant Package


Managing PCBs–Containing Building Materials during Demolition: Guidance, Tools, Outreach and Training

Bay Area Stormwater Management Agencies Association

August 2018 (Revised July 2, 2019)

This document is a deliverable of the Bay Area Stormwater Management Agencies Association (BASMAA) project *Managing PCBs−Containing Building Materials during Demolition: Guidance, Tools, Outreach and Training*. BASMAA developed guidance, tools, and outreach and training materials to assist with San Francisco Bay Area municipal agencies' efforts to address the requirements of Provision C.12.f. of the Bay Area Municipal Regional Stormwater Permit (referred to as the MRP). Provision C.12.f of the MRP requires Permittees to manage PCBs–containing building materials during demolition.

We gratefully acknowledge the BASMAA Steering Committee for this project, which provided overall project oversight, including during the development of this and other project deliverables:

- Reid Bogert, Stormwater Program Specialist, San Mateo Countywide Water Pollution Prevention Program (BASMAA Project Manager)
- Amanda Booth, Environmental Program Analyst, City of San Pablo
- Kevin Cullen, Program Manager, Fairfield-Suisun Urban Runoff Management Program
- Matt Fabry, Program Manager, San Mateo Countywide Water Pollution Prevention Program
- Gary Faria, Supervisor, Inspection Services, Building Inspection Division, Contra Costa County
- Napp Fukuda, Deputy Director - Watershed Protection Division, City of San José
- Ryan Pursley, Chief Building Official, Building Division, City of Concord
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- Melody Tovar, Regulatory Programs Division Manager, City of Sunnyvale

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Stakeholder Group	**Representative(s)**
Regulatory – stormwater/PCBs	Luisa Valiela and Carmen Santos, U.S. EPA Region 9
Regulatory – stormwater/TMDL	Jan O'Hara, San Francisco Bay Regional Water Quality Control Board
Regulatory – experience with related program (asbestos management)	Ron Carey and Richard Lew, Bay Area Air Quality Management District
Industry – demolition contractors	Avery Brown, Ferma Corporation
Industry – remediation consultants	John Martinelli, Forensic Analytical Consulting John Trenev, Bayview Environmental Services, Inc.
MRP Permittee – large municipality	Patrick Hayes, City of Oakland
MRP Permittee – medium municipality	Kim Springer, San Mateo County Office of Sustainability
MRP Permittee – small municipality	Amanda Booth, City of San Pablo

Prepared for:

BASMAA
P.O. Box 2385
Menlo Park, CA 94026

Bay Area Stormwater Management Agencies Association

Prepared by:

EOA, Inc.
Larry Walker Associates
Geosyntec Consultants
Stephanie Hughes
David J. Powers & Associates, Inc.

PCBs in Priority Building Materials: Model Screening Assessment Applicant Package

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The material presented in this document is intended solely for the implementation of a municipal regulatory program required by the San Francisco Bay Area Regional Water Quality Control Board Municipal Regional Stormwater Permit for the protection of water quality under the Clean Water Act.

BASMAA prepared the tools and guidance herein to assist MRP Permittees' efforts to address the requirements of Provision C.12.f. of the MRP. The project team received input from a variety of stakeholders during development of the tools and guidance, including regulators (San Francisco Bay Regional Water Quality Control Board, U.S. EPA, and Bay Area Air Quality Management District staff), Bay Area municipal agency staff, and industry representatives.

This document does not address other environmental programs or regulations (e.g., PCBs regulations under the Toxic Substances Control Act (TSCA); federal, state, or local regulations for hazardous material handling and hazardous waste disposal; health and safety practices to mitigate human exposure to PCBs or other hazardous materials; recycling mandates; and abatement at sites with PCBs (or other contaminants). The applicant is responsible for knowing and complying with all relevant laws and regulations.

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Process Overview

This document provides a model PCBs in Priority Building Materials Screening Assessment process to be conducted by demolition project proponents (applicants). A flow chart illustrating the above processes is provided in **Attachment A**.

Applicants proposing to demolish buildings must conduct the PCBs screening assessment. Through the PCBs screening assessment applicants will:

1) Determine whether the building proposed for demolition is likely to have PCBs-containing building materials (see discussion of applicable structure); and
2) Determine whether PCBs are present at a concentration equal to or greater than 50 parts per million (ppm) in building materials.

Use the *PCBs Screening Assessment Form* (**Attachment B**) to summarize and certify the information required by the municipality to issue the demolition permit. The form is divided into four parts:

- **Part 1** provide applicant information and project location.
- **Part 2** complete the questions to identify whether the project involves an *applicable structure.* If the demolition does not involve an applicable structure, the form may be certified and submitted without completing Part 3.
- **Part 3** complete the questions to provide the concentrations of PCBs in any *priority building materials*.
- **Part 4** certify the information being submitted.

Water quality within the San Francisco Bay Region is regulated by the San Francisco Bay Area Regional Water Quality Control Board (Regional Water Board).

In 2015, the Regional Water Board reissued the Municipal Regional Permit (MRP)[1] that regulates discharges of stormwater runoff. The MRP includes provisions for reducing discharges of polychlorinated biphenyls (PCBs) in stormwater runoff and requires municipalities to develop a program to manage priority PCBs–containing building materials during demolition and implement the program by July 1, 2019.

Existing federal and state regulations create the framework for managing PCBs in building materials once those PCBs are identified through this program and for disposing of wastes containing PCBs.

Note that fluorescent light ballasts, polyurethane foam furniture, and Askarel fluid used in transformers, all of which may contain PCBs, are typically managed during pre-demolition activities under current regulations and programs that require removal of universal waste and outdated transformers. For this process it is assumed that those materials will be evaluated and managed under those existing programs.

This screening process is part of a program for water quality protection and was designed in accordance with requirements in the MRP. [1] It does not address other environmental programs or regulations (e.g., PCBs regulations under the Toxic Substances Control Act (TSCA); federal, state, or local regulations for hazardous material handling and hazardous waste disposal; health and safety practices to mitigate human exposure to PCBs or other hazardous materials; recycling mandates; or abatement at sites with PCBs (or other contaminants). **The applicant is responsible for complying with all relevant laws and regulations. See the Notices to Applicants section for additional information.**

[1] A National Pollutant Discharge Elimination System (NPDES) permit, Order No. R2-2015-0049, issued to municipalities in the counties of Alameda, Contra Costa, San Mateo, and Santa Clara, and the Cities of Fairfield, Suisun City, and Vallejo.

Applicant Instructions for Completing the PCBs Screening Assessment Form

Applicants for demolition permits or other permits that involve the complete demolition of a building must conduct an assessment to screen for PCBs in *priority building materials*. *Use the PCBs Screening Assessment Form*, to summarize and certify the information needed by the municipality to issue a demolition permit. The form is provided in **Attachment B**. If the project includes the demolition of multiple buildings complete one form for each building to be demolished.

Key Definitions

Demolition means the wrecking, razing, or tearing down of any building. The definition is intended to be consistent with the demolition activities undertaken by contractors with a C-21 Building Moving/Demolition Contractor's License.

Priority Building Materials are:

1. Caulk;
2. Thermal insulation;
3. Fiberglass insulation;
4. Adhesive mastics; and
5. Rubber window gaskets.

Buildings are structures with a roof and walls standing more or less permanently in one place. Buildings are intended for human habitation or occupancy.

Applicable Structures are defined as buildings constructed or remodeled between January 1, 1950 and December 31, 1980. Wood framed buildings and single-family residential buildings are not applicable structure regardless of the age of the building.

Part 1. Owner and project information

Complete the owner and consultant information and the project location information.

For the Type of Construction select one of the following options:

- **Wood Frame** (Buildings constructed with lumber or timbers, which make up the studs, plates, joists, and rafters.)
- **Masonry Construction** (Buildings constructed with concrete blocks or bricks as the load bearing walls typically with the floors and ceilings constructed with wooden joists.)
- **Steel Frame Construction** (Buildings constructed with steel studs or steel columns and steel joists or trusses to support floors and roofs. Includes light gauge steel construction and high-rise steel construction.)
- **Concrete Frame** (Buildings constructed with reinforced concrete columns, concrete beams, and concrete slabs.)
- **Pre-Engineered** (Buildings constructed with pre-engineered parts bolted together.)

Part 2. Is building subject to the screening requirement based on type, use, and age of the building?

Part 2 documents the determination of whether the proposed demolition will affect an *applicable structure*. If the demolition does not affect an *applicable structure*, then the assessment is complete, and the form can be certified.

This determination screens out buildings that are a lower priority with regard PCBs-containing materials and provides an off-ramp from the rest of the screening process.

Question 2.a: Is the building to be demolished wood framed and/or single family residential?

- If YES the PCBs Screening Assessment is complete, skip to the certification in Part 4.
- If NO, continue to Question 2.b.

Question 2.b: Was the building to be demolished constructed or remodeled between January 1, 1950 and December 31, 1980?

- If YES continue to Question 2.c.
- If NO, the PCBs Screening Assessment is complete, skip to the certification in Part 4.

> Studies have found the highest concentrations of PCBs in building materials in buildings that were built or remodeled from 1950 to 1980.
>
> For this process, the date that the building permit was issued will be used to determine applicability.

Question 2.c: Is the proposed demolition a complete demolition of the building (as defined in key definitions of this document)?

- If YES continue to Part 3.
- If NO, the PCBs Screening Assessment is complete, skip to the certification in Part 4.

Part 3. Report concentrations of PCBs in priority building materials

Part 3 documents the results of the assessment of PCBs concentrations in *priority building materials*. Part 3 is only required for proposed demolition of an *applicable structure*, as determined in Part 2. Check the option used.

- **Option 1** Conduct representative sampling and analysis of the *priority building materials* per the *Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition* (August 2018) provided in **Attachment C**.
- **Option 2** Use existing sampling results of the *priority building materials.* Applicants who have conducted sampling prior to the publication of the protocol may use that data provided it is consistent with the protocol (e.g., analytical methods, sample collection frequency, QA/QC). It is anticipated that prior sampling results will rarely be available and that most Applicants will need to use Option1.

3.a Option 1 – Conduct representative sampling

Check this box if you conducted representative sampling and analysis of the *priority building materials* per the *Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition* (August 2018) (**Attachment C**).

- Complete the applicable tables for each priority building material.
- Attach the contractor's report[2] documenting the evaluation results.
- Attach (or include in the contractor's report) the QA/QC checklist (see **Attachment C**, Section 3.2.4).
- Attach copies of the analytical data reports.

[2] The contractor's report of the findings of the PCBs building material evaluation. See section 3 of Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition (Attachment C).

3.a Option 2 – Use existing sampling records

In some cases, a property owner may have conducted sampling of the *priority building materials* for PCBS. If such data exist, you may use these data to demonstrate the concentration of PCBs in the *priority building materials* for the PCBs screening. However, if the sampling must be consistent with the *Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition.*

- ➢ Complete the applicable tables for each priority building material.
- ➢ Attach the contractor's report/statement that the results are consistent with the *Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition*.
- ➢ Attach copies of the analytical data reports.

Part 3 Tables Summarize concentrations of PCBs in priority building materials

Use these tables to summarize the concentrations of PCBs in the *priority building materials*.

- Each page of the table is for a different material. Duplicate the pages as needed to report all concentration data.
- A blank page is provided. Applicants have the option of submitting PCBs concentration data on other materials in addition to the *priority building materials*.

Column 1: required for all priority building material PCBs concentrations

- ➢ Use column 1 to report all PCBs concentrations in the *priority building materials*. Provide short description of the sample location, concentration.

Column 2: only required for PCBs concentrations ≥50 ppm

- ➢ Use column 2 to estimate the amount of material associated with each sample.

Part 4. Certification

- ➢ Complete the certification. The certification must be signed by the property owner or the owner's agent or legal representatives and the consultant who complete the application form.

Notices to Applicants Regarding Federal and State PCBs Regulations

Applicants that determine PCBs exist in priority building materials must follow applicable federal and state laws. This may include reporting to U.S. Environmental Protection Agency (USEPA), the San Francisco Bay Regional Water Quality Control Board, and the California Department of Toxic Substances Control (DTSC). These agencies may require additional sampling and abatement of PCBs.

Depending on the approach for sampling and removing building materials containing PCBs, you may need to notify or seek advance approval from USEPA before building demolition. Even in circumstances where advance notification to or approval from USEPA is not required before the demolition activity, the disposal of PCBs waste is regulated under Toxic Substances Control Act (TSCA).

Additionally, the disposal of PCBs waste is subject to California Code of Regulations (CCR) California Code of Regulations (CCR) Title 22, Section Division 4.5, Chapter 12, Standards Applicable to Hazardous Waste Generators.

Building owners and employers need to consider worker and public safety during work involving hazardous materials and wastes including PCBs.

Federal and State Regulations

See 40 Code of Federal Regulations (CFR) 761.3 for important information relative to disposal of PCBs-containing building materials, including definitions of PCBs bulk product wastes and PCBs remediation wastes. Also see the memorandum dated October 24, 2012 “PCB Bulk Product Waste Reinterpretation” from Suzanne Rudzinski, Director, Office of Resource Conservation and Recovery, EPA.

Disposal of PCBs wastes are subject to TSCA requirements such as manifesting of the waste for transportation and disposal. See 40 CFR 761 and 40 CFR 761, Subpart K.

TSCA-regulated does not equate solely to materials containing PCBs at or above 50 ppm. There are circumstances in which materials containing PCBs below 50 ppm are subject to regulation under TSCA. See 40 CFR 761.61(a)(5)(i)(B)(2)(ii).

Disposal of PCBs wastes are subject to California Code of Regulations (CCR) Title 22, Section Division 4.5, Chapter 12, Standards Applicable to Hazardous Waste Generators.

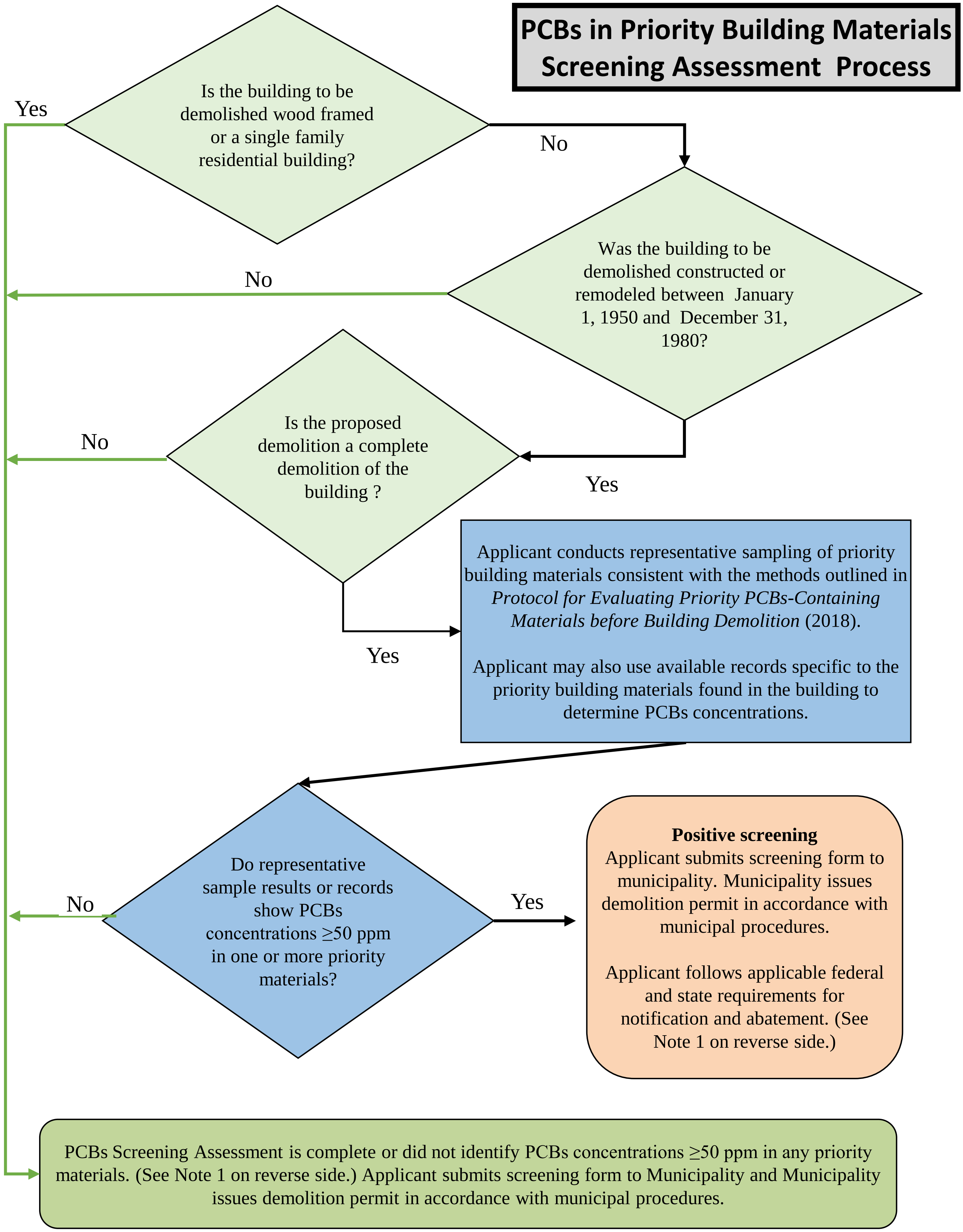
California hazardous waste regulatory levels for PCBs are 5 ppm based on the Soluble Threshold Limit Concentration test and 50 ppm based on the Total Threshold Limit Concentration test, see CCR, Title 22, Section 66261.24, Table III.

Agency Contacts

Applicants should contact the appropriate agencies and review the relevant guidance and information about PCBs in building materials. Municipal staff are not able to advise you on the requirements of the applicable federal and state laws.

Agency	Contact	Useful Links
US Environmental Protection Agency	Steve Armann (415) 972-3352 armann.steve@epa.gov	https://www.epa.gov/pcbs (EPA PCB website) https://www.epa.gov/pcbs/questions-and-answers-about-polychlorinated-biphenyls-pcbs-building-materials (PCBs in Building Materials Fact Sheet and Q/A Document) https://www.epa.gov/pcbs/pcb-facility-approval-streamlining-toolbox-fast-streamlining-cleanup-approval-process (USEPA PCB Facility Approval Streamlining Toolbox (PCB FAST)) https://www.epa.gov/pcbs/polychlorinated-biphenyls-pcbs-building-materials#Test-Methods (See Information for Contractors Working in Older Buildings that May Contain PCBs)
San Francisco Bay Regional Water Quality Control Board	Jan O'Hara (510) 622-5681 Janet.O'Hara@waterboards.ca.gov Cheryl Prowell (510) 622-2408 Cheryl.Prowell@waterboards.ca.gov	https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/sfbaypcbstmdl.shtml https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/sitecleanupprogram.html
Department of Toxic Substances Control	Regulatory Assistance Office 1-800-72TOXIC RAO@dtsc.ca.gov	http://www.dtsc.ca.gov/SiteCleanup/Brownfields/upload/PUB_SMP_Guide-to-Selecting-a-Consultant.pdf
California Division of Occupational Safety and Health (known as Cal/OSHA)	CalOSHA Consultations Services 1-800-963-9424	https://www.dir.ca.gov/dosh/consultation.html

Attachment A
Process Flow Chart


PCBs in Priority Building Materials Screening Assessment Process
Is the building to be demolished wood framed or a single family residential building?
Yes
No
Was the building to be demolished constructed or remodeled between January 1, 1950 and December 31, 1980?
No
Yes
Is the proposed demolition a complete demolition of the building ?
No
Yes
Applicant conducts representative sampling of priority building materials consistent with the methods outlined in Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition (2018).
Applicant may also use available records specific to the priority building materials found in the building to determine PCBs concentrations.
Do representative sample results or records show PCBs concentrations ≥50 ppm in one or more priority materials?
No
Yes
Positive screening
Applicant submits screening form to municipality. Municipality issues demolition permit in accordance with municipal procedures.
Applicant follows applicable federal and state requirements for notification and abatement. (See Note 1 on reverse side.)
PCBs Screening Assessment is complete or did not identify PCBs concentrations ≥50 ppm in any priority materials. (See Note 1 on reverse side.) Applicant submits screening form to Municipality and Municipality issues demolition permit in accordance with municipal procedures.

Note 1

- Building materials containing PCBs at or above 50 ppm that were manufactured with PCBs (e.g., caulk, joint sealants, paint) fall under the category of PCBs bulk product wastes. See 40 Code of Federal Regulations (CFR) 761.3 for a definition of PCBs bulk product wastes.

- Building materials such as concrete, brick or metal contaminated with PCBs are PCBs remediation wastes (e.g., concrete contaminated with PCBs from caulk that contains PCBs). 40 CFR 761.3 defines PCBs remediation wastes.

- Disposal of PCBs wastes are subject to TSCA requirements such as manifesting of the waste for transportation and disposal. See 40 CFR 761 and 40 CFR 761, Subpart K.

- TSCA-regulated does not equate solely to “materials containing PCBs at or above “50 mg/kg.” There are circumstances in which materials containing PCBs below 50 mg/kg are subject to regulation under TSCA. See 40 CFR 761.61(a)(5)(i)(B)(2)(ii).

- Disposal of PCBs wastes are subject to California Code of Regulations (CCR) Title 22, Section Division 4.5, Chapter 12, Standards Applicable to Hazardous Waste Generators.

- California hazardous waste regulatory levels for PCBs are 5 ppm based on the Soluble Threshold Limit Concentration test and 50 ppm based on the Total Threshold Limit Concentration test, see CCR, Title 22, Section 66261.24, Table III.

Attachment B
PCBs in Priority Building Materials Screening Assessment Form

PCBs Screening Assessment Form

For Municipality Use Only	
Date Received	
File #	

This screening process is part of a program for water quality protection and was designed in accordance with requirements in the Bay Area regional municipal stormwater NPDES permit (referred to as the Municipal Regional Permit). This process **does not** address other environmental programs or regulations (e.g., PCBs regulations under the Toxic Substances Control Act (TSCA); federal, state, or local regulations for hazardous material handling and hazardous waste disposal; health and safety practices to mitigate human exposure to PCBs or other hazardous materials; recycling mandates; or abatement at sites with PCBs or other contaminants). **The applicant is responsible for knowing and complying with all relevant laws and regulations. See Notices to Applicants section in the Applicant Instructions and at the end of this form.**

Complete all applicable parts of the PCBs Screening Assessment Form and submit with your demolition permit application.

All Applicants must complete Part 1 and Part 2.

Part 1. Owner/Consultant and project information		
Owner Information		
Name		
Address		
City	State	Zip
Contact (Agent)		
Phone	Email	
Consultant Information		
Firm Name		
Address		
City	State	Zip
Contact Person		
Phone	Email	
Project Location		
Address		
City	State CA	Zip
APN (s)		
Year Building was Built	Type of Construction Select	
Estimated Demolition Date		

Part 2. Is building subject to the PCBs screening requirement based on type, use, and age of the building?

2.a	Is the building to be demolished wood framed and/or single family residential?	◯Yes ◯No
If the answer to question 2.a is **Yes**, the PCBs Screening Assessment is complete, skip to Part 4. If the answer is **No**, continue to Question 2.b.		
2.b	Was the building to be demolished constructed or remodeled between January 1, 1950 and December 31, 1980?	◯Yes ◯No
➢	If the answer to Question 2.b is **No** the PCBs Screening Assessment is complete, skip to Part 4. If the answer is **Yes**, continue to Question 2.c.	
2.c	Is the proposed demolition a complete demolition of the building?	◯Yes ◯No
➢	If the answer to Question 2.c is **No** the PCBs Screening Assessment is complete, skip to Part 4. If the answer is **Yes**, complete Part 3.	

All applications affecting applicable structures and demolitions must complete Part 3 and the Part 3 Tables.

Part 3. Report concentrations of PCBs in priority building materials

Option 1. *Applicants conducted representative sampling and analysis of the priority building materials per the Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition (2018) (Attachment C).*

Option 2. *Applicants possess existing sample results that are that are consistent with the Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition (2018) (Attachment C).*

3.a Select option and report PCBs concentrations in the priority building materials and the source of data for each of the priority building materials. Provide the required supporting information

◯Option 1 Conduct Representative Sampling

- Summarize results on Part 3 Tables; and
- Provide the following supporting information:
  - ☐ Contractor's report documenting the assessment results;
  - ☐ *QA/QC checklist (see Attachment C, section 3.2.4); and*
  - ☐ Copies of the analytical data reports.

◯Option 2 Use Existing Sampling Records

- Summarize results on Part 3 Tables; and
- Provide the following supporting information:
  - ☐ Contractor's report/statement that the results are consistent with the *Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition.*
  - ☐ Copies of the analytical data reports.

All Applicants must complete Part 4.

Part 4. Certification

I certify that the information provided in this form is, to the best of my knowledge and belief, true, accurate, and complete. I further certify that I understand my responsibility for knowing and complying with all relevant laws and regulations related to reporting, abating, and handing and disposing of PCBs materials and wastes. I understand there are significant penalties for submitting false information. I will retain a copy of this form and the supporting documentation for at least 5 years.

Signature:______________________________ Date: ____________
(Property Owner//Agent/Legal Representative)

Print/Type:______________________________
(Property Owner/Agent/Legal Representative Name)

Signature:______________________________ Date: ____________
(Consultant Completing Application Form)

Print/Type:______________________________
(Consultant Completing Application Form)

Notices to Applicants Regarding Federal and State PCBs Regulations

Applicants that determine PCBs exist in building materials must follow applicable federal and state laws. This may include reporting to U.S. Environmental Protection Agency (USEPA), the San Francisco Bay Regional Water Quality Control Board, and the California Department of Toxic Substances Control (DTSC). These agencies may require additional sampling and abatement of PCBs. Depending on the approach for sampling and removing building materials containing PCBs, you may need to notify or seek advance approval from USEPA before building demolition. Even in circumstances where advance notification to or approval from USEPA is not required before the demolition activity, the disposal of PCBs waste is regulated under TSCA and the California Code of Regulations. (See Note 1)

Note 1 - Federal and State Regulations

Building materials containing PCBs at or above 50 ppm that were manufactured with PCBs (e.g., caulk, joint sealants, paint) fall under the category of PCBs bulk product wastes. See 40 Code of Federal Regulations (CFR) 761.3 for a definition of PCBs bulk product wastes.

Building materials such as concrete, brick, metal contaminated with PCBs are PCBs remediation wastes (e.g., concrete contaminated with PCBs from caulk that contains PCBs). 40 CFR 761.3 defines PCBs remediation wastes.

Disposal of PCBs wastes are subject to TSCA requirements such as manifesting of the waste for transportation and disposal. See 40 CFR 761 and 40 CFR 761, Subpart K.

TSCA-regulated does not equate solely to materials containing PCBs at or above 50 ppm. There are circumstances in which materials containing PCBs below 50 ppm are subject to regulation under TSCA. See 40 CFR 761.61(a)(5)(i)(B)(2)(ii).

Disposal of PCBs wastes are subject to California Code of Regulations (CCR) Title 22, Section Division 4.5, Chapter 12, Standards Applicable to Hazardous Waste Generators.

California hazardous waste regulatory levels for PCBs are 5 ppm based on the Soluble Threshold Limit Concentration test and 50 ppm based on the Total Threshold Limit Concentration test, see CCR, Title 22, Section 66261.24, Table III.

Agency	Contact	Useful Links
US Environmental Protection Agency	Steve Armann (415) 972-3352 armann.steve@epa.gov	https://www.epa.gov/pcbs (EPA PCBs website) https://www.epa.gov/pcbs/questions-and-answers-about-polychlorinated-biphenyls-pcbs-building-materials (PCBs in Building Materials Fact Sheet and Q/A Document) https://www.epa.gov/pcbs/pcb-facility-approval-streamlining-toolbox-fast-streamlining-cleanup-approval-process (USEPA PCB Facility Approval Streamlining Toolbox (PCB FAST)) https://www.epa.gov/pcbs/polychlorinated-biphenyls-pcbs-building-materials#Test-Methods (See Information for Contractors Working in Older Buildings that May Contain PCBs)
San Francisco Bay Regional Water Quality Control Board	Jan O'Hara (510) 622-5681 Janet.O'Hara@waterboards.ca.gov Cheryl Prowell (510) 622-2408 Cheryl.Prowell@waterboards.ca.gov	https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/sfbaypcbstmdl.shtml https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/sitecleanupprogram.html
Department of Toxic Substances Control	Regulatory Assistance Office 1-800-72TOXIC RAO@dtsc.ca.gov	http://www.dtsc.ca.gov/SiteCleanup/Brownfields/upload/PUB_SMP_Guide-to-Selecting-a-Consultant.pdf
California Division of Occupational Safety and Health (Cal/OSHA)	CalOSHA Consultations Services 1-800-963-9424	https://www.dir.ca.gov/dosh/consultation.html

Part 3 Caulk Applications Table			
Column 1. *Report all PCBs concentrations for each homogenous area of caulking area (see Attachment C, Section 3.2.2). Use sample designators/descriptions from laboratory report.*		***Column 2.*** *Complete for each concentration ≥ 50 ppm*	
Caulk Application Sample Description	**Concentration (mg/kg)**	**Estimate Amount of Material**	**Units**
Example:			
Caulk Sample 1	*320*	*48*	*Linear Feet*
1.________	________	________	Linear Feet
2.________	________	________	Linear Feet
3.________	________	________	Linear Feet
4.________	________	________	Linear Feet
5.________	________	________	Linear Feet
6.________	________	________	Linear Feet
7.________	________	________	Linear Feet
8.________	________	________	Linear Feet
9.________	________	________	Linear Feet
10.________	________	________	Linear Feet

Duplicate page if additional space is needed.

Part 3 Fiberglass Insulation Applications Table			
Column 1. *Report all PCBs concentrations for each homogenous area of fiberglass insulation (see Attachment C, Section 3.2.2). Use sample designators/descriptions from laboratory report.*		***Column 2.*** *Complete for each concentration ≥ 50 mg/kg*	
Fiberglass Insulation Application Sample Description	**Concentration (mg/kg)**	**Estimate Amount of Material**	**Units**
Example: *Fiberglass Insulation Sample 1*	*78*	*86*	*Square Feet*
1.________________	________	________	Square Feet
2.________________	________	________	Square Feet
3.________________	________	________	Square Feet
4.________________	________	________	Square Feet
5.________________	________	________	Square Feet
6.________________	________	________	Square Feet
7.________________	________	________	Square Feet
8.________________	________	________	Square Feet
9.________________	________	________	Square Feet
10.________________	________	________	Square Feet

The area of insulation wrapped around a pipe may be estimated using the following formula:
Area (square feet) = 2Πrh; where r is the pipe radius (feet) and h is the pipe length (feet).

Duplicate page if additional space is needed.

Part 3 Thermal Insulation Applications Table			
Column 1. *Report all PCBs concentrations for each homogenous area of thermal insulation (see Attachment C, Section 3.2.2). Use sample designators/descriptions from laboratory report.*		***Column 2.*** *Complete for each concentration ≥ 50 mg/kg*	
Thermal Insulation Application Sample Description	**Concentration (mg/kg)**	**Estimate Amount of Material**	**Units**
Example:			
Thermal Insulation Sample 1	*20*	______	*Square Feet*
1.______	______	______	Square Feet
2.______	______	______	Square Feet
3.______	______	______	Square Feet
4.______	______	______	Square Feet
5.______	______	______	Square Feet
6.______	______	______	Square Feet
7.______	______	______	Linear Feet
8.______	______	______	Square Feet
9.______	______	______	Square Feet
10.______	______	______	Square Feet

The area of of insulation wrapped around a pipe may be estimated using the following formula:
Area (square feet) = 2Πrh, where r is the pipe radius (feet) and h is the pipe length (feet).

Duplicate page if additional space is needed.

Part 3 Adhesive Mastic Applications Table			
Column 1. *Report PCBs concentrations for each homogenous area of mastic (see Attachment C, Section 3.2.2. Use sample designators/descriptions from laboratory report.)*		***Column 2.*** *Complete for each concentration ≥ 50 mg/kg*	
Adhesive Mastic Application Sample Description	**Concentration (mg/kg)**	**Estimate Amount of Material**	**Units**
Example: *Adhesive Mastic Sample 1*	*87.4*	*800*	*Square Feet*
1.___	___	___	Square Feet
2.___	___	___	Square Feet
3.___	___	___	Square Feet
4.___	___	___	Square Feet
5.___	___	___	Square Feet
6.___	___	___	Square Feet
7.___	___	___	Linear Feet
8.___	___	___	Square Feet
9.___	___	___	Square Feet
10.___	___	___	Square Feet

Duplicate page if additional space is needed.

Part 3 Rubber Window Gasket Applications Table			
Column 1. *Report PCBs concentrations for each gasket (see Attachment C, Section 3.2.2). Use sample designators/descriptions from laboratory report.*		***Column 2.*** *Complete for each concentration ≥ 50 mg/kg*	
Rubber Window Gasket Application Sample Description	**Concentration (mg/kg)**	**Estimate Amount of Material**	**Units**
Example:			
Window Gasket Sample 1	*70*	*75*	*Linear Feet*
1.			Linear Feet
2.			Linear Feet
3.			Linear Feet
4.			Linear Feet
5.			Linear Feet
6.			Linear Feet
7.			Linear Feet
8.			Linear Feet
9.			Linear Feet
10.			Linear Feet

Duplicate page if additional space is needed.

Part 3 Other Materials Table			
Column 1. *Optional: Use this form to report PCBs concentration data from materials other than priority building materials. Report PCBs concentrations for each material and homogeneous area. Use sample designators/descriptions from laboratory report.*		***Column 2.*** *Complete for each concentration ≥ 50 mg/kg*	
Material Sample Description	**Concentration (mg/kg)**	**Estimate Amount of Material**	**Units**
Example:			
Wall paint Sample 1	*228*	*1500*	*Square Feet*
1.___	___	___	___
2.___	___	___	___
3.___	___	___	___
4.___	___	___	___
5.___	___	___	___
6.___	___	___	___
7.___	___	___	___
8.___	___	___	___
9.___	___	___	___
10.___	___	___	___

Duplicate page if additional space is needed.

Attachment C
Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition

Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition


Managing PCBs–Containing Building Materials during Demolition: Guidance, Tools, Outreach and Training

Bay Area Stormwater Management Agencies Association

August 2018
(Revised November 2019)

This document is a deliverable of the Bay Area Stormwater Management Agencies Association (BASMAA) project *Managing PCBs−Containing Building Materials during Demolition: Guidance, Tools, Outreach and Training*. BASMAA developed guidance, tools, and outreach and training materials to assist with San Francisco Bay Area municipal agencies' efforts to address the requirements of Provision C.12.f. of the Bay Area Municipal Regional Stormwater Permit (referred to as the MRP). Provision C.12.f of the MRP requires Permittees to manage PCBs–containing building materials during demolition.

We gratefully acknowledge the BASMAA Steering Committee for this project, which provided overall project oversight, including during the development of this and other project deliverables:

- Reid Bogert, Stormwater Program Specialist, San Mateo Countywide Water Pollution Prevention Program (BASMAA Project Manager)
- Amanda Booth, Environmental Program Analyst, City of San Pablo
- Kevin Cullen, Program Manager, Fairfield-Suisun Urban Runoff Management Program
- Matt Fabry, Program Manager, San Mateo Countywide Water Pollution Prevention Program
- Gary Faria, Supervisor, Inspection Services, Building Inspection Division, Contra Costa County
- Napp Fukuda, Deputy Director - Watershed Protection Division, City of San José
- Ryan Pursley, Chief Building Official, Building Division, City of Concord
- Pam Boyle Rodriguez, Manager, Environmental Control Programs – Stormwater, City of Palo Alto
- Jim Scanlin, Program Manager, Alameda Countywide Clean Water Program
- Melody Tovar, Regulatory Programs Division Manager, City of Sunnyvale

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Stakeholder Group	Representative(s)
Regulatory – stormwater/PCBs	Luisa Valiela and Carmen Santos, U.S. EPA Region 9
Regulatory – stormwater/TMDL	Jan O'Hara, San Francisco Bay Regional Water Quality Control Board
Regulatory – experience with related program (asbestos management)	Ron Carey and Richard Lew, Bay Area Air Quality Management District
Industry – demolition contractors	Avery Brown, Ferma Corporation
Industry – remediation consultants	John Martinelli, Forensic Analytical Consulting John Trenev, Bayview Environmental Services, Inc.
MRP Permittee – large municipality	Patrick Hayes, City of Oakland
MRP Permittee – medium municipality	Kim Springer, San Mateo County Office of Sustainability
MRP Permittee – small municipality	Amanda Booth, City of San Pablo

Prepared for:

BASMAA
P.O. Box 2385
Menlo Park, CA 94026

Bay Area Stormwater Management Agencies Association

Prepared by:

EOA, Inc.
Larry Walker Associates
Geosyntec Consultants
Stephanie Hughes
David J. Powers & Associates, Inc.

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DISCLAIMER

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The material presented in this document is intended solely for the implementation of a municipal regulatory program required by the San Francisco Bay Area Regional Water Quality Control Board Municipal Regional Stormwater Permit for the protection of water quality under the Clean Water Act.

BASMAA prepared the tools and guidance herein to assist MRP Permittees' efforts to address the requirements of Provision C.12.f. of the MRP. The project team received input from a variety of stakeholders during development of the tools and guidance, including regulators (San Francisco Bay Regional Water Quality Control Board, U.S. EPA, and Bay Area Air Quality Management District staff), Bay Area municipal agency staff, and industry representatives.

This document does not address other environmental programs or regulations (e.g., PCBs regulations under the Toxic Substances Control Act (TSCA); federal, state, or local regulations for hazardous material handling and hazardous waste disposal; health and safety practices to mitigate human exposure to PCBs or other hazardous materials; recycling mandates; and abatement at sites with PCBs (or other contaminants). The applicant is responsible for knowing and complying with all relevant laws and regulations.

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Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition

1. INTRODUCTION

The San Francisco Bay Region Municipal Regional Stormwater NPDES permit, referred to as the Municipal Regional Permit (MRP)[1], includes provisions that implement stormwater-related aspects of the Total Maximum Daily Load (TMDL) for polychlorinated biphenyls (PCBs) in the Bay. Provision C.12.f. requires that Permittees develop and implement or cause to be developed and implemented an effective protocol for managing materials with PCBs concentrations of 50 milligrams per kilogram (mg/kg) (equivalent to parts-per-million, or ppm), the target management level, or greater in applicable structures at the time such structures undergo demolition[2], so that PCBs do not enter municipal storm drain systems. Applicable structures include, at a minimum, non-residential structures constructed or remodeled between the years 1950 and 1980 with building materials such as caulking and thermal insulation with PCBs concentrations of 50 ppm or greater. Single-family residential and wood frame structures are exempt. Also, a Permittee is exempt from this requirement if it provided evidence acceptable to the Executive Officer in its 2016/17 Annual Report that the only structures that existed pre-1980 within its jurisdiction were single-family residential and/or wood-frame structures.[3]

Permittees were required to develop a protocol by June 30, 2019 that includes each of the following components, at a minimum:

1. The necessary authority to ensure that PCBs do not enter municipal storm drains from PCBs-containing materials in applicable structures at the time such structures undergo demolition;
2. A method for identifying applicable structures prior to their demolition; and
3. Method(s) for ensuring PCBs are not discharged to the municipal storm drain from demolition of applicable structures.

By July 1, 2019 and thereafter, Permittees are required to:

- Implement or cause to be implemented the PCBs management protocol for ensuring PCBs are not discharged to municipal storm drains from demolition of applicable structures via vehicle track-out, airborne releases, soil erosion, or stormwater runoff.
- Develop an evaluation methodology and data collection program to quantify in a technically sound manner PCBs loads reduced through implementation of the protocol for controlling PCBs during demolition of applicable structures.

On behalf of MRP Permittees, the Bay Area Stormwater Management Agencies Association (BASMAA) conducted a regional project to assist MRP Permittees to achieve compliance with

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[1] The Municipal Regional Stormwater Permit, Order No. R2-2015-0049, was adopted November 19, 2015.
[2] Demolition means the wrecking or taking out of any load-supporting structural member of a facility together with any related handling operations (40 CFR., Part 61, Subpart M).
[3] The City of Clayton provided evidence to support an exemption from the requirement.

Provision C.12.f. The regional project developed guidance materials, tools, protocols and training materials and conducted outreach. The goal was to assist Permittees to develop local programs to prevent PCBs from being discharged to municipal storm drains due to demolition of applicable buildings. Local agencies will need to tailor the BASMAA products for local use and train local staff to implement the new program.

This document is the deliverable for Task 3 of the regional project, which is to develop a protocol for the assessment of prioritized PCBs-containing building materials prior to demolition. The full scope of work for the regional project is presented in the Project team's *Proposal for Tools, Protocol, Outreach & Training Work Plan: PCBs Materials Management during Building Demolition Project* (dated January 31, 2017; revised March 2017). If materials are found or known to contain PCBs, those materials must be managed appropriately and according to all applicable local, state, and federal requirements. Guidance on the management of PCBs-containing materials is beyond the scope of this document.

To establish the PCBs protocol, currently established protocols were evaluated that are widely accepted in the building demolition industry for other Federal- and State-regulated constituents of concern. This document provides applicable examples of sampling and evaluation procedures for building materials potentially contaminated with asbestos-containing material (ACM)[4] and lead-based paint (LBP)[5], which are summarized and referenced in Appendix C. These components include guidance on sampling frequencies, laboratory sample analysis, quality assurance and quality control procedures, and reporting.

[4] Asbestos-containing material (ACM) means any material or product which contains more than one percent asbestos.

[5] Lead-based paint (LBP) is any paint, varnish, shellac, or other coating that contains lead equal to or greater than 1.0 mg/cm² as measured by XRF device or laboratory analysis, or 0.5 percent by weight (5,000 ppm or 5,000 mg/kg) as measured by laboratory analysis.

2. PCBS BUILDING MATERIAL EVALUATION PROTOCOL

This section presents the evaluation protocol for identifying building materials in structures constructed or remodeled between the years 1950 and 1980[6] that may contain a significant mass of PCBs. Once identified as containing PCBs at concentrations exceeding 50 ppm, these materials should be properly managed prior to building demolition, to ensure PCBs are not discharged to the municipal storm drain system.

This protocol is not intended to address all PCBs-containing materials that may be disturbed during building demolition. Additional sampling is likely to be required to comply with USEPA and Cal/OSHA regulations pertaining to the management, removal and disposal of PCBs-containing materials.

For this program, it is assumed that organizations and staff qualified to sample, test, remediate, and dispose of PCBs at the building site will coordinate processes for other hazardous building materials at the building site, to ensure proper sampling, testing, remediation, and disposal or all statutorily required hazardous materials handling.

2.1 Priority Building Materials to be Tested

A prioritized list of PCBs-containing materials is provided in Appendix A. Building materials were evaluated based upon the following criteria:

- **Source Material** – Does the building material contain PCBs through the original product manufacturing process or was the building material contaminated (impregnated) with PCBs from an adjacent building material that already contained PCBs? For the evaluation, building materials originally manufactured with PCBs at or above 50 mg/kg were prioritized.
- **Concentration** – Building materials were evaluated based on readily available existing data regarding ranges of PCBs concentrations identified in the materials.
- **Prevalence –** A prevalence factor was assigned based upon best professional judgement of the prevalence of occurrence of the PCBs-containing materials in buildings, which ranged from highly prevalent to low prevalence.
- **Ease of Removal –** Building materials were evaluated based on their attachment to the building, which ranged from "very easily removed" to "difficult to remove," under the assumption that higher ease of removal results in higher feasibility and lower costs for removing a material before demolition.

[6] Single-family residential and wood frame structures are exempt.

- **Flaking/Crumbling –** Building materials were evaluated based on their tendency to flake or crumble during disturbance or demolition, which could lead to a higher likelihood of entering stormwater as a result of building demolition.

- **PCBs Removed by Other Waste Program –** This factor addresses materials that are removed from buildings because of other waste management programs (e.g., Universal Waste Rule). Fluorescent light ballasts[7], polyurethane foam furniture, and Askarel fluid used in transformers, all of which may contain PCBs, are typically managed during pre-demolition activities under current regulations and programs that require removal of universal waste and outdated transformers. For this program it is assumed that those materials will be evaluated and managed under those existing programs.

Material prioritization was conducted by assigning a score on a scale of 1 to 5 (low to high) for each criterion. The final score for each material type was calculated as the average of the scores assigned to the six criteria. The materials given the highest scores through the prioritization analysis are shown below, along with their typical locations in a building. For this evaluation, thermal insulation and fiberglass insulation were grouped together as they tend to be co-located and are typically managed together.

Many building materials may contain PCBs. The building owner is responsible for identifying and handling all hazardous materials in accordance with all applicable laws, including all materials with 50 ppm or more PCBs. For purposes of obtaining a demolition permit, the building owner must sample at least the limited number of priority building materials listed below[8] (along with typical locations where they are found) using the protocols described in Section 2.2. This protocol is only for sampling of priority building materials. Building materials coming into contact with priority building materials are not the focus of this protocol.

1. Caulks and Sealants:
    a. Around windows or window frames (e.g., window glazing putty, window caulking, etc.);
    b. Around door frames; and
    c. Expansion joints between concrete sections (e.g., floor segments).
2. Thermal/Fiberglass Insulation and Other Insulating Materials:
    a. Around HVAC systems,

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[7] Fluorescent light ballasts that contain PCBs are not required to be managed under the Universal Waste Rule Program but are recommended by the EPA to be identified in a pre-demolition survey of a structure and to be managed with the removal of other required wastes in the abatement process.

[8] Applicants may use existing sampling results of the priority building materials. Applicants who have conducted sampling prior to the publication of this protocol may use that data provided it is consistent with this protocol (e.g., analytical methods, sample collection frequency, and QA/QC).

   b. Around heaters,
   c. Around boilers,
   d. Around heated transfer piping, and
   e. Inside walls or crawls spaces.

3. Adhesive/Mastic:
   a. Below carpet and floor tiles;
   b. On, under, or between roofing materials and flashing.

4. Rubber Window Seals/Gaskets:
   a. Around windows or window frames.

Examples of the prioritized PCBs-containing building materials and what they may look like in a building planned for demolition are provided in Appendix B.

It should be noted that some materials that are being evaluated for PCBs in this protocol may also be associated with asbestos, lead, or other hazardous substances. Since this protocol follows pre-established asbestos management program guidelines and procedures, the sampling frequency, types of building materials, and surveying techniques overlap with the PCBs survey protocol. If a material has been determined to contain asbestos, lead or other hazardous substances and will be abated under an associated waste program, that material need not be sampled for PCBs under this program.

2.2 PCBs Sampling Procedures

2.2.1 Sampling Equipment

Building materials that are planned to be collected for laboratory analysis should be placed in laboratory-supplied glass jars with Teflon-sealed lids following procedures established in USEPA Method 8082 / 8082A. Samples should be collected with either factory-sealed or decontaminated equipment that will be used to remove a representative building material sample (i.e., scissors, tweezers, pliers, spoons, or putty knife).

For sampling equipment (i.e., scissors, tweezers, pliers, spoons, putty knife, etc.) that will be decontaminated, the following three bucket wash procedure should be performed, which is in general accordance with standard decontamination procedures defined in SESDPROC-205-R3 (USEPA, 2015):

- In the first bucket, mix a residue free cleaning detergent (e.g., Alconox®), with distilled water to generate the recommended detergent concentration specified in the product directions;

- Fill the second bucket with distilled water;
- Fill the third bucket with distilled water;
- Clean the equipment in the first bucket with the cleaning detergent, then rinse in the second and then the third bucket. If the second bucket becomes slightly discolored during the rinse, change the contents of the second bucket with distilled water. Change the third bucket, if any dirt or material is observed in the water, since the third bucket needs to stay clean as it is the final rinse; and
- At the end of cleaning, let the equipment air dry in a clean area before use in sample collection. The rinse water should then be drummed and sampled for disposal. The planned disposal facility should be contacted to determine the required sample analysis for the rinse water characterization and profiling and that the disposal procedures comply with state and federal regulations.

If disposable sampling tools are used, the above decontamination procedures do not apply. Additionally, decon with certain solvents (e.g., hexane) may be utilized for cleaning of tar-like substances, followed with the standard decontamination procedures listed above. It is recommended that equipment is air-dried per the procedure above, but it is up to the discretion of the environmental professional to use alternative drying methods if time constraints for air-drying is prohibitive.

2.2.2 Sample Collection Frequency

For the four prioritized building materials, the following collection techniques and frequency should be followed.

Caulking

Three different types of caulking should be evaluated:

1. Window caulking;
2. Door frame caulking; and
3. Floor and expansion joint caulking.

For each type of caulking material identified, the following number of samples should be collected:

- Collect at least one sample from each homogenous area that contains less than 50 linear feet of caulking;
- Collect at least three samples from each homogenous area that contains between 50 and 250 linear feet of caulking;
- Collect at least five samples from each homogenous area that contains between 250 and 1,000 linear feet of caulking;

- Collect at least seven samples from each homogenous area that contains between 1,000 and 2,500 linear feet of caulking; and
- Collect at least nine samples from each homogenous area that contains greater than 2,500 linear feet of caulking.

If homogenous caulking material is found throughout the building, samples should be spatially distributed so as to not collect the required number of samples from one area. In addition, the width or cross-sectional area of the caulking bead is not relevant for determining the linear footage to be sampled. It is also recommended that the sampler performing the evaluation inspect the entire building prior to sample collection to insure proper distribution is performed.

Thermal/Fiberglass Insulation

For thermal/fiberglass insulation:

- Collect at least one bulk sample from each homogeneous area.

Adhesive/Mastic

For each type of adhesive/mastic material identified, the following number of samples should be collected:

- Collect at least three samples from each homogenous area less than 1,000 square feet;
- Collect at least five samples from each homogenous area between 1,000 and 5,000 square feet; and
- Collect at least seven samples from each homogenous area greater than 5,000 square feet.

If homogenous adhesive/mastic material is found throughout the building, samples should be spatially distributed so as to not collect the required number of samples from one area. It is recommended that the sampler performing the evaluation inspect the entire building prior to sample collection to insure proper distribution is performed.

Rubber Window Seals/Gaskets

For rubber window seals/gaskets identified, the following number of samples should be collected:

- Collect at least one sample from each homogenous area that contains less than 50 linear feet of caulking (of any width or cross-sectional are of bead);
- Collect at least three samples from each homogenous area that contains between 50 and 250 linear feet of caulking;
- Collect at least five samples from each homogenous area that contains between 250 and 1,000 linear feet of caulking;

- Collect at least seven samples from each homogenous area that contains between 1,000 and 2,500 linear feet of caulking; and
- Collect at least nine samples from each homogenous area that contains greater than 2,500 linear feet of caulking.

If homogenous rubber window seals/gaskets are found throughout the building, samples should be spatially distributed so as to not collect the required number of samples from one area. It is also recommended that the sampler performing the evaluation inspect the entire building prior to sample collection to insure proper distribution is performed.

2.2.3 Sample Analysis and Preservation

Samples collected to evaluate building materials for PCBs should be analyzed for Aroclors by EPA Method 8082/8082A[9] by an accredited analytical laboratory. The reporting limit goal should be 500 micrograms per kilogram (µg/kg).[10] The laboratory should be contacted before sampling to confirm that it can meet the reporting limit objectives.

Samples should be chilled and then kept cool between 0 and 6 degrees Celsius (32 and 42.8 degrees Fahrenheit) during storage and transportation to the laboratory following procedures established in USEPA Method 8082/8082A. Proper chain-of-custody[11] procedures should be followed from the time the samples are collected until they are delivered to the laboratory for analysis. Holding times for EPA Method 8082/8082A are sample extraction within 14 days of sample collection and analysis of the extract within 40 days of extraction. <u>However, PCBs are very stable in a variety of matrices and holding times may be extended to as long as one year. Once extracted, analysis of the extract should take place within 40 days.</u>

2.2.4 Quality Assurance and Quality Control

For this program, general quality assurance and quality control (QA/QC) procedures will be utilized. The following checklist should be used by the contractor performing the evaluation:

- QA/QC Checklist:
    - Proper specified sampling equipment was used (pre-cleaned or other, stainless steel);

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[9] Provision C.12.f. requires that Permittees develop and implement or cause to be developed and implemented an effective protocol for managing materials with PCBs concentrations of 50 ppm. EPA Method 8082/8082A is an acceptable method to quantify PCBs. Analysis of PCBs congeners is not required to meet the permit requirement.
[10] The reporting limit can be modified to account for necessary dilutions or interferences, as determined by the laboratory. This reporting limit, which is below the target management level of 50 mg/kg, was selected to allow for data to be collected on the concentration of PCBs in building materials.
[11] Chain-of-custody is the procedure to document, label, store, and transfer samples to personnel and laboratories. For a detailed list of procedures, refer to the *Sample and Evidence Management,* Operating Procedure (SESDPROC-005-R2), January 29, 2013

- o Proper decontamination procedures were followed;
- o Sampling collection spatial frequency was met;
- o A National Environmental Laboratory Accreditation Program (NELAP) laboratory or a California-ELAP (CA-ELAP) were utilized;
- o Samples were received by the laboratory within proper temperature range;
- o Samples were extracted and analyzed within the method holding time for EPA Method 8082/8082A; and
- o Sample reporting limit met data quality objectives.

2.3 Reporting and Notifications

The following considerations are applicable to reporting and notification:

- Assessment results must be submitted to the applicable Permitting Authority by the project applicant;
- Applicants that determine PCBs exist in priority building materials must follow applicable federal and state laws. This may include reporting to USEPA, the San Francisco Bay Regional Water Quality Control Board, and the California Department of Toxic Substances Control (DTSC). These agencies may require additional sampling and abatement of PCBs.
- Depending on the approach for sampling and removing building materials containing PCBs, applicants may need to notify or seek advance approval from USEPA before building demolition. Even in circumstances where advance notification to or approval from USEPA is not required before the demolition activity, the disposal of PCBs waste is regulated under TSCA.
- The disposal of PCBs waste is subject to California Code of Regulations (CCR) Title 22, Section Division 4.5, Chapter 12, Standards Applicable to Hazardous Waste Generators.
- Building owners and employers need to consider worker and public safety during work involving hazardous materials and wastes including PCBs.

For further information, applicants should refer to the *PCBs in Priority Building Materials Screening Assessment Applicant Package*, BASMAA, July 2018.

3. REFERENCES

Guidelines for Asbestos Sampling:

- https://www.epa.gov/asbestos/asbestos-laws-and-regulations

Guidelines for Lead-Based Paint Evaluations:

- Environmental Protection Agency (EPA) - Created the Renovation, Repair, and Painting (RRP) Rule which requires training and certification for anyone working for compensation in pre-1978 residential structures, day care centers, and schools where known or assumed lead-based paint is impacted. The EPA website with complete information on this regulation is https://www.epa.gov/lead/renovation-repair-and-painting-program.
- California Department of Public Health (CDPH) - Created "Title 17" which includes lead testing and abatement provisions in residential and public structures in California. Several important definitions are contained in Title 17 including Abatement, Clearance Inspection, Containment, Lead-Based Paint.
- Lead Contaminated Dust and Soil, Lead Hazard, and Lead Hazard Evaluation. Title 17 establishes that lead testing be performed using XRF equipment or by paint chip sample analysis in California. Lead test kits are not accepted. It also establishes testing in California be performed by a State certified lead inspector/assessor if the testing is related to a project involving compensation.
- Department of Housing and Urban Development (HUD) - Created the HUD Guidelines which contain protocols for lead testing and abatement.

EPA Method 8082A – Polychlorinated Biphenyls (PCBs) by Gas Chromatography

- https://www.epa.gov/sites/production/files/2015-07/documents/8082a.pdf

SESDPROC-205-R3, *Field Equipment Cleaning and Decontamination*, replaces SESDPROC-205-R2. December 18, 2015

- https://www.epa.gov/sites/production/files/2016-01/documents/field_equipment_cleaning_and_decontamination205_af.r3.pdf

SESDPROC-005-R2, *Sample and Evidence Management*, Operating Procedure, January 29, 2013

- https://www.epa.gov/sites/production/files/2015-06/documents/Sample-and-Evidence-Management.pdf

APPENDIX A

PCBs Building Material Prioritization Worksheet

Appendix A - PCBs Building Materials Prioritization

Material	Material Class	Median/Average/Single Reported Concentration (ppm)	Minimum (ppm)	Maximum (ppm)	PCBs Source Material? (Rating values: source = 5, or not source = 1)	Concentration (Rating values: 1 to 5, higher value means higher concentration)	Prevalence of PCBs Containing Material in Buildings (Rating values: high = 5, medium = 3, or low = 1)	Ease of Removal (Rating values: 1 to 5, higher value means easier to remove)	Flaking/ Crumbling (Rating values: 1 to 5, higher value means more likely to flake/crumble)	PCBs Removed by Other Waste Program? (Rating values: not removed by other = 5, or removed = 1)	Prioritization Score
Caulking (sealant, plaster)	**Caulk/sealant/tape/glue**		**0.001**	**752,000**	**5**	**5**	**5**	**3**	**5**	**5**	**4.67**
Thermal insulation	**Insulation**			**73,000**	**5**	**5**	**5**	**4**	**4**	**5**	**4.67**
Fiberglass insulation	**Insulation**			**39,158**	**5**	**4**	**5**	**4**	**4**	**5**	**4.50**
Adhesives/mastic	**Caulk/sealant/tape/glue**			**3,100**	**5**	**3**	**5**	**3**	**5**	**5**	**4.33**
Rubber gaskets	**Gaskets/Rubber**			**84,000**	**5**	**5**	**3**	**3**	**4**	**5**	**4.17**
Wool felt gaskets	Gaskets/Rubber			688,498	5	5	3	3	4	5	4.17
Cloth/paper insulating material	Insulation			12,000	5	4	3	4	4	5	4.17
Foam rubber insulation	Insulation			13,100	5	4	3	4	4	5	4.17
Ceiling tiles coated w/flame resistant sealant	Internal nonstructural surface		53	110,000	5	5	5	3	2	5	4.17
Backer rod	Caulk/sealant/tape/glue			99,000	1	5	5	3	5	5	4.00
Roofing/siding material	External nonstructural surface		0	30,000	5	4	5	3	2	5	4.00
Paint (complete removal)	Paint/pigment/coatings		0.001	97,000	5	5	5	1	3	5	4.00
Insulating materials in electric cable	Electrical		0	280,000	5	5	3	4	1	5	3.83
Adhesive tape	Caulk/sealant/tape/glue			1,400	5	3	1	3	5	5	3.67
Surface coating	Paint/pigment/coatings			255	5	3	5	1	3	5	3.67
Coal-tar enamel coatings	Paint/pigment/coatings			1,264	5	3	5	1	3	5	3.67
Grout	Caulk/sealant/tape/glue			9,100	5	4	1	2	5	5	3.67
Cove base	Internal nonstructural surface			170	5	3	3	4	2	5	3.67
Plastics/plasticizers	Electrical			13,000	5	4	3	3	1	5	3.50
GE silicones	Caulk/sealant/tape/glue	<1.9	0	1.8	5	1	3	2	5	5	3.50
Glazing	Caulk/sealant/tape/glue	Up to 100% liquid PCBs		51	5	2	3	3	3	5	3.50
Flooring and floor wax/sealant	Internal nonstructural surface	Maximum likely >50		51	5	2	3	3	2	5	3.33
Light ballast	Light ballasts	Minimum likely <50	49	1,200,000	5	5	3	5	1	1	3.33
Anti-fouling compounds	Paint/pigment/coatings			59,000	5	4	1	1	3	5	3.17
Polyurethane foam (furniture)	Caulk/sealant/tape/glue			50	5	2	1	5	5	1	3.17
Askarel fluid/cutting oils/hydraulic fluid	Oils/dielectric fluids			450,000	5	5	1	5	2	1	3.17
Fire retardant coatings	Paint/pigment/coatings			59,000	5	4	1	1	3	5	3.17
Waterproofing compounds	Paint/pigment/coatings			59,000	5	4	1	1	3	5	3.17
Electrical wiring	Electrical			14	5	1	3	4	1	5	3.17
Concrete	Concrete/stone	2.5	0.001	17,000	1	4	3	1	4	5	3.00
Foam rubber	Gaskets/Rubber			1,092	1	3	1	3	4	5	2.83
Soil/sediment/sand	Soil/dust	0.15	0.001	581	1	3	1	2	5	5	2.83
Brick/mortar/cinder block	Concrete/stone			1,100	1	3	3	1	4	5	2.83
Wood	Wood			380	1	3	3	3	2	5	2.83
Door frame	Internal nonstructural surface			102	1	2	3	4	2	5	2.83
Metals surfaces in contact with caulk/sealant	Metal surfaces	448	51	448	1	3	1	2	4	5	2.67

Appendix A - PCBs Building Materials Prioritization

Material	Material Class	Median/Average/Single Reported Concentration (ppm)	Minimum (ppm)	Maximum (ppm)	PCBs Source Material? (Rating values: source = 5, or not source = 1)	Concentration (Rating values: 1 to 5, higher value means higher concentration)	Prevalence of PCBs Containing Material in Buildings (Rating values: high = 5, medium = 3, or low = 1)	Ease of Removal (Rating values: 1 to 5, higher value means easier to remove)	Flaking/ Crumbling (Rating values: 1 to 5, higher value means more likely to flake/crumble)	PCBs Removed by Other Waste Program? (Rating values: not removed by other = 5, or removed = 1)	Prioritization Score
Asphalt	Concrete/stone			140	1	2	1	2	4	5	2.50
Carpet	Internal nonstructural surface		0.46	9.7	1	1	1	5	2	5	2.50
Stone (granite, limestone, marble, etc.)	Concrete/stone			130	1	2	1	1	4	5	2.33
Air handling system	Air system		0.46	9.7	1	1	1	3	1	5	2.00

APPENDIX B

Priority Building Materials

Photographic Log

Appendix B

Priority Building Materials to be Tested for PCBs

Photograph 1 **<u>Window Caulking</u>:** **Damaged caulking around a window.**	
Photograph 2 **<u>Window Caulking</u>:** **Worn and cracked caulking around a window.**	

Appendix B

Priority Building Materials to be Tested for PCBs

Photograph 3

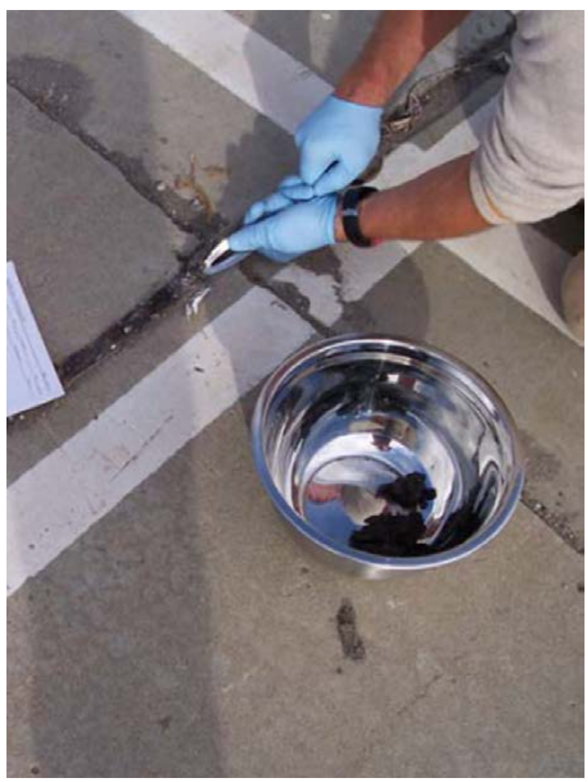
<u>Door Frame Caulking</u>:

Caulking on an interior door or window frame.

Photograph 4

<u>Floor and Expansion Joint Caulking</u>:

Caulking material placed in concrete expansion joints.



Appendix B

Priority Building Materials to be Tested for PCBs

Photograph 5	
<u>Thermal Insulation</u>: **Foam-style thermal insulation material along wall.**	

Photograph 6	
<u>Thermal Insulation</u>: **Damaged floor foam insulation.**	

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Priority Building Materials to be Tested for PCBs

Photograph 7

<u>Thermal Insulation</u>:

Damaged felt-style thermal insulation.

Photograph 8

<u>Thermal Insulation</u>:

Exposed/damaged fiberglass insulation.

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<table>
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<u>Rubber Window Seal/Gasket:</u>

Grey rubber window seal/gasket in a wood type frame.</td><td></td></tr>
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<u>Rubber Window Seal/Gasket:</u>

Off white rubber window seal/gasket in an aluminum type frame.</td><td></td></tr>
</table>

APPENDIX C

Currently Established Building Material Evaluation Protocols

1. CURRENTLY ESTABLISHED BUILDING MATERIAL EVALUATION PROTOCOLS

This section presents evaluation protocols for ACM and LBP, which provide a foundation for the PCBs protocol summarized in Section 3. This section includes guidance on sampling frequencies, laboratory sample analysis, quality assurance and quality control procedures derived from regulatory procedures for ACM and LBP.

1.1 Asbestos Containing Material Evaluation Procedures

Asbestos bulk sampling procedures are specified in several Federal regulations, implemented primarily by the United States Environmental Protection Agency (EPA) as well as the Occupational Safety and Health Administration (OSHA). The Consumer Product Safety Commission (CPSC) and the Mine Safety and Health Administration (MSHA) specify additional regulations and procedures, but these are generally less applicable to evaluation procedures.

The foundational regulations pertaining to asbestos sampling in buildings are the Asbestos Hazard Emergency Response Act (AHERA; Toxic Substances Control Act [TSCA] Title II) (15 U.S.C. § 2641-2656) as well as the Asbestos School Hazard Abatement Reauthorization Act (ASHARA). EPA promulgated regulations under AHERA to require inspection of schools for asbestos-containing building materials, and to perform resultant corrective actions. Furthermore, AHERA tasked the EPA with developing a plan for accreditation of asbestos inspectors. ASHARA extended funding for asbestos programs at schools and expanded accreditation requirements to cover asbestos abatement at commercial buildings other than schools.

Pursuant to AHERA, the Asbestos-Containing Materials in Schools rule (40 CFR Part 763, Subpart E) details specific requirements for building material inspections at schools, preparation of asbestos management plans, and implementation of response actions. EPA regulation on asbestos related to structure demolition is specified in subpart M of the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations (40 CFR Part 61, Subpart M).

The following sections summarize the evaluation procedures specified in the Asbestos-Containing Materials in Schools rule as well as the Asbestos NESHAP regulations. Both OSHA and EPA worker protection requirements are also discussed.

1.1.1 Asbestos-Containing Materials in Schools Rule

The following sections summarize the inspection, re-inspection, sampling, analysis, and evaluation procedures specified in the Asbestos-Containing Materials in Schools rule (40 CFR Part 763, Subpart E).

Evaluation

For each inspection and re-inspection of asbestos-containing building material (ACBM)[12], the local education agency shall have an accredited inspector provide a written evaluation of all friable known or assumed ACBM. The evaluation shall consider the following:

- Location and amount of material, both in total quantity and as a percentage of the functional space;
- Condition of the material, specifying:
  - Type of damage or significant damage (e.g., flaking, blistering, water damage, or other signs of physical damage);
  - Severity of damage (e.g., major flaking, severely torn protective jackets, as opposed to occasional flaking, minor tears to jackets);
  - Extent or spread of damage over large areas or large percentages of the homogeneous[13] area;
- Whether the material is accessible;
- The material's potential for disturbance;
- Known or suspected causes of damage or significant damage (e.g., air erosion, vandalism, vibration, water); and
- Preventive measures that could potentially eliminate the reasonable likelihood of undamaged ACBM from becoming significantly damaged.

The inspector shall classify and give reasons in the written evaluation for classifying the ACBM and suspected ACBM assumed to be ACM into one of the following categories:

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[12] Asbestos-containing building material (ACBM) means surfacing ACM, thermal system insulation ACM, or miscellaneous ACM that is found in or on interior structural members or other parts of a building.

[13] Homogenous refers to a substance or area that is uniform in texture, color, and general physical appearance and properties.

1. Damaged or significantly damaged thermal system insulation ACM;
2. Damaged friable surfacing ACM;
3. Significantly damaged friable surfacing ACM;
4. Damaged or significantly damaged friable miscellaneous ACM;
5. ACBM with potential for damage;
6. ACBM with potential for significant damage; and
7. Any remaining friable ACBM or friable suspected ACBM.

Inspection and Re-inspection

Inspect any building that is to be used as a school, prior to such use, by an accredited inspector. In emergency situations, inspect the building within 30 days of commencement of such use.

For each area of the building, complete the following inspection procedure:

- Visually inspect the area to identify suspected ACBM;
- Touch suspected ACBM to determine friability (Friable material is material that may be crumbled or pulverized by hand pressure alone. Note that thermal system insulation that has retained its structural integrity and that has an undamaged protective jacket or wrap that prevents fiber release shall be treated as non-friable.);
- Categorize all areas into homogenous areas of friable suspected ACBM and non-friable suspected ACBM;
- Assume that some or all the homogeneous areas are ACBM, and for each homogeneous area that is not assumed to be ACBM, collect and submit samples for bulk analysis. Do not sample areas that an accredited inspector assumes to contain ACBM. For uncertain areas, collect and bulk samples and submit for analysis (see Sampling below);
- Assess friable material in areas where samples are collected, in areas where samples are not collected but ACBM is assumed to be present, and in areas identified in previous inspections;
- Record the following information and submit a copy for inclusion in an asbestos management plan, within 30 days of the inspection:

  - An inspection report including the signature, state of accreditation, and accreditation number of each inspector, as well as the date of the inspection;
  - A comprehensive inspection inventory, including the date and locations of samples, locations of areas assumed to contain friable ACBM, and locations of areas assumed to contain non-friable ACBM;
  - A description of the manner used to determine sampling locations;
  - A list of all categorized and identified homogenous areas into surfacing material, thermal system insulation, or miscellaneous material; and
  - Evaluations made of friable material.

Repeat this process as a re-inspection at least once every 3 years after a management plan is in effect. Reassess the condition of friable known or assumed ACBM previously identified. Identify any homogenous areas with material that has become friable since the last inspection or re-inspection and collect and submit samples of the material.

Sampling

Collect samples in a statistically random manner that is representative of each homogeneous area.

- For surfacing material, the number of samples to be collected is as follows:
  - Collect at least three samples from each homogenous area less than 1,000 square feet;
  - Collect at least five samples from each homogenous area between 1,000 and 5,000 square feet; and
  - Collect at least seven samples from each homogenous area greater than 5,000 square feet.
- For thermal system insulation:
  - Collect at least one bulk sample from each homogeneous area that is not assumed to be ACM;
  - Collect at least one bulk sample from each homogeneous area of patched insulation that is not assumed to be ACM, if the patched section is less than six linear or square feet;

    - Where cement or plaster is used on fittings such as tees, elbows or valves, collect samples to determine if material is ACM or not;
    - If the accredited inspector determines that the thermal system insulation is fiberglass, foam glass, rubber, or other non-ACBM, samples are not required to be collected;
- For miscellaneous material, collect bulk samples from each homogeneous area of friable material that is not assumed to be ACM.

Analysis

Samples should be analyzed by laboratories accredited by the National Bureau of Standards (NBS). The laboratories must have received interim accreditation for polarized light microscopy (PLM) analysis under the EPA Interim Asbestos Bulk Sample Analysis Quality Assurance Program until the NBS PLM laboratory accreditation program for PLM is operational.

Samples should be analyzed for asbestos content by PLM using the "Interim Method for the Bulk Determination of Asbestos in Bulk Insulation Samples", found at Appendix E to Subpart E of 40 CFR Part 763. Samples should not be composited.

A homogenous area is considered not to contain ACM only if the results of all samples from that area show asbestos in concentrations of 1 percent or less. An area is considered to contain ACM if at least one sample from the area shows asbestos in concentrations greater than 1 percent.

Submit the name and address of each laboratory performing the analysis, the date of the analysis, and the person performing the analysis for inclusion into the management plan within 30 days of the analysis.

1.2 Lead-Based Paint (LBP) Evaluation Procedures

Lead-Based Paint (LBP) evaluation procedures are codified in various federal and state regulations.

Title IV of the Toxic Substances Control Act (TSCA) as well as other authorities in the Residential Lead-Based Paint Hazard Reduction Act of 1992 directs the EPA to regulate lead-based paint hazards. The primary Federal regulations and guidelines related to LBP evaluation procedures include:

- The Lead Renovation, Repair and Painting Program (RRP) Rule (40 CFR 745, Subpart E);
- The National Lead Laboratory Accreditation Program (TSCA Section 405(b)); and
- The Housing and Urban Development (HUD) Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing (2012 Edition) (pursuant to Section 1017 of the Residential Lead-Based Paint Hazard Reduction Act of 1992, A.K.A. “Title X”)

Furthermore, the California Department of Public Health (CDPH) Title 17, California Code of Regulations, Division 1, Chapter 8 “Accreditation, Certification, and Work Practices for Lead-Based Paint and Lead Hazards,” specifies some LBP evaluation procedures as part of the accreditation program.

The HUD Guidelines provide the most comprehensive procedures for LBP evaluations and are referenced by many other regulations.

There are three primary methods of performing LBP evaluation: test kits, X-ray Fluorescence (XRF) devices, and laboratory testing of paint chips. Sampling procedures for each method are detailed in the following sections.

Under CDPH Title 17, certified Lead Inspector/Assessors are required to use XRF devices or laboratory analysis, and not test kits.

1.2.1 LBP Sampling Procedures: Test Kits

In 2008, the EPA published the RRP rule, which, among other things, established criteria for lead test kits for use in LBP evaluation. Lead test kits recognized by EPA before September 1, 2010, must meet only the negative response criterion outlined in 40 CFR 745.88(c)(1):

> *For paint containing lead at or above the regulated level, 1.0 mg/cm^2 or 0.5% by weight, a demonstrated probability (with 95% confidence) of a negative response less than or equal to 5% of the time must be met.*

Lead test kits recognized after September 1, 2010, must meet both the negative response and positive response criteria outlined in 40 CFR 745.88(c)(1) and (2). The positive-response criterion states:

For paint containing lead below the regulated level, 1.0 mg/cm² or 0.5% by weight, a demonstrated probability (with 95% confidence) of a positive response less than or equal to 10% of the time must be met.

To date, no lead test kit has met both criteria[14]. However, three lead test kits recognized before September 1, 2010, exist and are recognized by EPA:

- 3M™ LeadCheck™, manufactured by the 3M Company, for use on wood, ferrous metal, drywall, and plaster surfaces;
- D-Lead®, manufactured by ESCA Tech, Inc., for use on wood, ferrous metal, drywall, and plaster surfaces; and
- The Commonwealth of Massachusetts lead test kit, for use only on drywall and plaster surfaces.

Test kits cannot determine the concentration of lead, only presence or absence at best. For this reason, test kits are best used by homeowners or other non-professionals as a preliminary evaluation before using an XRF device or laboratory analysis of paint chips.

In California, test kits are not utilized as XRF is shown to be more reliable for testing of lead concentrations in paint.

There are currently no detailed sampling procedures for test kits that would be applicable to PCBs evaluation. However, test kit technology may be a useful paradigm for PCBs evaluation if a kit can be developed to test PCBs at an acceptable concentration that uses a repeatable methodology to meet the data quality objectives.

1.2.2 LBP Sampling Procedures: XRF Devices

The following sections summarize LBP evaluation procedures for XRF devices, including description of sampling equipment, collection techniques and frequency, sample analysis, and quality assurance.

LBP Analyzers

According to the HUD Guidelines, portable XRF devices are the most common primary analytical method for inspections in housing because of their versatility in analyzing a

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[14] US EPA, Lead Test Kits, https://www.epa.gov/lead/lead-test-kits, accessed September 19, 2017.

wide variety of surface types, non-destructive measurement, high speed, and low cost per sample. Each XRF device must have a HUD-issued XRF Performance Characteristic Sheet (PCS), which contains information about XRF readings taken on specific surface types, calibration check tolerances, and interpretation of XRF readings.

Collection Techniques and Frequency

HUD Guidelines provide separate sampling techniques for single- and multi-family housing. However, the general approach to sampling is the following seven-step procedure:

- List all testing combinations of building components and substrates (e.g., wood doors, metal doors, plaster walls, concrete walls);
- Select testing combinations. A numbering system, floor plan, sketch or other system may be used to document which testing combinations were tested;
- Perform XRF testing, including calibration;
- Collect and analyze paint-chip samples as needed;
- Classify XRF and paint-chip results;
- Evaluate the work and results to ensure the quality of the inspection; and
- Document the findings in a summary and in a complete technical report.

Because of the large surfaces and quantities of paint involved, and the potential for spatial variation, HUD Guidelines recommend taking at least four readings per room, with special attention paid to surfaces that clearly have different painting history. The selection of test locations should be representative of locations most likely to be coated with old paint or other lead-based coatings, such as areas with thick paint; areas with worn or scraped off paint should be avoided.

For large buildings with many similar units, HUD Guidelines recommend testing a designated sample of units to provide 95% confidence that most units are below the lead standard. The sample size should be carefully chosen using statistical techniques (see HUD Guidelines, Table 7.3).

Sample Analysis

Portable XRF devices expose a surface to X-ray or gamma radiation and measure the emission of characteristic X-rays from each element in the analyzed surface. The XRF reading is compared with a range specified in the PCS for the specific XRF device being used and the specific substrate beneath the painted surface.

When discrepancies exist between the PCS, HUD Guidelines, and the XRF device's manufacturer's instructions, the most stringent guideline should be followed.

Quality Assurance

HUD Guidelines provide several techniques for evaluation of inspection quality.

A knowledgeable observer independent of the inspection firm should be present for as much XRF testing as possible, especially if they have knowledge of LBP evaluation and/or the paint history of the facility.

The client should ask the inspector to provide copies of the results as soon as possible, or daily, allowing for immediate review.

Data from HUD's private housing lead-based paint hazard control program show that it is possible to successfully retest painted surfaces without knowing the exact spot which was tested. Therefore, the client may consider selecting 10 testing combinations for retesting at random from the already compiled list of all testing combinations, using the XRF device used for the original measurements, if possible. The average of the 10 repeat XRF results should not differ from the 10 original XRF results by more than the retest tolerance limit. The procedure for calculating the retest tolerance limit is specified in the PCS. If the limit is exceeded, the procedure should be repeated using 10 different testing combinations. If the retest tolerance limit is exceeded again, the original inspection is considered deficient.

Currently XRF technology and methods are not applicable to PCBs building material evaluation, as the precision is not adequate to provide a concentration that could be relied upon for this program.

1.2.3 LBP Sampling Procedures: Laboratory Testing of Paint Chips

The following sections summarize LBP evaluation procedures for XRF devices, including the description of sampling equipment, collection techniques and frequency, sample analysis, and quality assurance.

Laboratory analysis of paint chip samples is only recommended by HUD for inaccessible areas or building components with irregular (non-flat) surfaces that cannot be tested using

XRF devices, for confirmation of inconclusive XRF results, or for additional confirmation of conclusive XRF results.

Unlike XRF analysis, paint chip collection techniques may be more directly applicable to potential PCBs collection techniques.

Sampling Equipment

Common hand tools can be used to scrape paint chips from a surface; specialized equipment is not necessary. However, HUD Guidelines recommend that samples should be collected in sealable rigid containers rather than plastic bags, which generate static electricity and make laboratory transfer difficult.

Collection Techniques

HUD Guidelines, which are consistent with ASTM E1729, Standard Practice for Field Collection of Dried Paint Samples for Subsequent Lead Determination, recommend that only one paint chip needs to be taken for each testing combination, although additional samples are recommended for quality control.

The paint chip sample should be taken from a representative area that is at least 4 square inches in size. The dimensions of the surface area must be accurately measured to the nearest $1/16^{th}$ of an inch so that laboratory results can be reported in units of mg/cm^2. Paint chip collection should include collection of all the paint layers from the substrate, but collection of actual substrate should be minimized. Any amount of substrate included in the sample may cause imprecise results.

Sample Analysis

A laboratory used for LBP analysis must be recognized under EPA's National Lead Laboratory Accreditation Program (NLLAP) for the analysis of lead paint; however, States or Tribes may operate an EPA-authorized lead-based paint inspection certification program with different requirements.

There are several standard laboratory techniques to quantify lead in paint chip samples, including Atomic Absorption Spectroscopy, Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES), Anodic Stripping Voltammetry, and Potentiometric Stripping Analysis.

For analytical methods that require sample digestion, samples should be pulverized so there is adequate surface area to dissolve the sample before laboratory instrument measurement. In some cases, the amount of paint collected from a 4-square-inch area may exceed the amount of paint that can be analyzed successfully. It is important that the actual sample mass analyzed not exceed the maximum mass the laboratory has successfully tested using the specified method. If subsampling is required to meet analytical method specifications, the laboratory must homogenize the paint chip sample (unless the entire sample will eventually be analyzed, and the results of the subsamples combined). Without homogenization, subsampling would likely result in biased, inaccurate lead results. If the sample is properly homogenized and substrate inclusion is negligible, the result can be reported as a loading, in milligrams per square centimeter (mg/cm^2), the preferred unit, or as percent by weight, or both.

Quality Assurance

Laboratory reference materials processed with the paint chip samples for quality assurance purposes should have close to the same mass as those used for paint-chip samples (refer to ASTM methods E1645, E1613, E2051, and E1775).

Reporting

The laboratory report for analysis of paint chip samples should include at a minimum, the information outlined in the EPA National Lead Laboratory Accreditation Program Laboratory Quality System Requirements, Revision 3.0, section 5.10.2, Test Reports[15]. In addition to those minimum requirements, test reports containing the results of sampling must include specified sampling information, if available.

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[15] National Lead Laboratory Accreditation Program: Laboratory Quality System Requirements https://www.epa.gov/sites/production/files/documents/lqsr3.pdf, accessed September 20, 2017.

APPENDIX D

Document Revision History

Protocol for Evaluating Priority PCBs-Containing Materials before Building Demolition

Summary of Revisions November 2019

1. The description of currently established building material evaluation protocols for asbestos and lead-based paint were moved from Section 2 to Appendix C.
2. Both window glazing putty and window caulking were added as examples within the "Caulks and Sealants" category to the list of priority materials to sample in Section 2.1.
3. Added clarification in Section 2.1 that sampling of the priority building materials listed in the protocol is required at a minimum. Sampling of building materials coming into contact with priority building materials is not required specifically by this protocol, but may or may not be part of any subsequent remediation. Also clarified that applicants who have conducted sampling prior to the publication of the protocol may use that data provided it is consistent with the protocol.
4. California-ELAP was added to Section 2.2.4 as an acceptable accreditation for a laboratory used to analyze priority building materials for PCBs (in addition to the national NELAP accreditation).
5. Added a clarification to Section 2.2.1 that decontamination with certain solvents (e.g., hexane) may be utilized for cleaning of tar-like substances off of sampling tools, followed with the standard decontamination procedures listed in the protocol. It is recommended that equipment is air-dried, but it is up to the discretion of the environmental professional to use alternative drying methods if time constraints for air-drying are prohibitive.
6. Section 2.2.3 was revised to increase the reporting limit from 50 to 500 micrograms per kilogram and to allow for the reporting limit to be modified to account for necessary dilutions or interferences, as determined by the laboratory.
7. Minor edits were made to the text throughout to correct typographical errors and improve clarity. In addition, clarifying edits to nomenclature were made to the photo log in Appendix B.

APPENDIX C

ACCWP Green Infrastructure Cost Estimation Methodology Memo

Geosyntec consultants

1111 Broadway, 6th Floor
Oakland, California 94607
PH 510.836.3034
FAX 510.836.3036
www.geosyntec.com

Memorandum

Date:	December 10, 2018
To:	Jim Scanlin, Alameda Countywide Clean Water Program
Copies to:	Laura Prickett, Horizon
From:	Lisa Austin, Principal; Kelly Havens, Senior Engineer; and Brian Rowley, Senior Engineer
Subject:	Green Infrastructure Cost Estimation Methodology Geosyntec Project Number: WW2127

1. INTRODUCTION

This memorandum provides a simple methodology for estimating green infrastructure capital (design and construction) and operations and maintenance (O&M) costs for use in green infrastructure (GI) planning.

To develop the methodology, GI facility cost data were gathered from several sources within the San Francisco Bay Area and Southern California to develop relationships between project size (tributary shed area) and total capital cost (construction and design). Likewise, O&M cost data were gathered from these sources, as well as through literature review.

2. COST ESTIMATE METHODOLOGY OVERVIEW

2.1 Projects Reviewed

Geosyntec assessed available cost information for 51 constructed projects, as follows:

- Ten projects constructed as part of the Caltrans BMP Retrofit Pilot Program;
- Fifteen projects constructed in the following California jurisdictions:
    - City of Concord,
    - City of El Cerrito,
    - City of La Mesa,
    - City of Los Angeles,
    - City of Oakley,
    - City of Pittsburg,

  - City of San Diego,
  - Union City, and
  - Unincorporated Contra Costa County;
- Six projects constructed as part of the BASMAA Clean Watersheds for a Clean Bay (CW4CB) Project (BASMAA, 2017); and
- Twenty constructed projects from Enhanced Watershed Management Plans (EWMPs) located in Southern California.

2.2 Cost Estimation Project Categories

Construction costs vary by facility type and project location. For example, green street projects often include ancillary construction costs associated with retrofitting the existing right-of-way and therefore are often relatively more expensive than other project types per unit area treated. Regional facilities have greater tributary areas and thus often have reduced costs per acre treated given fixed mobilization costs.

Information on facility type and location was used to group the projects into three cost estimation project categories: Green Street, Distributed Green Infrastructure, and Regional Stormwater Control. The following facility types that were included in each category include:

- <u>Green Street</u>: Projects built within the right-of-way, which include curb cutting and other costs associated with street retrofits. The treatment control measures may include infiltration trenches, bioretention, and infiltration galleries.

- <u>Distributed Green Infrastructure</u>: Biofilters, swales, infiltration strips, and bioretention installed within a parcel to treat runoff generated on that parcel.

- <u>Regional Stormwater Control</u>: Infiltration basins, large storage facilities, and treatment wetlands installed to treat runoff from a larger drainage area.

Projects with significant subsurface components were removed from the analysis for the Green Streets and Distributed Green Infrastructure categories due to large variances in overall trends. Subsurface green infrastructure work often involves shoring, utility relocations, and unforeseen costs associated with unknown subsurface conditions. These cost impacts did not appear to affect trends in the Regional Stormwater Control category, and thus projects with subsurface treatment facilities were included.

2.3 Source of Cost Data

Data sources varied for the projects that are summarized. For instance, for EWMP projects, data was collected from various sources, including the Proposition O monthly progress report from

August 2016 (Bureau of Engineering Prop O Clean Water Division, 2016) and publicly available online information, such as the project fact sheets provided by the City of Los Angeles stormwater program (http://www.lastormwater.org/). For CW4CB and Caltrans, cost data was published as part of Project Reports and "BMP Retrofit Pilot Program", respectively. For municipal projects, information was obtained via communication with relevant city staff.

3. COST ESTIMATE RESULTS

3.1 Design and Construction Cost Estimate

Table 1 below presents unit cost for design and construction, in 2018 dollars, for each project category. When analyzing these cost data, best professional judgment was used to distribute the design and construction costs when the information provided was unclear. If design costs were not available for a project, an estimate for design was inferred from other projects for which such costs were available. From these, the cost of design is approximately 30% of the construction cost.

Table 1: Statistical Summary of Unit Capital Cost for Each Project Category

Project Category	No. of Projects (n)	Unit Capital Cost ($/ac treated) in 2018 Dollars[1]					
		Minimum	25th-percentile	Median	75th-percentile	Maximum	Mean
Green Street	19	$25,000	$70,000	$137,000	$267,000	$1,290,000	$213,000
Distributed Green Infrastructure	21	$16,000	$90,000	$121,000	$176,000	$416,000	$153,000
Regional Stormwater Control	11	$15,000	$25,000	$61,000	$127,000	$427,000	$101,000

[1] Units have been rounded to the nearest $1,000.

3.2 Annual O&M Cost Estimate

Annual O&M costs are intended to account for activities necessary to maintain the effectiveness of a project that recur on a regular basis, such as routine maintenance on an annual basis or repairs following a large storm event. For this cost analysis, annual O&M costs do not include replacement (of portions) or rehabilitation of green infrastructure facilities, which occurs approximately every 20 to 30 years.

Data was compiled from the cost estimation sources listed in Section 2.1., when available, as well as from a literature review of reports and studies. Additionally, interviews were conducted in May and June of 2017 [City of Tacoma, Washington (J. Knickerbocker, personal communication, June 1, 2017, and the City of Portland, Oregon (M. Juon, personal communication, May 30, 2017)]. Sources of O&M data are summarized in Table 2.

For planning purposes, annual O&M costs are often assumed to be a percentage of the capital (design and construction) costs. As shown in Table 2 below, annual O&M costs range from approximately 1% to 6% of the capital costs, with an average of 4% of capital cost for the data sources reviewed.

Table 2: Comparison of O&M Cost Estimates

Source	Cost Estimation Category	O&M Annual Cost Factor (Percent of Capital Costs)
EWMP	Green Street	3.6 %
EWMP	Distributed GI	1.3 %
EWMP	Regional	1.3 %
City of Tacoma, Interview, 2017	Green Street	1.0 % - 4.6 %
City of Tacoma, Interview, 2017	Regional	5 %
City of Portland, Interview, 2017	Regional	1.5 % - 4.7 %
City of Portland, Interview, 2017	Green street	1.0 % - 3.1 %
Los Angeles Alliance for a New Economy (LAANE) Liquid Assets Report, 2018 (LAANE, 2018)	Not Specified	4.3 %
Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management, 2013 (Houle et al., 2013)	Not specified	4.1 % - 6.3 %
Caltrans BMP Retrofit Pilot Program Final Report, 2004 (Caltrans, 2004)	Not specified	3.2 %
EPA Green Streets Municipal Handbook, 2008 (EPA, 2008)	Not specified	5.6 %

3.3 Total Project Cost Estimation

The total cost of a project includes the capital costs and the annual O&M costs over the design life of the project.

$$Total\ Cost = Capital\ Cost + Present\ Value\ O\&M\ Cost$$

The capital cost, which includes both the design cost and the construction cost, is estimated for a new project based upon its cost estimation category and treatment area using the equations provided in Table 2. The annual O&M cost is calculated by multiplying the capital cost by the applicable fixed O&M cost factor of 4%, derived from the sources listed in Table 3. For the purposes of this analysis, a 20-year design life and a 3% inflation rate were used to calculate the total present value of the annualized O&M costs.

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APPENDIX D

BASMAA Source Control Loads Reduction Accounting for RAA Report

SOURCE CONTROL LOAD REDUCTION ACCOUNTING

FOR REASONABLE ASSURANCE ANALYSIS

Prepared for

Bay Area Stormwater Management Agencies Association

Prepared by

Geosyntec Consultants, Inc.
1111 Broadway, 6th Floor
Oakland, California 94607

EOA, Inc.
1410 Jackson Street
Oakland, California 94612

Project Number: LA0499

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ACRONYMS AND ABBREVIATIONS

ACCWP	Alameda Countywide Clean Water Program
BASMAA	Bay Area Stormwater Management Agencies Association
CCCWP	Contra Costa Clean Water Program
GSI	Green Stormwater Infrastructure
GIS	Geographic Information System
IMR	Integrated Monitoring Report
mg/ac/yr	milligram per acre per year
mg/kg	milligram per kilogram
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
OFEE	Oil-Filled Electrical Equipment
PCBs	Polychlorinated Biphenyls
PG&E	Pacific Gas and Electric Company
POC	Pollutants of Concern
POTW	Publically Owned Treatment Works
RAA	Reasonable Assurance Analysis
ROW	Right-of-Way
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFEI	San Francisco Estuary Institute
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
TMDL	Total Maximum Daily Load
WY	Water Year

1. INTRODUCTION

1.1 Background

Municipal Regional Permit (MRP; SFBRWQCB, 2015[1]) Provisions C.11.b and C.12.b required the Permittees to develop and implement an assessment methodology and data collection program to quantify mercury and polychlorinated biphenyls (PCBs) loads reduced through implementation of pollution prevention, source control, and treatment control measures. BASMAA prepared the report *Interim Accounting Methodology for TMDL Loads Reduced* (BASMAA, 2017a), which was approved by the Water Board for use during MRP 2.0. The Permittees have used this assessment methodology to demonstrate progress towards achieving the load reductions required in the MRP 2.0 permit term. This report has been prepared to address the requirements of MRP Provisions C.11.b.iii.(3) and C.12.b.iii.(3), which require the Permittees to submit, for Executive Officer approval, refinements to the Interim Accounting Methodology to assess mercury and PCBs load reductions in the next permit term (i.e., MRP 3.0).

MRP Provisions C.11.d. and C.12.d. require the Permittees to prepare plans and schedules for mercury and PCBs control measure implementation and a reasonable assurance analysis (RAA) demonstrating that those control measures will be sufficient to attain the mercury total maximum daily load (TMDL) wasteload allocations by 2028 and the PCBs TMDL wasteload allocations by 2030. The *Bay Area RAA Guidance Document* (BASMAA, 2017b) establishes a regional framework and guidance for conducting RAAs in the Bay Area, including the types of modeling and data inputs that may be used by the Programs and Permittees for estimating loads reduced by green stormwater infrastructure (GSI). Section 4.2 of the *Bay Area RAA Guidance Document* states that load reductions for source control measures should be calculated based on methods provided in an approved refinement of the Interim Accounting Methodology, which was previously developed by BASMAA. This report refines the Interim Accounting Methodology for the purposes of non-green infrastructure load reduction accounting in the RAAs.

This report does not include methods used to account for the implementation of GSI and other types of stormwater treatment control measures. The RAA methodologies for GSI are preliminarily described in countywide reports submitted to the SFBRWQCB in September 2018 (ACCWP, 2018; CCCWP, 2018; FSURMP, 2018; SMCWPPP, 2018; and SCRURPPP, 2018) and will be more fully described in the countywide RAA reports that will be submitted in September 2020. The GSI RAA methodologies have undergone external peer review and the results of the countywide GSI RAA modeling for each county will be submitted to the SFBRWQCB in September 2020. Non-GSI treatment control measure[2] load reductions would be modeled similarly to GSI load reductions, so are not discussed in this report.

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[1] Reissued November 19, 2015 with effective date January 1, 2016, to 77 Phase I municipal stormwater Permittees in five Bay Area counties which are among over 90 local agencies comprising the Bay Area Stormwater Management Agencies Association (BASMAA).
[2] Non-GSI treatment control measures that are not included in this report, for example, include treatment wetlands or media filters. Full trash capture devices, enhanced operations and maintenance activities, and diversion to POTW could also be considered as treatment control measures; these measures are included in this report.

1.2 Report Overview

A description of the source control measures, load reduction accounting methodologies, reporting requirements, and assumptions are presented in Sections 2 through 10 of this report for the following mercury and PCBs source control measure categories:

- Source Property Identification and Abatement;
- Management of PCBs in Building Materials;
- Management of PCBs in Electrical Utilities;
- Management of PCBs in Roadway and Storm Drain Infrastructure;
- Enhanced Operations and Maintenance Control Measures;
- Trash Full Capture Systems Implementation;
- Diversion to Publicly Owned Treatment Works (POTW); and
- Mercury Load Avoidance and Reduction.

The appendices present:

- A summary of how the land used-based PCBs and mercury yields were developed;
- A statistical summary of the observed urban sediment concentrations;
- Source area investigation and abatement guidance and referral/self-abatement forms;
- An estimate of load reductions for the PCBs in Electrical Utilities Management Program and the PCBs in Roadway and Storm Drain Infrastructure Program;
- Enhanced inlet cleaning efficiency factor data analysis for storm drain inlets with and without inlet-based full trash capture devices;
- Enhanced street sweeping efficiency factors; and
- Non-inlet-based trash capture device unit efficiency factor data analysis.

1.3 Source Control Load Reduction Accounting Basis

The source control load reduction accounting methodology outlined in this report is based on relative mercury and PCBs yields from different land use categories. This methodology was first outlined in the 2014 Integrated Monitoring Reports (IMRs) (ACCWP, 2014; CCCWP, 2014; SCVURPPP, 2014; SMCWPPP, 2014) and was described in the MRP 2.0 Fact Sheet. The method involves using default factors for PCBs and mercury load reduction credits resulting from foreseeable control measures. This report updates and refines the accounting system to account for new information; justifies the assumptions, analytical methods, sampling schemes, and parameters used to quantify the load reduction for each type of control measure; and indicates what information will be collected and submitted to confirm the calculated load reduction for each unit of activity for each control measure.

As described in the MRP 2.0 Fact Sheet, a land use-based yield is an estimate of the mass of a contaminant contributed by an area of a particular land use per unit time. Essentially, different types of land uses yield different amounts of pollutants because land use types differ in their degree of contamination resulting from differing intensities of historic or ongoing use of pollutants. The land use categories used to calculate land use-based yields were identified from studies conducted to identify potential POC sources and source areas, as described below.

The Regional Watershed Spreadsheet Model (RWSM) was developed as part of the Regional Monitoring Program's Small Tributaries Loading Strategy as a regional-scale planning tool primarily for the purpose of estimating long-term average annual pollutant loads from the small tributaries surrounding San Francisco Bay, and secondarily to provide supporting information for prioritizing watersheds or areas within watersheds for management actions (Wu et al, 2016). The RWSM is structured with three stand-alone empirical models: the hydrology model, sediment model, and pollutant models. The hydrology model uses runoff coefficients based on land use-soil-slope combinations to estimate annual runoff from a watershed. The sediment model uses a function of geology, slope, and land-use to simulate suspended sediment transport in the landscape while adjusting for watershed storage factors. The pollutant model is essentially a "concentration map" that can be driven by either the hydrology model (for pollutant concentrations in water) or the sediment model (for pollutant concentrations on fine sediment particles as particle ratios[3] for specific land use or source areas). Starting in 2010, a multi-year effort was undertaken to systematically develop and calibrate the RWSM. Calibration was completed[4] and the model was released in 2018.

A PCBs source property yield was derived as the product of a representative PCBs concentration in shallow surface soils at known source properties and a representative soil/sediment yield for Old Industrial land use areas. The derivation of the estimated PCBs source property yield is described in Appendix A.

PCBs were more heavily used in older industrial areas so older industrial land use areas yield a much higher mass of PCBs per unit area than newer urban land use areas. The estimated average PCBs and mercury yields from the RWSM are summarized for six land use yield categories in Table 1-1 below. These yields are assigned based on land use but may also be assigned by the Permittees based on monitoring data and/or inspection results (e.g., to assign the Source Property yield to a parcel mapped as Old Industrial). These yield values have been developed using the best available data and technical approach at this time. The Permittees may re-evaluate these yields in the future as more information becomes available.

[3] Particle ratios = pollutant concentration in water (ng/L) / suspended sediment concentration (mg/L), equivalent to mg/kg.
[4] The calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (SFEI, 2017).

Table 1-1: Land Use-Based Yields for PCBs and Mercury

Land Use Category	Assumed Average PCBs Yield (mg/ac/yr)	Assumed Average Mercury Yield[1] (mg/ac/yr)
Source Property	5,078	53
Old Industrial	259	53
Old Commercial / Old Transportation	49	57
Old Residential	2.8	57
New Urban	0.4	4
Agriculture/Open Space	0.4	81

mg/ac/yr – milligrams per acre per year
Source: RWSM Toolbox v1.0 Pollutant Model, Pollutant Spreadsheet Model Calculations – Region. Spreadsheet dated 6/9/2017.
1. The model calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

Appendix B presents concentration statistics for PCBs and mercury observed in street, storm drain, and private property sediment samples collected by BASMAA from 1999 through 2019. The data are summarized by the predominant land use within the vicinity of where the sediment was collected.

2. SOURCE AREA IDENTIFICATION AND ABATEMENT PROGRAM

2.1 Control Measure Description

Source area identification and abatement involves investigations of properties located in historically industrial land use or other land use areas where PCBs were used, released, and/or disposed of and/or where sediment concentrations are significantly elevated above urban background levels[5] and are being transported to the municipal separate storm sewer system (MS4). The source area identification and abatement control measure begins with performing investigations in High Likelihood/Interest areas to identify PCBs sources. Once a source property is identified, the source of PCBs on the property may be abated or caused to be abated directly by the Permittee or the Permittee may choose to refer the source property to the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) for investigation and abatement by the SFBRWQCB. Source properties may include sites that were previously remediated but still have soils concentrations of PCBs that are elevated above urban background levels or may be newly identified source properties. Source properties may also include industrial facilities with ongoing industrial activities that are covered under the General Permit for Stormwater Discharges Associated with Industrial Activities (Industrial General Permit) or another National Pollutant Discharge Elimination System (NPDES) permit.

The Permittees identify significantly elevated PCBs concentrations through surface soil/sediment sampling in the right-of-way or through water sampling where visual inspections and/or other information suggest that a specific property is a potential source of significantly elevated PCBs concentrations. Where data confirm significantly elevated concentrations (e.g., a sediment PCBs concentration equal to or greater than 1.0 mg/kg or a sediment concentration greater than 0.5 mg/kg and other lines of evidence) are present in soil/sediment from a potential source property or in stormwater samples, the Permittees may take actions to cause the property to be abated or may refer that property to the SFBRWQCB to facilitate the issuance of orders for further investigation and remediation of the subject property.

For each referred source property, the applicable Permittee will implement or cause to be implemented one or a combination of interim enhanced operation and maintenance (enhanced O&M) measures in the street or storm drain infrastructure adjacent to the source property during the source property abatement process, or will implement a stormwater treatment system downstream of the property to intercept historically deposited sediment. The intent is to prevent further contaminated sediment from being discharged from the storm drain system. These enhanced O&M measures and/or treatment systems will be described in the source property referral form that is sent to the SFBRWQCB.

The selected enhanced O&M control measure(s) or stormwater treatment must be implemented and maintained during the source property abatement process and should be sufficient to intercept historically deposited sediment in the public right-of-way and prevent additional contaminated sediment from being discharged from the MS4. The Permittee should discuss the

[5] See Appendix B for a statistical summary of urban sediment concentrations.

referral and achieve resolution with the SFBRWQCB prior to submitting the source property referral.

When a referred industrial facility is considered to be abated by the Permittee and the SFBRWQCB, the enhanced O&M measures may be discontinued, and ongoing facility inspections would be conducted as appropriate as part of the Permittee's routine industrial inspection program.

Source area investigation and abatement program guidance is provided in Appendix C.

2.2 Loads Reduced Accounting Methodology

The amount of PCBs loads (i.e., annual mass or milligrams per year (mg/yr)) reduced will be assessed for source properties using the following accounting method:

$$Load\ of\ PCBs\ Reduced = SP_A \bullet (SP_Y - OCOT_Y)$$

Where:

SP_A	=	Source property area (acres (ac))
SP_Y	=	Source property PCBs yield (mg/ac/yr)
$OCOT_Y$	=	Old Commercial/Old Transportation land use PCBs yield (mg/ac/yr)

Thus, the PCBs load reduced in mg/yr will be calculated as the area of the source property in acres multiplied by 5,029 mg/ac/yr (i.e., 5,078 – 49 mg/ac/yr).

There is no mercury load reduction credit given to PCBs source property referrals, as there is not a significant difference between the estimated source property, old industrial, old residential, and old commercial/old transportation mercury yield values.

Fifty percent of this load reduction will be credited to the Permittee for properties that are referred to the SFBRWQCB for abatement at the time of referral provided that enhanced O&M measures or stormwater treatment are implemented or caused to be implemented in the vicinity of the referred source property to prevent further contaminated sediment from being discharged from the storm drain system. The remaining 50% load reduction for referred properties will be credited to the Permittee upon completion of the abatement process or at ten years, whichever occurs first. The SFBRWQCB will notify the Permittee when the abatement process is complete.

Source properties that drain directly to the Bay (as opposed to the street or public storm drain infrastructure) do not allow for implementation of enhanced O&M measures or stormwater treatment by the Permittee. These properties may be submitted to the SFBRWQCB as a referral; 100% load reduction credit will be awarded upon completion of the abatement process, after ten years, or the TMDL compliance date (i.e., 2030 for PCBs), whichever occurs first.

If a source property has been abated without referral to the SFBRWQCB, either through voluntary actions by the property owner or using municipal enforcement powers, then 100% of the load reduction will be credited to the Permittee at the time that the abatement is complete. The Permittee shall provide documentation to the SFBRWQCB that abatement has effectively eliminated the transport of PCBs or mercury to the MS4 or directly to the Bay for all transport mechanisms that apply to the site (e.g., stormwater runoff, wind, vehicle tracking). The documentation shall include information on the type and extent of abatement that has occurred (e.g., have the sources of PCBs to the MS4 been eliminated via soil removal, capping, paving, walls, plugging/removal of internal storm drains, etc.). Documentation may be from a cleanup regulatory agency such as the US Environmental Protection Agency (USEPA) or the California Department of Toxic Substances Control (DTSC). For sites with ongoing industrial activities, water or sediment monitoring data that demonstrates the effective elimination of transport of PCBs offsite into the MS4 or to the Bay should be provided. Information that supports the determination of abatement should be submitted to the SFBRWQCB for review using the Abatement Form in Appendix D.

For source properties that include a combination of industrial area and area that is not likely to be a source of PCBs (e.g., unimpacted open space area), the source property yield will only be applied to the portion of the property that is an industrial area.

Load reduction credit for enhanced O&M measures conducted as a part of a source property referral is included in the credit afforded by the source property referral. Enhanced O&M measures conducted adjacent to a source property that has not been referred to the SFBRWQCB may receive load reduction credit under the enhanced O&M control measure category using the source property yield (see Section 6).

2.3 Reporting

Standard report forms are provided for Source Property Referral and Source Property Self Abatement in Appendix D.

For load reduction reporting associated with the source property identification and abatement control measure, the area of each property will be estimated using the County Assessor's parcel map or an equivalent method. For those source properties that are referred to the SFBRWQCB for abatement, the referral form has a space to describe any enhanced O&M control measures or downstream treatment control measures that have been implemented or are planned to be implemented at the source property. For those source properties that have been abated, the Permittee will provide a statement that the property has been abated, along with documentation on the date, type, and extent of abatement, as described above.

3. PCBS IN BUILDING MATERIALS MANAGEMENT PROGRAM

3.1 Control Measure Description

The MRP Permittees have developed and implemented a process, beginning in July 2019, for managing materials with PCBs concentrations of 50 ppm or greater in applicable structures at the time such structures undergo demolition. Applicable structures include commercial, public, institutional, and industrial buildings constructed or remodeled between the years 1950 and 1980 undergoing full-building demolition. Single-family residential and wood frame structures are exempt.

Permittees have implemented the following process for this control measure:

- Municipalities inform applicable demolition permit applicants that their projects are subject to the program for managing materials with PCBs, necessitating, at a minimum, an initial screening for priority PCBs–containing materials.
- For every applicable demolition project, applicants implement the BASMAA protocol for identifying building materials with PCBs concentrations of 50 ppm and then complete and submit a version of BASMAA's model "PCBs Screening Assessment Form" (Screening Form) or equivalent to the municipality.
- The municipality reviews the Screening Form to make sure it is filled out correctly and is complete and works with the applicant to correct any deficiencies.
- The municipality then issues the demolition permit or equivalent, according to its procedures.
- The municipality sends each completed Screening Form for applicable structures and any supporting documents to its countywide program. The countywide program compiles the forms and works with the other MRP countywide programs to manage and evaluate the data, and to assist Permittees with associated MRP reporting requirements.

3.2 Loads Reduced Accounting Methodology

The load of PCBs reduced through implementation of the PCBs in Building Materials Management Program will be assessed using the following accounting method:

$$Load\ of\ PCBs\ Reduced = \left[\sum_{i=1}^{n}(N_i \bullet M_i \bullet SW_i)\right] \bullet E_f$$

Where:

N_i	=	Number of applicable buildings demolished each year (units/yr)
M_i	=	Average mass of PCBs per applicable building (mg/unit)
SW_i	=	Average fraction of PCBs that enters the MS4 due to demolition without controls (%)

E_f = Average fraction of PCBs prevented by controls from entering MS4 (%)

Reasonable values were used to assign the load reduction for this control measure in MRP 2.0. Permittees received a total of 2,000 g/yr (2 kg/yr) PCBs load reduction value in 2019 when protocols for managing PCBs-containing materials during demolition, as required in MRP 2.0 Provision C.12.f., were developed and implemented. Table 3-1 below lists the four terms and the assumed values used to derive the 2 kg/yr credit. These values may be updated based on data gathered in the future, as described below.

Table 3-1: Terms Used to Estimate the Loading of PCBs in Building Materials for MRP 2.0

Term	Estimated Value	Units
1. Number of applicable buildings[1] demolished per year	50	buildings/year
2. Average mass of PCBs per applicable building	5	kg
3. Average fraction of PCBs that enters MS4s due to demolition without controls[2]	0.01	dimensionless fraction
4. Average fraction of PCBs prevented by controls[2] from entering MS4	0.8	dimensionless fraction

[1]Applicable buildings: constructed from 1950 through 1980 with PCBs concentration in caulks/sealants greater than 50 ppm, excluding single family residential and wood frame buildings.

[2]The term "controls" refers to the proposed new demolition management program, not existing construction controls.

The 2 kg/yr PCBs load reduction stipulated during MRP 2.0 will be retained. During the MRP 3.0 permit term, Permittees may, with the necessary supporting data, request an increase in the credit received for the current program and/or expand the scope of the program to increase loads reduced. Any proposed revision of load reduction credit and/or program expansion would be submitted to the Regional Water Board for Executive Officer approval.

The new management program implemented by Permittees as of July 1, 2019 requires that demolition project proponents identify priority materials in applicable buildings, collect representative samples for analysis, and report the concentrations of PCBs. When a sample concentration is equal to or greater than 50 ppm, the estimated amount of material in the building associated with that sample (and presumably removed and properly disposed of before the demolition occurs) is also reported. These concentration and quantity data can be combined to determine the mass of PCBs removed from the building. These data represent an estimate of the mass of PCBs removed from the building via removal of the priority materials (rather than the estimate provided in the MRP 2.0 fact sheet of the total mass of PCBs in the building in all PCBs-containing materials). Thus, the value of Term 4 in Table 3-1 may be set to 1 when evaluating the PCBs load avoided using data from the new program, since it may be assumed that the program removes 100% of the priority materials identified by the sampling.

3.3 Reporting

BASMAA is developing a regional data management system for compiling the data reported by demolition project applicants. This data for applicable structures, listed below, may be used to support a request for additional loads reduced by the existing program and/or an expansion of the program:

- Project information (e.g., address, APN, year building built, type of construction, estimated demolition date).
- Is building subject to the PCBs screening requirement based on type, use, and age of the building?
- PCBs concentration in each sample of a priority material. Currently, the BASMAA protocol identifies priority materials as caulk, thermal insulation, fiberglass insulation, adhesive mastics, and rubber window gaskets.
- When PCBs equal to or greater than 50 ppm are measured in a priority material sample, the estimated amount of that material in the building (only required to report on sampling of priority materials but reporting any available data on other materials is encouraged).

Permittees will provide documentation of each of the following items:

- The number of applicable structures that applied for a demolition permit during the reporting year; and
- A running list of the applicable structures that applied for a demolition permit (since the date the PCBs control protocol was implemented) that had material(s) with PCBs at 50 ppm or greater, with the address and demolition date.

4. PCBS IN ELECTRICAL UTILITIES MANAGEMENT PROGRAM

4.1 Control Measure Description

The Electrical Utilities Management Program will include improved procedures for documenting removal and disposal of PCBs-containing electrical equipment as part of ongoing equipment maintenance practices.

Electrical utility equipment in both the transmission and distribution systems are distributed across the MRP region. In the past, PCBs were routinely used in electrical utility equipment that contained dielectric fluid as an insulator. This is because prior to the 1979 PCBs ban, dielectric fluid was typically formulated with PCBs due to a number of desirable properties (e.g., high dielectric strength, thermal stability, chemical inertness, and non-flammability). Electrical equipment containing dielectric fluid is typically identified as Oil-Filled Electrical Equipment (OFEE). Any OFEE that contained PCBs in the past could still potentially contain PCBs today. The most common types of OFEE that may contain PCBs are transformers, capacitors, circuit breakers, reclosers, switches in vaults, substation insulators, voltage regulators, load tap changers, and synchronous condensers (PG&E, 2000).

There are hundreds of thousands of pieces of OFEE in public rights-of-way and at hundreds of electrical sub-station facilities across the MRP region. Some portion of these OFEE that are older and/or refurbished may contain (or contained in the past) dielectric fluids with PCBs at concentrations that are of concern if released to MS4s. Due to their large quantity, dispersed nature, and the difficulty in tracking and monitoring discharges, Permittees are limited in their ability to implement and/or enforce consistent and appropriate control measures to reduce releases of PCBs from this source category. This creates a potential missed opportunity to account for past and ongoing removal of PCBs-containing OFEE which has been and continues to reduce loads of PCBs from MS4s to the Bay.

For this control measure, Permittee owned electrical utilities will document the removal of PCBs-containing OFEE since the start of the TMDL and in the future until all PCBs-containing OFEE have been removed from active service, and provide data to support calculations of the associated stormwater load reductions due to these efforts. Additionally, it is anticipated that non-municipally owned regional electrical utilities that are not currently subject to PCBs load reduction requirements (i.e., PG&E) have been and will continue to remove PCBs-containing OFEE and document these efforts, past and present, consistent with methods used by applicable MRP permittees.

4.2 Loads Reduced Accounting Methodology

The load of PCBs reduced through implementation of the Electrical Utilities Management Program will be assessed using the following accounting method:

$$Load\ of\ PCBs\ Reduced = \left[\sum_{i=1}^{n}(LR_i)\right]$$

Where:

LR_i = Load of PCBs reduced for Action i during a given time period of interest (kg/yr).

The PCBs loads reduced in mg/yr will be assessed using the following equation:

$$Load\ of\ PCBs\ Reduced\ (LR) = L_0\ \bullet ER_1 \bullet Y_i$$

Where:

L_0 = Estimated annual load of PCBs that enters MS4 from OFEE at the start of the PCBs TMDL.

ER_1 = Estimated percent of PCBs load prevented from entering the MS4 each year due to equipment removal (percent per year); the percent of loads prevented each year is assumed equivalent to the annual average rate of PCBs-containing equipment removal.

Y_i = Number of Years during the time period of interest i.

The above equation assumes the rate of load reduction achieved over the time period of interest is approximately equivalent to the equipment removal rate.

Reasonable values were developed for each of the terms shown in the equation above in order to calculate the total load reduction credit for implementing the Electrical Utilities Management Program (Table 3, see Appendix E for further detail). Based on equipment removal rates of 1.3% to 4.8% per year (average = 2.3% per year) for municipally-owned electrical utilities between 2005 and 2020 (calculated as described in detail in Appendix E), equipment removals since the start of the PCBs TMDL have reduced PCBs loads each year between 0.014 kg/yr to 0.053 kg/yr (average = 0.025 kg/yr). This equates to a total load reduction achieved by 2020 of between 0.210 kg/yr and 0.795 kg/yr (average = 0.375 kg/yr) due to equipment removals across the Bay Area. Assuming the same annual equipment removal rates in the future, then during the five-year term of MRP 3.0, additional load reductions will range from 0.072 kg/yr to 0.264 kg/yr (average 0.127 kg/yr) for equipment removals. Table 4-1 below identifies the assumed ranges of values for the terms in the above equation that were used to calculate the load reductions achieved since the start of the PCBs TMDL and during MRP 3.0. The derivation of each of the terms shown in Table 4-1 is presented in detail in Appendix E. These values may be updated based on data gathered during MRP 3.0.

Table 4-1: Range of Values used to Estimate the Load Reductions due to the Electrical Utilities Management Program Actions Since the Start of the PCBs TMDL and for MRP 3.0.

Term	Description	Estimated Values	Units
L_0	Annual load of PCBs to MS4 from OFEE at the start of the PCBs TMDL; this value is assumed to be the TMDL-normalized McKee et al. (2006) estimated load to stormwater from transformers and large capacitors in 2005 (see Appendix E for details on how this value was developed).	1.1	kg/yr
ER_1	Percent of PCBs prevented from entering MS4 due to ongoing equipment removals; these values are assumed equivalent to the annual equipment removal rates for municipally owned electrical utilities in the Bay Area between 2005 and 2020 (see Appendix E for details on how these values were developed).	1.3 - 4.8 (Average=2.3)	%/year

Term	Description	Estimated Values	Units
Y_i	The time period of interest since the start of the PCBs TMDL is the fifteen years between 2005 and 2020.	15	years
Y_i	The time period of interest during MRP 3.0 is the five years of the permit term.	5	years

All Permittees will receive a share of the total PCBs load reductions achieved as a result of program implementation based on the accepted countywide apportionment method (e.g., population).

4.3 Reporting

Permittees will summarize the steps they have taken to begin implementing this control measure, either collectively or individually.

Additionally, a report will be developed and provide the following information:

- Estimates of the current annual PCBs loads released to the MS4 from OFEE, based on the best available data;
- Permittees will document efforts by municipally owned electrical utilities in the MRP area to remove PCBs-containing equipment since the TMDL baseline period (i.e., 2003). The report will include the following information:
    - Describe actions that remove PCBs-containing OFEE, including handling and disposal methods; and
    - Document loads avoided calculations, inputs, and assumptions.

5. PCBS IN ROADWAY AND STORM DRAIN INFRASTRUCTURE CAULK MANAGEMENT PROGRAM

5.1 Control Measure Description

The BASMAA study *Evaluation of PCBs in Caulk and Sealants in Public Roadway and Storm Drain Infrastructure* (BASMAA, 2018) sampled caulk and sealant materials from public roadway and storm drain infrastructure around the Bay Area. The sampling program was designed to specifically target roadway and storm drain structures that were constructed during the most recent time period when PCBs were potentially used in caulk and sealant materials (i.e., prior to 1980, with a focus on the 1960's and 1970's). A total of 54 caulk and sealant samples were collected from ten different types of roadway and storm drain structures in the right-of-way (ROW), including concrete bridges/overpasses, sidewalks, curbs and gutters, roadway surfaces, above and below ground storm drain structures (i.e., flood control channels and storm drains accessed from manholes), and electrical utility boxes or poles attached to concrete sidewalks. The individual samples were grouped by structure type and sample appearance (color and texture) and the groups were combined into 20 composites; 10 of these groups were collected from concrete bridges, overpasses, or roadways.

Total PCBs concentrations across the 20 composite samples ranged from non-detect to greater than 4,000 mg/kg. The majority of the composites had PCBs concentrations that were below 0.2 mg/kg. PCBs were not detected in ten of the composite samples, representing nearly 60% of the individual samples collected during this program. PCBs in twenty-five percent (5 of 20) of the composites were above 1 mg/kg. Of these, two composites had very high PCBs concentrations (greater than 1,000 ppm) that indicate PCBs were likely part of the original caulk or sealant formulations. Both of these composites were comprised of black, pliable joint filler materials that were collected from concrete bridges/overpasses.

This control measure has been developed as a result of the outcome of this study. For this control measure, Permittees will track development of a Caltrans specification for managing PCBs-containing caulks and sealants on bridges or roadway overpasses during bridge replacement or joint maintenance. The Caltrans standard specifications for removal, handling, and disposal of caulk or sealant materials during infrastructure replacement or joint maintenance projects will be used to prevent the release of PCBs to the MS4. The Caltrans specification will be applied to all applicable public bridges or roadway overpass structures when the bridge infrastructure undergoes replacement or joint maintenance. Additionally, Permittees will implement the following actions:

1. Maintain a list of applicable bridges that are scheduled for replacement or joint maintenance.
2. Implement or cause to be implemented the Caltrans specifications during applicable bridge projects that are under the direction of the Permittee.
3. Track and report on the use of the specifications for all applicable bridge projects within the Permittee's jurisdiction.

5.2 Loads Reduced Accounting Methodology

A detailed load reduction accounting methodology is provided in Appendix F and summarized here.

Total PCBs load contained in bridges built and/or reconstructed prior to 1981 within the jurisdictions subject to the MRP was estimated using the following equation:

$$\text{Total Load}_{\text{PCBs, Bridges}} = \text{Density}_{\text{sealant}} * \text{Concentration}_{\text{PCBs}} * \sum \text{Volume}_{\text{sealant, bridges}}$$

Where:

$\text{Density}_{\text{sealant}}$ = average sealant density [kg/m^3]

$\text{Concentration}_{\text{PCBs}}$ = empirically derived concentration of PCBs [mg/kg]

$\sum \text{Volume}_{\text{sealant, bridges}}$ = Volume of sealant in all applicable bridges [m^3]

The volume of joint sealant was calculated using an assumed cross-section of sealant, multiplied by the assumed length of applied sealant:

$$\text{Volume}_{\text{sealant, bridges}} = \text{Cross-Section}_{\text{sealant}} * \text{Length}_{\text{sealant}}$$

Where:

$\text{Cross-Section}_{\text{sealant}}$ = Cross-section of applied sealant

$\text{Length}_{\text{sealant}}$ = Length of applied sealant

A summary of the data inputs is provided in Table 5-1 below. The derivation of the values presented in Table 5-1 is described in Appendix F.

Table 5-1: Bridge Load Calculation Data Inputs

Input	Result	Units	Source
Density of Sealant	1,100	kg/m^3	Takhar, 2013
Cross-Section of Sealant	1	square inch	Caltrans, 2007
PCBs Concentration	184	mg/kg	See Section 2.2.1

The estimated total PCBs load contained in bridges built and/or reconstructed prior to 1981 within the jurisdictions subject to the MRP is provided in Table 5-2.

Table 5-2: Total Calculated Loads for Bridges within the MRP Area, Built and/or Reconstructed Prior to 1981

County	Total Sealant PCBs Mass - Joints Only (kg)	Total Sealant PCBs Mass - Joints and Longitudinal Seal (kg)	Number of Bridges[1]
Alameda	3.8	11.2	340
Contra Costa	1.7	7.3	277
San Mateo	2.5	7.2	254
Santa Clara	3.7	10.1	473
Solano	0.9	3.2	133

County	Total Sealant PCBs Mass - Joints Only (kg)	Total Sealant PCBs Mass - Joints and Longitudinal Seal (kg)	Number of Bridges[1]
Total	**12.6**	**39.0**	**1,477**

1. U.S. Department of Transportation Federal Highway Administration, 2019. National Bridge Inventory. Visited 24 March 2020.

To estimate the load reduction associated with long-term bridge or expansion joint replacement, it is assumed that an ongoing PCBs release rate from bridge joints is mitigated through bridge joint maintenance and whole bridge replacement projects. The load reduction estimation is based on the assumption that PCBs in caulk are leaching from bridge joints and longitudinal seals over their lifetime. When that PCBs-containing caulk is replaced or removed through maintenance or replacement projects, the source of PCBs release is removed, and the associated annual released load is also removed. PCBs leaching from the material could occur through incremental wear or through larger damage (e.g., pieces of caulk torn out) over the lifetime of the caulk.

Lacking a literature-based release rate of sealant over time, two potential average annual release rates (i.e., average over the life of the seal) were assumed to calculate an estimated load reduction from removing the joint seal –0.5% and 1.0%. These average annual release rates were applied to the estimated mass for the 1,477 bridges meeting the identified age criteria (Table 5-3). These releases would be eliminated through removal of the joint seal through joint replacement or bridge replacement.

Table 5-3: Long-Term Load Reduction (i.e., Replacement of PCBs-Containing Joints in All Older Bridges)

County	Total Sealant PCBs Load Reduced - Joints Only (g/year)		Total Sealant PCBs Load Reduced - Joints and Longitudinal Seal (g/year)	
	0.5% annual loss rate over life	1% annual loss rate over life	0.5% annual loss rate over life	1% annual loss rate over life
Alameda	19	38	56	112
Contra Costa	8	17	37	73
San Mateo	12	25	36	72
Santa Clara	19	37	50	101
Solano	5	9	16	32
Total	63	126	195	390

This load reduction would occur no later than 2080, based on the assumption that all older joints will be removed/replaced within 100 years of installation.

5.3 Reporting

Permittees will report on the development and use of the Caltrans specification during all applicable replacement activities.

6. ENHANCED OPERATIONS AND MAINTENANCE PROGRAM

6.1 Control Measure Description

Routine MS4 operation and maintenance (O&M) activities include street sweeping, drain inlet cleaning, and pump station maintenance. In addition, culverts and channels are also routinely maintained (i.e., desilted). Enhancements to routine operations and new actions such as storm drain line and street flushing may enhance the Permittees' ability to reduce PCBs and mercury in stormwater. PCBs load reductions achieved through implementation of enhanced O&M control measures, aside from enhanced O&M control measures associated with source property referrals, may be counted as part of the overall load reductions expected during this permit term.

6.2 Loads Reduced Accounting Methodology

6.2.1 Enhanced Inlet Cleaning (With and Without Small Full Trash Capture Devices) and Street Sweeping

Load reductions for enhanced inlet cleaning and street sweeping will be calculated as follows:

$$\textbf{\textit{Annual Load of PCB Reduced}} = P_A \bullet P_Y \bullet EE_f$$

Where:

P_A	=	Catchment area for enhanced O&M measure (acres)
P_Y	=	Area-weighted PCBs yield (mg/acre-year) for the enhanced O&M catchment area based on land use yield (see Table 1-1)
EE_f	=	Enhancement Efficiency factor for enhanced O&M control measure (See Appendix G for enhanced inlet cleaning with and without small full trash capture devices and Appendix H for enhanced street sweeping).

6.2.2 Pump Station Cleanout, Storm Drain Line Cleanout, Street Flushing, and Culvert/Channel Desilting

Load reductions for enhanced pump station cleanout, storm drain line cleanout, street flushing, and culvert/channel desilting will be calculated as follows:

$$Enhanced_{LR} = Current_{LR} - Baseline_{LR}$$

Where:

$Current_{LR}$	=	$Vol_{Current} \bullet \%Sed \bullet \rho \bullet Conc$
$Baseline_{LR}$	=	$Vol_{Baseline} \bullet \%Sed \bullet \rho \bullet Conc$
$Vol_{Current}$	=	Average volume of material collected via the enhanced O&M control measure in current year(s) (post-Fiscal Year 2001-02) (m3/yr)

$Vol_{Baseline}$	=	Average volume of material collected via the O&M control measure in baseline years (prior to and including Fiscal Year 2001-02) (m^3/yr) (assumed to be zero for storm drain line cleanout and street flushing)
%Sed	=	Percent of material collected (by volume) by the enhanced O&M control measure that is sediment < 2mm in diameter (measured)
ρ	=	Sediment density of the material collected by the enhanced O&M control measure (weight per unit volume) (measured)
Conc	=	Average concentration of PCBs in sediments collected by the enhanced O&M control measure (mg/kg; see Appendix B for land use-based sediment concentrations to calculate area-weighted concentrations or alternatively use project-specific measurements).

6.3 Reporting

The following information will be reported for this control measure:

- Description of O&M measure enhancement, including the location of the enhanced measure and description of the enhancement (e.g., increased frequency of implementation over the baseline frequency).
- Baseline and current volumes of material collected.
- Assumptions/data on the percent of the material that was < 2 mm
- Assumptions/data on sediment density
- The calculated loads reduced.

7. TRASH FULL CAPTURE SYSTEMS IMPLEMENTATION PROGRAM

7.1 Control Measure Description

This control measure includes the implementation of large (non-inlet based) full trash capture devices, including hydrodynamic separators (HDS), gross solids removal devices (GSRDs), and baffle boxes in existing developed areas for the purposes of MRP Provision C.10 compliance. These devices collect sediment and debris along with trash, so are considered as a source control measure for the PCBs and mercury associated with the sediment that is captured.

7.2 Loads Reduced Accounting Methodology

The Permittees will quantify and report the amount of PCBs and mercury loads reduced from implementation of large full trash capture devices using the following accounting method:

$$Load\ of\ POC\ Reduced = P_A \bullet P_Y \bullet E_f$$

Where:

P_A	=	Tributary area treated by large full trash capture device (acres)
P_Y	=	Area-weighted PCBs or mercury yield (mg/acre-year) (see Table 1-1)
E_f	=	Efficiency factor for large full trash-capture devices (assumed to be 20%)[6]

7.3 Reporting

The following information will be reported for large full trash capture projects:

- Project name, type of device, and location.
- The year that project construction was completed.
- Total project tributary drainage area.
- The land use area(s) for the project and the area-weighted land use-based yield for the project area.
- POC loads reduced for each project.

[6] See Appendix I for large trash capture device unit efficiency factor data analysis.

8. DIVERSION TO POTW PROGRAM

8.1 Control Measure Description

This control measure consists of diverting dry weather and/or first flush events from MS4s to publicly owned treatment works (POTWs) as a method to reduce loads of PCBs and mercury in urban runoff.

8.2 Loads Reduced Accounting Methodology

The load reduction calculation method for this control measure is:

$$EnhancedReductionDiversion = CurReductionDiversion - BaseReductionDiversion$$

Where:

BaseReductionDiversion	=	Mass of PCBs or mercury reduced via POTW diversions of urban stormwater in 2010 (assume zero for all diversions prior to MRP 1.0 except the Palo Alto Diversion Structure)
CurReductionDiversion	=	Mass of PCBs or mercury reduced via POTW diversions of urban stormwater in Year of Interest

And:

Base or Cur ReductionDiversion = ConcDiversion • VolDiversion

Where:

ConcDiversion	=	Average concentration of PCBs or mercury in sediment and/or water diverted to POTW (measured)
VolDiversion	=	Volume of sediment and/or water diverted to POTW (measured)

8.3 Reporting

For diversions, a project-specific report will be prepared that describes the diversion and project-specific load reduction calculations.

9. MERCURY LOAD AVOIDANCE AND REDUCTION PROGRAM

9.1 Control Measure Description

Mercury load avoidance and reduction includes a number of source control measures listed in the California Mercury Reduction Act adopted by the State of California in 2001. These source controls include material bans, reductions of the amount of mercury allowable for use in products, and mercury device recycling. The following source controls bans are included:

- Sale of cars that have light switches containing mercury;
- Sale or distribution of fever thermometers containing mercury without a prescription;
- Sale of mercury thermostats; and,
- Manufacturing, sale, or distribution of mercury-added novelty items.

In addition, fluorescent lamps manufacturers continue to reduce the amount of mercury in lamps sold in the U.S. Manufactures have significantly reduced the amount of mercury in fluorescent linear tube lamps and streetlamps. The use of mercury containing bulbs has also decreased through replacement of these bulbs with LED lamps.

Mercury Device Recycling Programs resulting in Mercury load reduction generally include three types of programs that promote and facilitate the collection and recycling of mercury–containing devices and products:

1. Permittee-managed household hazardous waste (HHW) drop-off facilities and curbside or door-to-door pickup;
2. Private business take-back and recycling programs (e.g., Home Depot); and,
3. Private waste management services for small and large businesses.

9.2 Loads Avoided/Reduced Accounting Methodology

The load avoidance/reduction methodology for this control measure is:

$$HgReductionL/S/T = BaseLoadLST - CurLoadLST$$

Where:

BaseLoadLST	=	Baseline load of mercury in urban stormwater in 2002 from lamps (L), switches (S), and thermostats (T)
CurLoadLST	=	Current load of mercury in urban stormwater in year of interest from lamps (L), switches (S), and thermostats (T)

And:

BaseLoadLST	=	BaseMassL/S/T • BaseNumL/S/T • T
CurLoadLST	=	CurMassL/S/T • CurNumL/S/T • T

Where:

$BaseMass_{LST}$	=	Average mass of total mercury in each lamp (L), switch (S), and thermostat (T) in 2002 (Assume: 93mg per kilogram of linear fluorescent lamp or Compact Fluorescent Lamp (CFL); 2.9g per switch; and 4g per thermostat).
$CurMass_{LST}$	=	Average mass of total mercury in each lamp (L), switch (S), and thermostat (T) recycled in year of interest (Assume: 35mg per kilogram of linear fluorescent lamp or CFL; 2.9g per switch; and 4g per thermostat).
$BaseNum_{LST}$	=	Number or weight of lamps (L), switches (S), and thermostats (T) improperly discarded into the environment in 2002.
$CurNum_{LST}$	=	Number or weight of lamps (L), switches (S), and thermostats (T) discarded into the environment improperly in year of interest.
T	=	% of total mercury in lamps (L), switches (S), and thermostats (T) that when improperly discarded are transported to the Bay via urban stormwater (Assume 4.8%).

And:

BaseNumLST	=	BaseSpentL/S/T - BaseRecycleL/S/T
CurNumLST	=	CurSpentL/S/T - CurRecycleL/S/T

Where:

BaseSpentLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) that reached their end-of-life in 2002
BaseRcyLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) recycled in 2002
CurSpentLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) that reached their end-of-life in year of interest
CurRecycleLST	=	Number or weight of lamps (L), switches (S), and thermostats (T) recycled in year of interest

Table 9-1 below provides conversion factors and references for the assumed values used in these calculations.

Table 9-1: Mercury Recycling Conversion Factors and References

Item	Conversion and Citation
Fluorescent Lamps	The average mercury content for a four-foot linear fluorescent lamp is 8.3 milligrams (mg). This is equal to 2.075 mg (2.075 X 10 -6 kilograms (kg)) per linear foot. Source: NEMA 2005. Fluorescent and Other Mercury-Containing Lamps and the Environment: Mercury Use, Environmental Benefits, Disposal Requirements. National Electrical Manufacturers Association. March 2005. 14p.

Item	Conversion and Citation
Compact Fluorescent Lamps (CFLs)	The National Electrical Manufacturers Association (NEMA) announced that under the new voluntary commitment, effective October 1, 2010, participating manufacturers will cap the total mercury content in CFLs that are under 25 watts at 4 mg per unit, and CFLs that use 25 to 40 watts of electricity will be capped at 5 mg per unit. Each CFL recycled is assumed to have an average mass of 4.5 mg (4.5 X 10 -6 kg). New CFLs are also assumed to have 4.5 mg on average. Source: NEMA 2010. NEMA Lamp Companies Agree to Reduction in CFL Mercury Content Cap. Available at http://www.nema.org/media/pr/20101004a.cfm. Accessed April 11, 2012.
High Intensity Discharge (HID) Lamps	The average content of a HID bulb is .5 milligrams of mercury (0.5 x 10 -6 kg). Source NEMA Opposition to Ban on Mercury Containing Headlamps, 2004 http://www.nema.org/Policy/Environmental-Stewardship/Lamps/Documents/HID%20Headlamps%2010%2004.pdf
Thermostats	The amount of mercury in a thermostat is determined by the number of ampoules. There are generally one or two ampoules per thermostat (average is 1.4) and each ampoule contains an average of 2.8 grams (g) of mercury. Therefore, each thermostat recycled is assumed to contain approximately 4.0 g (0.004 kg) of mercury. Source: TRC 2008. Thermostat Recycling Corporation's Annual Report for the U.S. Prepared by the Thermostat Recycling Corporation. http://www.thermostat-recycle.org/files/u3/2008 TRC Annual Report.pdf. Each thermostat recycled is assumed to contain approximately 4.0 g (0.004 kg) of mercury. The average weight of one thermostat is 12 ounces. There are 1.3333 thermostats in a pound of thermostats (1 pounds/0.75 pounds = 1.33 thermostats. It is estimated that 0.005333 kg of mercury is recycled for every pound of thermostat recycled (1.333*0.004= 0.005333). Source: Average weight of thermostat obtained from retail websites - www.amazon.com.
Switches	The Recycling Corporation reports that one mercury switch contains 2.87 g (0.00287 kg) of mercury. Source: TRC 2010. Thermostat Recycling Corporation's Annual Report for California. Prepared by the Thermostat Recycling Corporation. Prepared for the State of California's Office of Pollution Prevention and Green Technology, Department of Toxic Substances Control. March 31, 2010.

9.3 Reporting

The Permittees will provide a description of their ongoing mercury recycling program and activities.

10. PROGRAM UPDATES AND REFINEMENTS

The accounting methodology outlined in this report may be updated and refined to account for significant new information as it becomes available. If needed, the proposed updates will be submitted as an addendum to this report for Executive Office approval during the MRP 3 permit term.

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San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), 2014. Integrated Monitoring Report – Part C Pollutants of Concern Load Reduction Opportunities. March 2014.

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Wu, J., Gilbreath, A.N., McKee, L.J., 2016. Regional Watershed Spreadsheet Model (RWSM): Year 5 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 788. San Francisco Estuary Institute, Richmond, California.

APPENDIX A
Land Use-Based Yield Analysis

A.1 METHODOLOGY

The methodology presented in this appendix was developed to assist the MRP Permittees in identifying which watershed characteristics correlate well with areas that have high, moderate, and low rates of pollutant of concern (POC) (i.e., mercury and PCBs) loading to receiving waters via stormwater runoff. The methodology was developed using the collective local understanding of the types of land areas, facilities, and activities that generate POCs, with a focus on PCBs. The ultimate goal of the analysis was to provide first order estimates of POC loading rates from high, moderate, and low likelihood source areas and to assist Permittees in identifying areas for implementing POC load reduction measures that would have the greatest load reduction benefit.

A.1.1 Source Area Mapping

Documented uses and sources of PCBs and mercury in the urban environment and the results of PCBs source identification and abatement studies described in the 2014 Integrated Monitoring Report (IMR) Part B (BASMAA, 2014) have been used to identify PCBs source areas. Findings demonstrate that PCBs (and to a lesser extent mercury) sources are generally associated with watershed areas where equipment containing POCs were transported or used and facilities that recycle POCs or POC-containing devices and equipment. These sources include current and historic metal, automotive, and hazardous waste recycling and transfer stations; electrical properties and power plants; and rail lines. These sources are typically located in areas that were industrialized between the late 1920’s and the late 1970’s, the timeframe when PCBs and mercury production were the greatest in the U.S.

To assist Permittees in identifying potential POC sources and source areas, a number of preliminary GIS data layers were developed using existing and historical information on land use and facility types that were located in the Bay Area during the early to mid-20th century. GIS data layers included a revised “Old Industrial” land use layer that attempted to depict industrial areas that were present in the year 1968; an “Old Urban” land use layer that depicts urban areas developed by 1974, other than those depicted as Old Industrial; points depicting current facilities that have the potential to have or have had PCBs on-site; and historical and current rail lines where PCBs may have been transported.

A.1.1.1. Old Industrial Land Areas

Three sets of data layers were acquired and served as the primary sources of information used to create the Old Industrial data layer: 1) the 2005 version of the Association of Bay Area Governments (ABAG) land use data layers for the five Bay Area counties, which depicts current industrial land use areas; 2) 1968 aerial photographs for the Bay Area at 30,000 scale acquired from the United States Geological Survey’s (USGS) Earth Explorer website; and 3) the most currently available County Assessor parcel data layers for Bay Area counties. Through the development of the Old Industrial layer, two data layers were created. The first depicts industrial land areas in 1968 that are not currently characterized as industrial by ABAG. This data layer was created by panning through 1968 aerial photography and identifying industrial land areas outside of the areas characterized as industrial land use in roughly 2005 by ABAG. The purpose of this layer was to identify potential industrial facilities that were present in 1968, but possibly redeveloped or incorrectly identified within the ABAG land use data. The second data layer that was created depicts areas characterized by ABAG in 2005 as industrial land uses that were clearly not industrial in the 1968 aerial photographs. Most of these areas were developed into industrial land uses after 1968 and are most commonly agricultural in the aerial photographs. All parcels that were identified as at least partially industrial in 1968 were visually checked in the data layer to provide greater confidence in its accuracy. Minor edits were then made based on this quality assurance check. If there was uncertainty as to whether a parcel in the 1968 photographs was industrial, then the parcel was classified based on the ABAG land use data. As a final check, the 1968 aerial photographs were also compared to current aerial photographs and each parcel that had been redeveloped was attributed with the current land use, even if that land use remained industrial.

A.1.1.2. Old and New Urban Land Areas

Old Urban and New Urban land use data layers that depict areas urbanized prior to and after 1974, respectively, were developed using an urban extents data layer from 1974, the closest year to 1968 that the data were available. All areas that were within the urban extent in 1974 were defined as Old Urban; those areas that fell outside of this definition were classified as New Urban. Old Urban areas have been further divided into residential and parks areas versus commercial areas in the current land use classification schema.

A.1.1.3 Identification of Potential POC Associated Facilities

Point data were collected for a number of facility types that may be associated with either PCBs or mercury. These facility types include those associated with electrical generation, known mercury emitters, metal manufacturing, drum recycling, metal recycling, shipping, automotive recycling, general recycling, and those known to have or historically have had PCBs in use. This information was primarily gathered by the San Francisco Estuary Institute (SFEI) as part of the Urban Stormwater Best Management Practices (BMPs) Proposition 13 Grant project and contains data from a variety of sources, including the California Air Resources Board, EnviroStor, Superfund, Department of Toxic Substances Control, and the State Water Resource Control Board.

Certain facility types for which point data were developed were mapped in greater detail to develop polygons to allow area calculations to be performed. Of particular interest for PCBs were the several hundred electrical substations in the Bay Area. Areas for these facilities were delineated using current and 1968 aerial photographs to attribute whether each facility was built prior to or after 1968. Additionally, military, port, and railroad land use areas were developed using ABAG 2005 land use data and the latest assessor's parcel data. Military parcels were further edited to only include developed areas.

Land use and facility data layers created as part of this effort were then combined to create one contiguous data layer. This data layer was attributed with additional information such as city, county, and watershed.

A.2 Regional Watershed Spreadsheet Analysis

A.2.1 Background

The Regional Watershed Spreadsheet Model (RWSM) was developed as part of the Regional Monitoring Program's (RMP) Small Tributaries Loading Strategy as a regional-scale planning tool primarily for the purpose of estimating long-term average annual loads from the small tributaries surrounding San Francisco Bay, and secondarily to provide supporting information for prioritizing watersheds or areas within watersheds for management actions (Wu et al., 2016).

The RWSM is structured with three stand-alone empirical models: the hydrology model, the sediment model, and the pollutant model (Wu et al., 2016). The hydrology model uses runoff coefficients based on geospatially identified land use-soil-slope combinations along with rainfall based on PRISM average precipitation[7] to estimate annual runoff from a defined watershed area. The sediment model uses a function of geology, slope, and land-use to simulate suspended sediment transport in the landscape of a defined watershed while adjusting for watershed storage factors. The pollutant model is a spreadsheet model that combines land use-based pollutant concentrations (i.e., pollutant concentrations in water or pollutant concentrations on fine sediment particles as particle ratios[8] corresponding with specific land use types or source areas) with land use-based hydrology model output or sediment model output. Land use-based loading results are compiled to obtain pollutant loading across a defined watershed.

Starting in 2010, a multi-year effort was undertaken to systematically develop and calibrate the RWSM for San Francisco Bay watersheds using RMP data. Calibration was completed[9] and the model was released in 2018 (SFEI, 2018). For further detail about each component of the model, see the RWSM User Manual (SFEI, 2018).

A.2.2 RWSM Results

The estimated average PCBs and mercury yields from the RWSM Toolbox v1.0 Pollutant Model, "Pollutant Spreadsheet Model Calculations – Region" for the modeled land use yield categories are provided in Table A-1 below. The "Region" spreadsheet results were developed using RMP data from well-sampled watersheds to calibrate pollutant concentration coefficients and applying the resulting coefficients to the region to get average pollutant yield results (Gilbreath, 2019).

[7] 800-m grid, from PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu.
[8] Particle ratios = pollutant concentration in water (ng/L) / suspended sediment concentration (mg/L), equivalent to mg/kg.
[9] The calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

Table A-1: RWSM Land Use-Based Yields for PCBs and Mercury

Land Use Category	Average PCBs Yield (mg/ac/yr)	Average Mercury Yield[1] (mg/ac/yr)
Old Industrial and Source Areas	259	53
Old Commercial and Old Transportation	49	57
Old Residential	2.8	57
New Urban	0.4	4
Agriculture/Open Space	0.4	81

mg/ac/yr – milligrams per acre per year
Note: RWSM Toolbox v1.0 Pollutant Model, Pollutant Spreadsheet Model Calculations - Region. Spreadsheet dated 6/9/2017.
1. The model calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

Table A-2 below presents the RWSM Toolbox v1.0 Pollutant Model, "Pollutant Spreadsheet Model Calculations – Region" results for PCBs and mercury average concentrations in runoff for the five RWSM modeled land use categories (SFEI, 2018).

Table A-2: Regional Watershed Spreadsheet Model PCBs and Mercury Concentrations in Runoff

Land Use Category	Total PCBs (ng/L)	Total Mercury[1] (ng/L)
Old Industrial and Source Areas	204	40
Old Commercial and Old Transportation	40	63
Old Residential	4	63
New Urban	0.2	3
Agriculture/Open Space	0.2	80

1. The model calibration for PCBs is "reasonable" but there remains a lower confidence in the calibration for mercury (Wu et al., 2017).

A.3 Source Area/Property PCBs Yield

The derivation of the estimated PCBs source property yield is described below. The PCBs source property yield was derived as the product of a representative PCBs concentration in surface soils at known source properties and a representative soil/sediment yield for old industrial areas.

Table A-3 and Table A-4 present descriptive statistics for measured concentrations of PCBs from source properties located in Alameda, Contra Costa, Santa Clara, and San Mateo Counties. This dataset includes 670 PCBs surface soil samples from twelve source property locations as well as on-site source property data identified in the street and storm drain sediment dataset that has been compiled by BASMAA to-date (see Appendix B). All soil samples included in the analysis were collected from the 0 to 0.5-foot depth interval, with the exception those collected at one site, based on the assumption that the top six inches of soil would have the most potential to mobilize offsite via wind or rainfall erosion. Data collected from the 0 to 1.0-depth interval were included for the General Electric site in Oakland, as this represented the shallowest reported depth for that site. The range of PCBs concentration (mg/kg) in surface soils for individual Bay Area source properties are provided in Table A-3 and the summary statistics for all sites combined are provided in Table A-4.

Table A-3: Site specific PCBs concentration in surface soil collected on-site from source properties located in Alameda, Contra Costa, Santa Clara, and San Mateo Counties.

Site Location	Minimum (mg/kg)	Average (mg/kg)	Maximum (mg/kg)	Count	Reference
1411 Industrial Rd, San Carlos	1.66	236.31	418.00	5	EKI Environment and Water, 2018. Letter from EKI to Mark Johnson, RWQCB, October 8, 2018. Subject: PCB Storm Drain Sediment Sampling Results 1411 Industrial Road, San Carlos, CA (EKI B80090.00)
270 Industrial Road and 495 Bragato Rd, San Carlos (Delta Star Inc./Tiegel Manufacturing Co.)	3.40	28.36	122.00	14	GHD, 2016. Incremental Sampling Investigation Report. August 4.
335 Brokaw Road, Santa Clara	3.56	3.56	3.56	1	SCVURPPP POC Monitoring
1645 Old Bayshore Highway, San Jose	11.91	11.91	11.91	1	SCVURPPP POC Monitoring
1695 and 1775 Monterey Highway, San Jose	5.47	6.26	7.06	2	SCVURPPP POC Monitoring
1800 South Monterey Road, San Jose	1.79	2.70	3.61	2	SCVURPPP POC Monitoring
Union Pacific Railroad at Schallenberger Road, San Jose	2.80	2.80	2.80	1	CW4CB Final Report/database (http://basmaa.org/Clean-Watersheds-for-a-Clean-Bay-Project)
Union Pacific Railroad Leo Avenue, San Jose	0.02	12.86	127.00	45	GHD, 2017. Remedial Investigation Report. Union Pacific Railroad Property, Leo Avenue ROW, San Jose, CA. September.
ETT111, Oakland	3.70	3.70	3.70	1	Kleinfelder, 2006. Private Property Sediment Sampling Report: Ettie Street Watershed, Oakland, California. Kleinfelder West, Inc.
3430 Wood Street, Oakland (Granite Expo)	93.41	93.41	93.41	1	ibid
1797 12th St, Oakland (Cole Brothers Auto Wrecker)	1.67	1.67	1.67	1	ibid
3015 Adeline St, Oakland (California Electric)	6.08	6.08	6.08	1	ibid
1266 14th St, Oakland (Amtech Lighting)	5.70	5.70	5.70	1	ibid
3425 Ettie St, Oakland (Allied Painter)	1.75	1.75	1.75	1	ibid
2838 Hannah St, Oakland (Former Giampolini)	0.74	9.23	17.73	2	ibid
3428-3434 Helen Street, Oakland (ACM)	10.62	10.62	10.62	1	ibid

Site Location	Minimum (mg/kg)	Average (mg/kg)	Maximum (mg/kg)	Count	Reference
1639 18th St, Oakland (Martinez Bros Trucking)	1.95	1.95	1.95	1	ibid
2601-2812 Peralta St, Oakland (Custom Alloy Scrap Sales)	1.78	7.09	14.73	4	ibid
280 West MacArthur Blvd, Oakland (Kaiser Oakland)	0.01	1.67	27.20	101	Forensic Analytical Environmental Health Consultants, 2017. PCB Soil and Sediment Waste Characterization and Disposal Plan, Kaiser Permanente Medical Center Oakland Legacy Tower Demolition Project, 280 West MacArthur Boulevard, Oakland, CA. Revised April 21, 2017.
710 73rd Avenue, Oakland (Former Aero Plating)	0.01	101.42	790.00	8	Fugro Consultants, Inc. 2016. Limited Soil Sampling Investigation, 710 73rd Avenue, Oakland, CA. January.
700 73rd Avenue, Oakland (Union Pacific Railroad)	0.92	88.16	1,100	14	CDM Smith, 2014. Report of Findings for Data Gaps Investigation Phase B - On-site Investigations, Union Pacific Railroad Company Property, 700 73rd Avenue Oakland, CA. November 14.
5441 International Boulevard, Oakland (General Electric)	0.03	248.36	11,000	134	Geosyntec Consultants, 2009. Feasibility Study Report for the GE Site at 5441 International Boulevard, Oakland, CA. June.
4560 Horton Street, Emeryville (Former South Southern Pacific Railroad)	0.03	0.40	1.91	6	EKI, 2016. Corrective Action Work Plan – Shallow Soil Excavation, Former SPRR Parcel South of 53rd Street, Emeryville, CA. June 29.
One Cyclotron Rd, Berkeley (Lawrence Berkeley National Laboratory)	0.0019	3.23	135.0	227	Lawrence Berkeley National Laboratory, 2016. Quarterly and Semiannual Progress Reports, for the LBNL Hazardous Waste Facility Permit. Environmental Restoration Program. August 1993 through February 2016.
CC-SPL-600-P	1.29	1.29	1.29	1	Contra Costa County 2015 POC Sampling
San Diego St, Richmond (San Diego St)	0.03	0.12	1.20	14	Arcadis, 2016. San Diego Street Transformer Oil Release Cleanup and Closure Report, West End of San Diego Street Richmond, CA, February.
1014 Chesley Ave, Richmond (World Oil)	0.01	0.79	6.50	70	APEX, 2018. PCB Characterization Report, World Oil Corporation Property, 1014 Chesley Avenue, Richmond, California. July 13.
1215 Willow Pass Road, Pittsburg (Molino)	0.02	1.19	5.60	10	Ground Zero Analysis, 2016. Phase II Investigation at 1215 Willow Pass Road, Pittsburg, November 11.
Average for All Properties		**31.88**			

Table A-4: Summary of PCBs concentration in surface soil collected on-site from source properties located in Alameda, Contra Costa, Santa Clara, and San Mateo Counties.

Statistic	PCBs (mg/kg)
Maximum	11,000
90^{th} Percentile	36.90
75th Percentile	4.80
Average	57.71
Median	0.57
25^{th} Percentile	0.069
10^{th} Percentile	0.0020
Minimum	0.0019
N	670

Based on the data reviewed, the Bay Area wide average of PCBs in surface soil from known source properties based on individual property averages is 31.9 mg/kg (Table A-3) and the average based on individual sample concentrations is 57.7 mg/kg (Table A-4). An average concentration is the appropriate metric to use for the yield estimate as it is representative of the total expected loading, which is affected by very high concentrations.

A sediment yield for Old Industrial land uses within the Santa Clara Basin watersheds was estimated based on a Loading Simulation Program – C++ (LPSC) watershed model developed for the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) as part of their reasonable assurance analysis (Paradigm Environmental, 2019 (attached)). The sediment yield estimated from the LPSC watershed model represents baseline hydrology and water quality, specifically sediment and solids. The median, LPSC-modeled sediment yield from Old Industrial land uses in the Santa Clara Basin is 39 grams/m^2/year or 157.8 kg/acre/year. Using the average PCBs concentration, estimated in two different approaches, of 31.9 mg/kg and 57.7 mg/kg from surface soils on Bay Area source properties presented above and the median Old Industrial sediment yield of 157.8 kg/acre, the estimated PCBs yield from source properties is 5,031 mg/acre/year and 9,108 mg/acre/year, respectively.

For mercury, the RWSM yield value for old industrial/source areas will be used for load reduction accounting.

A.4 LIMITATIONS AND UNCERTAINTY

Land use is used as a surrogate for actual PCBs and mercury sources, and although the types of potential sources have been identified, the actual locations and sizes of sources are difficult to determine at this level of analysis. While categorized the same for modeling and analysis purposes, similar land use in different locations may have very different sources and thus distinctly different PCBs and mercury concentrations in runoff.

It is difficult to quantitatively assess the implications of these limitations on the projected magnitude of loads, especially as analysis shifts from regional to more refined spatial scales. The projected loads should be considered first order approximation and reflective of the central tendency of the data for the Bay Area as a whole.

A.5 REFERENCES

Gilbreath, Alicia, 2019. Personal communication via email, 2/26/2019.

McKee, L.J., Gilbreath, A.N., Wu, J., Kunze, M.S., Hunt, J.A., 2014. Estimating Regional Pollutant Loads for San Francisco Bay Area Tributaries using the Regional Watershed Spreadsheet Model (RWSM): Year's 3 and 4 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 737. San Francisco Estuary Institute, Richmond, California.

San Francisco Estuary Institute (SFEI), 2018. Regional Watershed Spreadsheet Model (RWSM) Toolbox v1.0 User Manual and Pollutant Model. Available here: https://www.sfei.org/projects/regional-watershed-spreadsheet-model#sthash.kOKnKvF2.dpbs.

Wu, J., Gilbreath, A.N., McKee, L.J., 2017. Regional Watershed Spreadsheet Model (RWSM): Year 6 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 811. San Francisco Estuary Institute, Richmond, California.

Wu, J., Gilbreath, A.N., McKee, L.J., 2016. Regional Watershed Spreadsheet Model (RWSM): Year 5 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 788. San Francisco Estuary Institute, Richmond, California.

APPENDIX B
Urban Sediment Concentration Statistics

B.1 Descriptive Statistics

Tables B-1 and B-2, and Figures B-1 and B-2 presents descriptive statistics for the PCBs and mercury street and storm drain sediment dataset that has been compiled by BASMAA to-date. This dataset includes 1,535 PCBs samples and 1,350 mercury samples taken within the street right-of-way, storm drain conveyance system, and private properties from 1999 through 2019. Data are summarized by the predominant land use within the vicinity of where the sediment was collected.

Table B-1: PCBs concentrations in sediment (mg/kg) collected from streets, stormwater conveyance systems, and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2019.

Statistic	Old Industrial	Old Urban (Not Residential/Parks)	Old Urban (Residential /Parks)	New Urban	Open Space	All Samples
Maximum	193	17	5.7	0.72	1.1	193
90th Percentile	1.1	0.18	0.30	0.27	0.19	0.77
75th Percentile	0.21	0.08	0.10	0.047	0.054	0.16
Mean	0.79	0.22	0.20	0.066	0.067	0.65
Geometric Mean	0.26	0.09	0.12	0.059	0.058	0.22
Median	0.05	0.03	0.023	0.016	0.009	0.041
25th Percentile	0.01	0.01	0.006	0.001	0.002	0.009
10th Percentile	ND	ND	ND	ND	ND	ND
Minimum	ND	ND	ND	ND	ND	ND
n	1,205	110	98	69	53	1,535

Table B-2: Mercury concentrations in sediment (mg/kg) collected from streets, stormwater conveyance systems, and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2015.

Statistic	Old Industrial	Old Urban Not Res/Parks	Old Urban Res/Parks	New Urban	Open Space	All Samples
Maximum	21	1.7	4.5	13	4.3	21
90th Percentile	0.80	0.41	0.78	0.63	0.35	0.74
75th Percentile	0.30	0.22	0.40	0.27	0.20	0.29
Mean	0.43	0.20	0.43	0.46	0.29	0.41
Geometric Mean	0.29	0.13	0.19	0.27	0.11	0.28
Median	0.15	0.11	0.18	0.14	0.11	0.15
25th Percentile	0.088	0.071	0.082	0.100	0.046	0.086
10th Percentile	0.057	0.051	0.045	0.056	0.030	0.054
Minimum	ND	0.015	0.015	ND	0.020	ND
n	1,069	80	91	62	48	1,350

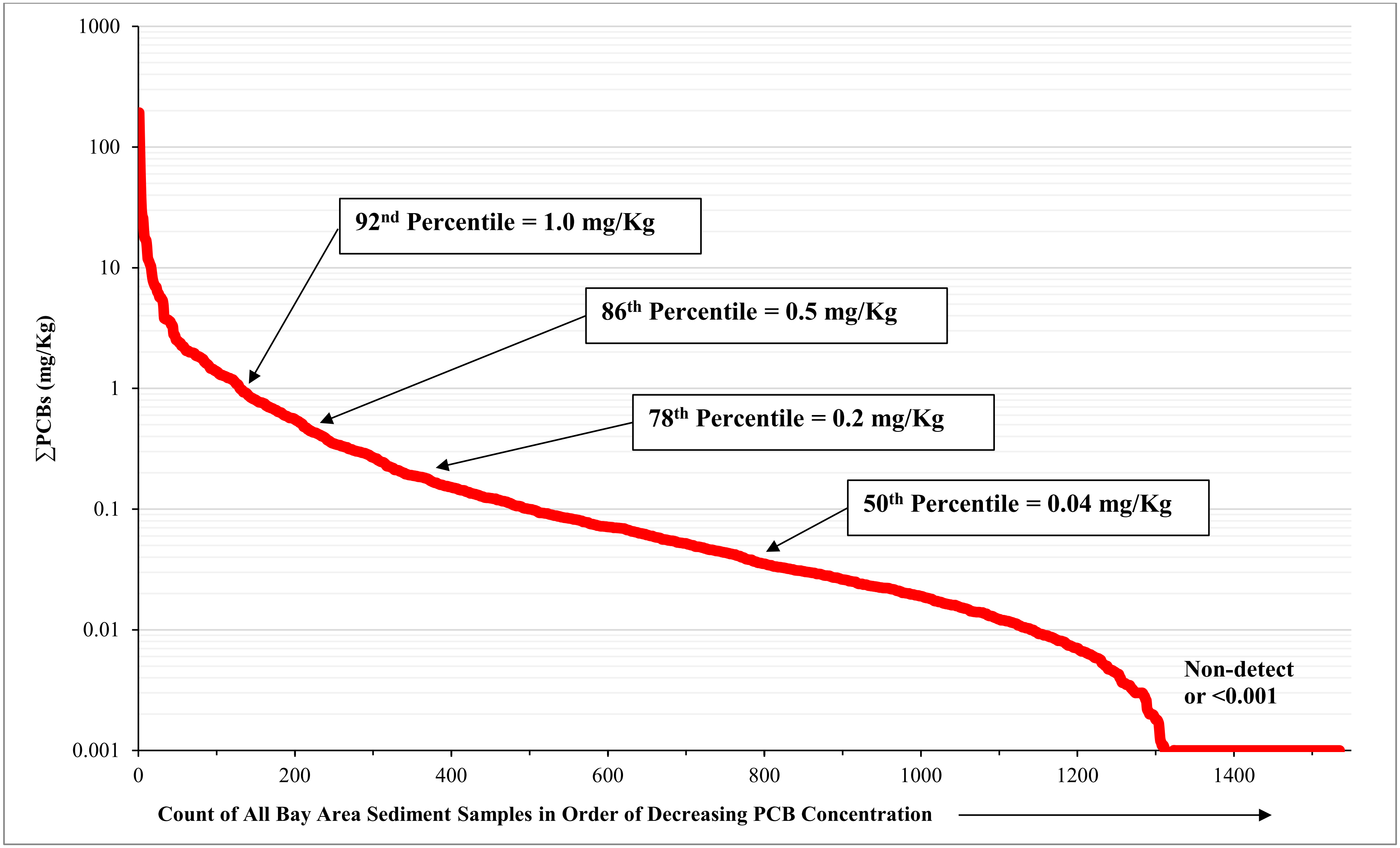

Figure B.1: Total PCB concentrations in sediment collected from streets, stormwater conveyance systems, and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2019.

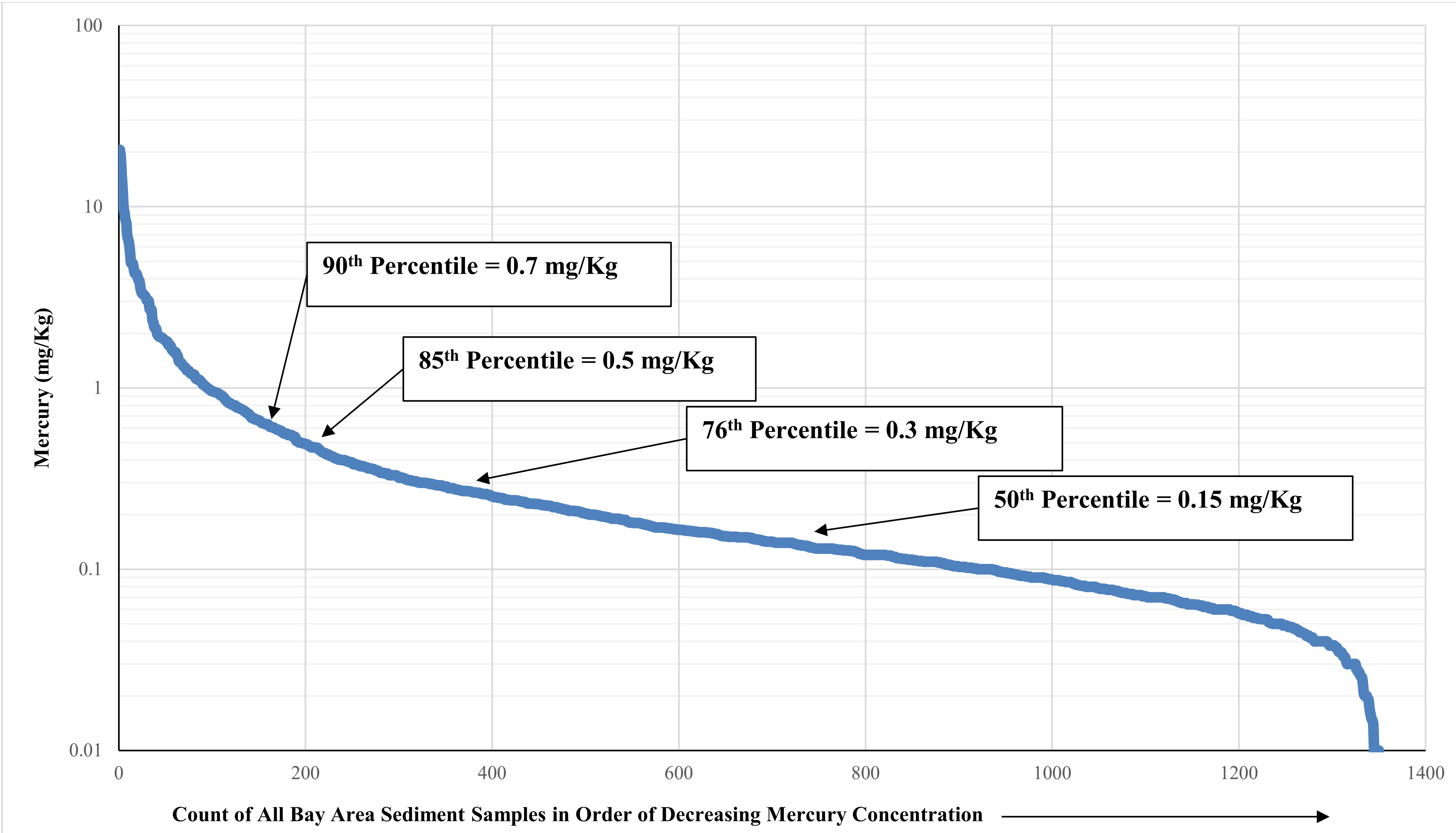

Figure B.2: Total mercury concentrations in sediment collected from streets, stormwater conveyance systems and private properties located in Alameda, Contra Costa, Santa Clara, San Mateo, and Solano Counties between 1999 and 2019.

APPENDIX C
Source Area Investigation and Abatement Guidance

C.1 BACKGROUND

Since 2000, Bay Area stormwater programs have conducted investigations on behalf of MRP Permittees to identify land areas or properties that contribute substantial amounts of PCBs to Bay Area municipal separate storm sewer systems (MS4s). These investigations have largely focused on land areas where industrial land use activities occurred prior to 1980 and continue today (i.e., old industrial land use areas). The *Interim Accounting Methodology for TMDL Loads Reduced Report* (BASMAA, March 2017) described this control measure and defined the methodology that was used for PCBs load reduction accounting during the MRP 2.0 permit term.

The pollutant reduction benefits and costs of conducting source property investigations were examined, along with other stormwater control measures, via the *Clean Watersheds for Clean Bay* (CW4CB) project. The CW4CB project concluded that PCBs source property investigations are much more cost-effective at reducing loads of PCBs than retrofitting old industrial areas with green stormwater infrastructure (GSI). This finding and the pollutant reductions achieved during the MRP 2.0 permit term via this control measure provide an impetus for MRP Permittees to continue source property investigations as a viable control measure for PCBs during MRP 3.0.

The process for conducting source area investigations that would be followed by each stormwater program during MRP 3.0 is presented below.

C.2 SOURCE AREA INVESTIGATION PROCESS

The source area investigation process consists of the four steps outlined below:

1. Identify areas that should be considered for source area investigations;
2. Conduct screening-level investigations in the areas identified in (1) to prioritize these areas as high, moderate, or low-likelihood source areas;
3. Conduct targeted source area investigations in areas prioritized as high or moderate-likelihood source areas in (2) to identify and confirm source areas; and
4. Determine next steps for confirmed source areas.

Each of these steps is described in more detail below.

C.2.1 Step 1: Identify Areas Considered for Source Area Investigations

Identify areas that should be considered for source area investigations as follows:

A. Identify the extent of old industrial land use areas that were present in 2002, the starting date for accounting for POC load reductions;

B. Remove those old industrial land use areas that have already been investigated, referred, and/or abated since 2002;

C. Remove those old industrial land use areas that have undergone redevelopment or GSI retrofit since 2002;

D. Remove those old industrial land use areas that do not drain to an MS4, rather drain directly to the Bay shoreline; and

E. Identify the remaining old industrial land use areas that should be considered for source property investigations by subtracting B, C, and D from A above.

Each countywide stormwater program has implemented this process to identify the total area that will be considered for investigation within each of the five MRP counties.

C.2.2 Step 2: Conduct Screening-level Source Area Investigations

The purpose of screening-level source area investigations is to identify both (1) areas that are likely to contain sources of PCBs, and (2) areas that are unlikely to contain sources of PCBs. This effort will assist Permittees in narrowing the focus for more in-depth, targeted source investigations to those areas that are most likely to contain sources. The screening methods described below are designed to categorize areas at the watershed, MS4 catchment, or individual parcel-scale as high-, moderate-, or low-likelihood source areas according to the following criteria:

- Low-likelihood source areas:
  - No evidence of current or historical use of PCBs; and,
  - all MS4 sediment concentrations and stormwater particle ratios are below 0.5 mg/kg.
- Moderate-likelihood source areas
  - There may be evidence of current or historical use of PCBs; and/or
  - At least one MS4 sediment or stormwater particle ratio between 0.5 and 1.0 mg/kg.
- High-likelihood source areas:
  - There is evidence of current or historical use of PCBs; and/or
  - At least one MS4 sediment or stormwater particle ratio is greater than 1.0 mg/kg.

Screening-level investigation methods may involve any of the following:

- Desktop Analysis. Desktop analysis conducted to gather available information on potential sources of PCBs in a given area or on a specific parcel can also be used to screen areas for further investigation or to remove them from further consideration. This type of screening may include review of current and historic land uses, historical parcel records, contaminated properties databases (e.g., Geotracker and EnviroStor), and aerial photography to identify past and current activities that may be associated with PCBs (e.g., recycling facilities, parcels with large electrical equipment, PCBs manufacturing sites, industrial activities that used PCBs, etc.). Any stormwater or MS4 sediment data collected in the past may also be used as an indicator of likely PCBs sources that warrant further investigation.
- Stormwater Monitoring. Stormwater samples collected at the outlet of a defined drainage area (watershed, MS4 catchment, or individual parcel scale) can be used to screen the entire area that drains to the sampling location; if the PCBs particle ratio in all

stormwater samples is less than 500 ng/g[10], then the entire area draining to that sampling location can be identified as a low-likelihood source area.

- Sediment Monitoring. Suspended sediment samples collected from storm drain infrastructure or a channel that drains a defined area (e.g., a watershed, MS4 catchment, or one or more individual parcels) can be also be used to screen potential source areas. If the PCBs particle ratio in samples collected are less than 0.5 mg/kg, then the area or parcels that drain to the sampling location can be identified as low-likelihood area/parcels.

C.2.3 Step 3: Conduct Targeted Source Area Investigations

Select parcels or smaller areas within areas that are identified in Step 2 as high- and moderate-likelihood source areas may be targeted for more in-depth source investigation. The purpose of a targeted source area investigation is to identify and confirm specific source properties that contribute elevated PCBs to MS4s. Once a source property has been confirmed, Permittees may refer the property to the Regional Water Board for abatement, or the Permittee can oversee property abatement directly. The targeted source area investigation steps are modeled after the CW4CB Source Property Identification and Referral Pilot Projects (BASMAA, 2017). The targeted source area investigation process proceeds through the following four tasks:

1. Records Review. The purpose of the records review is to evaluate available information on specific parcels of interest within an investigation area to identify sources of PCBs. The types of information reviewed may include the following:

    - Site history, cleanup records, or monitoring data available through online databases (i.e., Geotracker and EnviroStor);
    - Cal OES records of PCBs releases from electrical utility equipment;
    - Changes in aerial photos from prior to 1980 and present condition;
    - Outdoor storage, suspected waste areas or ponds;
    - Available stormwater inspection history, including occurrence of PCBs, spills, and stormwater violations on prior inspection reports; and
    - Industrial General Permit (IGP) facility data.

2. Public ROW Surveys / Facility Site Visits. The purpose of public ROW surveys / facility site visits is to verify information obtained during records review, document possible sources, observe sediment migration and flow patterns from parcels of interest to the public ROW, document existing stormwater control measures, and identify potential sample locations. Information documented during public ROW surveys / site visits may include the following:

[10] This value may be adjusted in the future based on the results of the Advanced Data Analysis under development by the Regional Monitoring Program Sources, Pathways, and Loadings workgroup or equivalent analyses conducted by the Permittees.

- Electrical equipment associated with PCBs (e.g., transformers and capacitors);
- Old equipment with hydraulic fluids;
- Outdoor hazardous material/waste storage areas (e.g., tanks, drums), especially with poor housekeeping;
- Signs related to hazardous materials and wastes;
- Recycling/scrap yards (e.g., for automobiles);
- Building demolition activities;
- Unidentified puddles or stains;
- Flow patterns and storm drain structures;
- Existing and potential stormwater control measures;
- Sediment erosion from a property and migration to the street or storm drains;
- Properties that have been redeveloped or are in the process of redevelopment; and
- Redeveloped areas where older exposed soils are available for tracking off site.

The combined results of the records reviews, public ROW surveys / facility site visits are then used to prioritize sampling and develop the sampling plan.

3. Sampling. The purpose of sampling is to confirm if the suspected source area is an actual source of elevated PCBs to the MS4 or is not. Sampling methods may include the collection of sediment in the ROW, and inlet, or the storm drain; and/or stormwater sampling.

4. Identification of Source Areas. This task will review the information gathered throughout the investigation process in order to identify and confirm any source areas. Pollutant concentrations provide the primary means of confirming the identification of source areas. Elevated soil/sediment or stormwater concentrations from samples collected onsite, at the border of a parcel, or at the junction of an onsite underground drainage pipe (lateral) and the MS4 provide the best definitive evidence of whether a property is a source of PCBs to the MS4 or is not. Parcels or areas with PCBs concentrations ≥ 1.0 mg/kg are considered *confirmed source areas* and need no further investigation.

C.2.4 Step 4: Determine Next Steps for Confirmed Source Areas

The options Permittees may pursue for confirmed source areas include the following:

- Submit a referral to the Regional Water Board (and/or other regulatory agency) for follow-up investigation and abatement. The referral process and standard referral form are more fully described in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020).

- Abate or cause the area to be abated directly, without referral to a regulatory agency. For this option, the City will work directly with the property owner to ensure the property is fully abated and a self-abatement report will be submitted to the Regional

Water Board according to the process outlined in the *Source Control Load Reduction Accounting for Reasonable Assurance Analysis* report (BASMAA, 2020).

- If the investigation conducted in Step 3 does not identify a specific source area for the observed elevated concentrations, then the source area will be considered for the application of other types of control measures.

APPENDIX D
Source Property Referral Form
Source Property Self Abatement Report

PCBs SOURCE PROPERTY REFERRAL FORM

The purpose of this form is to provide the Department of Toxic Substances Control, the United States Environmental Protection Agency (USEPA) or the Regional Water Quality Control Board with sufficient information to require site owner/operators to conduct follow-up investigations and/or PCB cleanup actions.

Referring Agency:

Staff Contact Name:

Phone:

Email Address:

Date of Report:

1. Name of Site:

2. Address City County ZIP:

3. APN(s):

4. Provide a Site Location Map and a Site Diagram showing significant features.
Parcel Area (acres):

5. Current Owner

   Name:

   Address:

   City, County & Zip Code:

   Phone:

   E-mail Address:

   Contact:

   Title:

6. Background: Current Business Operations

   Name:

   Period of Operation:

   Type:

7. Background: Previous Business Operations (if known)

   Name:

   Period of Operation:

   Type:

8. Summarize any available information that may indicate hazardous substances, pollutants, or contaminants OTHER than PCBs have been associated with the site.

9. Describe the known and suspected sources of PCBs at the site.

10. Has sampling or other investigation been conducted in the vicinity of the property to identify it as a source property? Yes No

Specify. For samples collected in the public right-of-way, show the nexus to the subject property as clearly as possible. Attach maps or pictures and coordinates (if applicable).

11. Is the site subject to the industrial general stormwater permit? Yes No

If yes, describe the findings of recent and past stormwater inspections conducted on the site, especially in regard to potential PCB sources.

12. Is there currently a potential for exposure of the community or workers to hazardous substances, pollutants, or contaminants at the site? Yes No

If yes, explain:

13. Are any Federal, State, or Local regulatory agencies involved with the site? Yes No

If yes, provide as much of the information below as known:

Agency	Involvement	Contact Name	Phone Number

14. Provide any other pertinent site information not covered above.

15. Describe enhanced control measures or downstream treatment control measures that will be implemented at the site. The selected enhanced O&M control measure(s) or stormwater treatment must be implemented and maintained during the source property abatement process and should be sufficient to intercept historically deposited sediment in the public right-of-way and prevent additional contaminated sediment from being discharged from the MS4.

Attach: Site Location Map, Site Diagram, and any pertinent sampling & analyses data

SOURCE PROPERTY ABATEMENT REPORT

The purpose of this form is to provide the Regional Water Quality Control Board with sufficient documentation that source property abatement has effectively eliminated the transport of PCBs or mercury offsite and from entering the municipal separate storm sewer system (MS4) infrastructure for all transport mechanisms that apply to the site (e.g., stormwater runoff, wind, vehicle tracking). This documentation shall include information on the type and extent of abatement that has occurred (e.g., have the sources of PCBs to the MS4 been eliminated via capping, paving, walls, plugging/removal of internal storm drains, etc.) and any available water or sediment monitoring data that demonstrates the effective elimination of transport of PCBs offsite into the MS4.

Responsible Agency:

Staff Contact Name:

Phone:

Email Address:

Date of Report:

1. Name of Site:

2. Address City County ZIP:

3. APN(s):

4. Provide a Site Location Map and a Site Diagram showing significant features. Parcel Area (acres):

5. Current Owner

   Name:

   Address

   City, County & Zip Code:

   Phone:

   E-mail Address:

6. Describe Current (Post-Abatement) Site Operations/Land Use.

7. Describe Previous Business Operations / Sources of PCBs or Mercury (if known).

8. Summarize any available information that may indicate hazardous substances, pollutants, or contaminants OTHER than PCBs have been associated with the site.

9. Has sampling or other investigation been conducted in the vicinity of the property to identify it as a source property? Yes No

Specify. For samples collected in the public right-of-way, show the nexus to the subject property as clearly as possible. Attach maps or pictures and coordinates (if applicable).

13. Were any Federal, State, or Local regulatory agencies involved with the site abatement?

Yes No

If yes, provide as much of the information below as known:

Agency	Involvement	Contact Name	Phone Number

14. Describe the type and extent of abatement that has occurred.

15. Describe how the property abatement has effectively eliminated the transport of PCBs offsite and from entering the MS4 infrastructure for all transport mechanisms that apply to the site (e.g., stormwater runoff via sheet flow or through a storm drain, wind, or vehicle tracking).

16. Describe any available water or sediment monitoring data that demonstrates the effective elimination of transport of PCBs offsite into the MS4.

Attach: Site Location Map, Site Diagram, and any pertinent sampling & analyses data

APPENDIX E

BASMAA Regional Stressor/Source Identification (SSID) Project Final Report PCBs from Electrical Utilities in San Francisco Bay Area Watersheds

PCBs from Electrical Utilities in San Francisco Bay Area Watersheds Stressor/Source Identification (SSID) Project

Prepared in support of provision C.8.e.iii of

NPDES Permit # CAS612008

Project Report

B A S M A A

Bay Area Stormwater Management Agencies Association

Prepared for:

Bay Area Stormwater Management Agencies Association (BASMAA)

Prepared by:

EOA inc.

FINAL June 30, 2020

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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
Bay	San Francisco Bay
Bay Area	San Francisco Bay Area
Basin Plan	San Francisco Bay Basin (Region 2) Water Quality Control Plan
BASMAA	Bay Area Stormwater Management Agencies Association
BMPs	Best Management Practices
BOD	BASMAA Board of Directors
Cal OES	California Office of Emergency Services
CCCWP	Contra Costa Clean Water Program
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CPUC	California Public Utilities Commission
CPAU	City of Palo Alto Utilities
CWA	Clean Water Act
dba	Doing Business As
DTSC	California Department of Toxic Substances Control
FERC	Federal Energy Regulatory Commission
FSURMP	Fairfield-Suisun Urban Runoff Management Program
kg/yr	kilogram per year
lb.	Pound
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
MT	Metric Tons
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System

PCBs	Polychlorinated Biphenyls
RMC	Regional Monitoring Coalition
ROW	right-of-way
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SVP	Silicon Valley Power
OFEE	Oil-filled Electrical Equipment
PG&E	Pacifica Gas and Electric Company
ppm	parts per million
PMT	BASMAA Project Management Team
RQ	reportable quantity
RCRA	Resource Conservation and Recovery Act
Regional Water Board	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	Standard Operating Procedure
SOW	Scope of Work
SPCC Plan	Spill Prevention Control and Countermeasure Plan
SSID	Stressor/Source Identification
TMDL	Total Maximum Daily Load
TSCA	Toxic Substances Control Act
UCMR	Urban Creeks Monitoring Report
US EPA	United States Environmental Protection Agency
VFWD	Vallejo Flood and Wastewater District
WQOs	Water Quality Objectives
WQS	Water Quality Standard

1.0 Introduction

This project report supports the requirement to implement a Stressor/Source Identification (SSID) Project as required by Provision C.8.e.iii of the San Francisco Bay (Bay) Region Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP) (Order No. R2-2015-0049, SFRWQCB 2015). Per MRP Provision C.8.e.ii, the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC)[1] members are working to initiate eight SSID projects during the five-year term of the MRP (i.e., 2016 – 2020). The RMC programs have agreed that seven SSID projects will be conducted to address local needs (for Santa Clara, Alameda, San Mateo, Contra Costa, Fairfield/Suisun and Vallejo counties), and one project (this project) will be conducted regionally (on behalf of all RMC members). SSID projects follow-up on monitoring conducted in compliance with MRP Provision C.8 (or monitoring conducted through other programs) with results that exceed trigger thresholds identified in the MRP. Trigger thresholds are not necessarily equivalent to Water Quality Objectives (WQOs) established in the San Francisco Bay Basin (Region 2) Water Quality Control Plan (Basin Plan) (SFRWQCB, 2017) by the San Francisco Bay Regional Water Quality Control Board (Regional Water Board); however, sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses.

BASMAA submitted a Regional SSID Work Plan to the Regional Water Board in March 2019. The SSID work plan described the steps that would be taken to investigate sources of polychlorinated biphenyls (PCBs) from electrical utility equipment in watersheds draining to the San Francisco Bay Basin. The Work Plan focused on Pacific Gas and Electric Company (PG&E), the largest electrical utility operating in the MRP area, and the only utility that is not owned by a municipality. The project team developed a letter requesting assistance from the Regional Water Board and outlining the specific data that are needed from PG&E to complete this project. The letter was ultimately approved by the BASMAA Board of Directors (BOD) and sent to the Regional Water Board in June 2019. The letter specifically asked the Regional Water Board to use their regulatory authority under Section 13267 of the Clean Water Act to compel PG&E to provide the needed data. However, PG&E is currently in bankruptcy proceedings, and the outcomes of that process have not yet been determined. As such, the Regional Water Board has delayed sending a "13267 letter" to PG&E, and is currently considering other options for moving forward with PG&E on this issue.

The BASMAA MRP 3.0 C.11/12 workgroup met with and discussed the issue of PCBs in electrical utility equipment with representatives of several municipally-owned electrical utilities in the permit area. Based on the information gained during these discussions, and given the current situation with PG&E, BASMAA requested the project team develop a revised scope of work (SOW) for Task 2 of the Regional SSID Work Plan.

BASMAA submitted a Regional SSID Revised Scope of Work to address PCBs in electrical utility applications in March 2020 to the Regional Water Board. The revised SOW would

[1] The BASMAA RMC is a consortium of San Francisco Bay Area municipal stormwater programs that joined together to coordinate and oversee water quality monitoring and several other requirements of the MRP. Participating BASMAA members include the Alameda Countywide Clean Water Program (ACCWP), Contra Costa Clean Water Program (CCCWP), Fairfield-Suisun Urban Runoff Management Program (FSURMP), San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), and City of Vallejo and Vallejo Flood and Wastewater District (VFWD).

implement the Regional SSID work plan, but would focus on municipally-owned electrical utilities in the San Francisco Bay Area (Bay Area), rather than PG&E. The Regional Water Board staff agreed[2] to a revised approach which focused on data gathering from municipally-owned electrical utilities. The Regional Water Board staff further acknowledged that revision of the work plan submitted in March 2019 is not needed to satisfy SSID project requirements. They also agreed the Regional SSID project will be considered complete based on the outcomes of the work described in this report, which focuses on data from municipally-owned electrical utilities instead of PG&E.

BASMAA retained EOA, Inc., of Oakland, CA to develop the work plan and implement the SSID project under the direction of a BASMAA Project Management Team (PMT). All work on this project is supported by funding provided by BASMAA.

1.1 Overview of SSID Project Requirements

SSID projects focus on taking action(s) to identify and reduce sources of pollutants, alleviate stressors, and address water quality problems. MRP Provision C.8.e.iii requires SSID projects to be conducted in a stepwise process, as described below.

Step 1: Develop a work plan that includes the following elements:

- Define the water quality problem (e.g., magnitude, temporal extent, and geographic extent) to the extent known;
- Describe the SSID project objectives, including the management context within which the results of the investigation will be used;
- Consider the problem within a watershed context and examine multiple types of related indicators, where possible (e.g., basic water quality data and biological assessment results);
- List potential causes of the problem (e.g., biological stressors, pollutant sources, and physical stressors);
- Establish a schedule for investigating the cause(s) of the trigger stressor/source which begins upon completion of the work plan. Investigations may include evaluation of existing data, desktop analyses of land uses and management actions, and/or collection of new data; and
- Establish the methods and plan for conducting a site-specific study (or non-site specific if the problem is widespread) in a stepwise process to identify and isolate the cause(s) of the trigger stressor/source.

Step 2: Conduct SSID investigations according to the schedule in the work plan and report on the status of the SSID investigation annually in the Urban Creeks Monitoring Report (UCMR) that is submitted to the Regional Water Board on March 31 of each year.

[2] Per Jan O'Hara at the BASMAA Monitoring and Pollutants of Concern Committee meeting held on March 3, 2020

Step 3: Follow-up actions:

- If it is determined that discharges to the municipal separate storm sewer system (MS4) contribute to an exceedance of a water quality standard (WQS) or an exceedance of a trigger threshold such that the water body's beneficial uses are not supported, submit a report in the UCMR that describes Best Management Practices (BMPs) that are currently being implemented and additional BMPs that will be implemented to prevent or reduce the discharge of pollutants that are causing or contributing to the exceedance of WQS. The report must include an implementation schedule.

- If it is determined that MS4 discharges are not contributing to an exceedance of a WQS, the SSID project may end. The Executive Officer must concur in writing before an SSID project is determined to be completed.

- If the SSID investigation is inconclusive (e.g., the trigger threshold exceedance is episodic or reasonable investigations do not reveal a stressor/source), the Permittee may request that the Executive Officer consider the SSID project complete.

1.2 SSID Project Report Organization

Step 1 of the SSID process described above in Section 1.1 was completed with the submittal of the BASMAA Regional SSID Work Plan in March 2019 and subsequent Revised Scope of Work (SOW) in March 2020.

The Work Plan and revised SOW identified the following tasks:

1. Conduct desktop analysis of data from Bay Area electrical utilities;
2. Develop Source Control Framework that summarizes the results of the desktop analysis and recommends approach to manage and control releases;
3. Develop data inputs that can be used to account for load reductions from new source control measures;
4. Develop Report that addresses management questions.

As described above, the revised SOW would implement the Regional SSID work plan, but would focus on municipally-owned electrical utilities in the Bay Area, rather than PG&E.

This Regional SSID Project Report provides background information, describes the work conducted in the desktop analysis, and proposes a source control framework to account for past load reductions and to further reduce ongoing loads of PCBs from electrical utility practices.

2.0 Problem Definition, Study Objectives, and Regulatory Background

2.1 Background

PCBs are commercially synthesized oily compounds consisting of carbon, hydrogen, and chlorine atoms. There are 209 possible arrangements of the atoms in PCB compounds. These are referred to as the 209 PCB congeners. PCBs were first manufactured in the United States (US) in 1929 and US production peaked in 1970. PCBs are non-flammable, chemically stable, have a high boiling point, and have electrical insulating properties. Therefore, they were used in hundreds of industrial and commercial applications. Most PCBs were manufactured as a mixture of several individual PCB congeners. The most common name for these mixtures in the US was the Aroclor series produced by Monsanto Company. There were more than ten common Aroclor mixtures.

Due to concern about their persistence in the environment, toxicity, and potential to cause cancer, the US Environmental Protection Agency (US EPA) banned the production and new use of PCBs in 1979. However, PCBs continue to be found in water and sediment collected from the San Francisco Bay, and urban stormwater runoff has been identified as a major source of PCBs to the Bay. Thus, PCBs are considered a legacy pollutant.

2.2 Problem Definition

Fish tissue monitoring in the Bay has revealed the bioaccumulation of PCBs in Bay sportfish at levels thought to pose a health risk to people consuming these fish. As a result, in 1994, the state of California issued a sport fish consumption advisory cautioning people to limit their consumption of fish caught in the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act (CWA) "Section 303(d) list" due to elevated levels of PCBs. In response, in 2008, the Regional Water Board adopted a Total Maximum Daily Load (TMDL) water quality restoration program targeting PCBs in the Bay[3]. The general goals of the TMDL are to identify sources of PCBs to the Bay, implement actions to control the sources, restore water quality, and protect beneficial uses.

The PCBs TMDL estimates baseline loads to the Bay from various source categories. The largest source category, at 20 kilograms (kg) per year, was estimated to be stormwater runoff. This category includes all sources to small tributaries draining to the Bay. The PCBs TMDL indicates that a 90% reduction in PCBs from stormwater runoff to the Bay is needed to achieve water quality standards and restore beneficial uses. The TMDL states that the wasteload allocation for stormwater runoff of 2 kg per year shall be achieved within 20 years (i.e., by March 2030). The PCBs TMDL is being implemented through NPDES permits to discharge stormwater issued to municipalities and industrial facilities in the Bay Area (e.g. the MRP).

This SSID project was triggered by monitoring conducted over the past 15+ years by BASMAA members that demonstrates municipal stormwater runoff is a source of PCBs to the Bay. PCBs were historically used in many applications, including electrical utility equipment and caulks and sealants used in building materials. However, the greatest use by far was in electrical

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[3] The PCBs TMDL was approved by the US Environmental Protection Agency (US EPA) on March 29, 2010 and became effective on March 1, 2010.

equipment such as transformers and capacitors (McKee et al. 2006). Existing electrical utility equipment, which is often located in the public right-of-way (ROW), may still contain PCBs that can be released to the MS4 when spills and leaks occur. Due to past leaks or spills of PCBs oil from electrical equipment, properties owned and operated by electrical utilities may potentially have elevated concentrations of PCBs in surrounding surface soils that can be released to the MS4. Because the cumulative releases of PCBs-laden soils from these properties, and spills or leaks of PCBs oils from electrical equipment to MS4s across the Bay Area may occur at levels that exceed the 2 kg per year TMDL waste load allocation, this potential source of PCBs may limit the ability of municipalities to meet the goals of the PCBs TMDL for the Bay. Therefore, this potential source warrants further investigation.

2.3 SSID Project Objectives

The overall goal of this SSID project is to investigate electrical utility equipment as a source of PCBs to urban stormwater runoff and identify appropriate actions and control measures to reduce this source. Building on the information presented by SCVURPPP (2018), this project is designed to achieve the following three objectives:

1. Gather information from Bay Area municipally-owned utility companies to improve estimates of current PCBs loadings to MS4s from electrical utility equipment, and document current actions conducted by utility companies to reduce or prevent release of PCBs from their equipment;

2. Identify opportunities to improve municipal spill response, cleanup protocols, or other programs designed to reduce or prevent releases of PCBs from electrical utility equipment to MS4s;

3. Develop an appropriate mechanism for municipalities to ensure adequate clean-up, reporting and control measure implementation to reduce urban stormwater loadings of PCBs from municipally-owned electrical utility equipment.

In addition, an outcome of the project was to provide data inputs that could be used in the accounting methodology presented in the BASMAA Source Control Load Reduction Accounting Methodology and Reasonable Assurance Analysis (RAA) (BASMAA, 2020). The methodology was developed to account for PCBs load reductions that may be achieved due to source control measures implemented through a regional control measure program for electrical utilities.

2.4 Management Questions

This SSID project work plan identified a number of key management questions regarding electrical utility applications as sources of PCBs to MS4s to address, including:

1. What is the current magnitude and extent of PCBs stormwater loadings from electrical utility equipment and operations in the San Francisco Bay Area region?

2. What aspects of equipment or operational procedures should electrical utilities be required to report to the Regional Water Board?

3. Are improvements to spill and cleanup control measures needed to reduce water quality impacts from the release of PCBs in electrical utility equipment?

4. Are additional proactive management practices needed to reduce releases of PCBs from electrical utility equipment?

5. What are the PCBs load reductions that can be achieved through implementation of a regional reporting and control measure program?

This SSID project was implemented to provide the information needed to address these management questions.

3.0 Background

3.1 Study Area

The study area for this SSID project is the portion of the San Francisco Bay Area region subject to the MRP. This section provides an overview of electrical utility systems and companies currently operating in the study area, and describes how and where PCBs are used within those systems.

Electrical utilities produce or buy electricity from generating sources, and then distribute that electricity to users through two networks: the transmission system and the distribution system. The **transmission system** carries bulk electricity at high voltages, often across long distances, directly from generation sources to substations via high voltage power lines. Substations connect the transmission and distribution systems. Substations may increase the voltage from nearby generating facilities for more efficient transmission over long distances or lower the voltage for transfer to the distribution system. Electricity at a typical substation flows from incoming transmission lines, to circuit breakers, to transformers (which step down the voltage), to voltage regulators and cut out switches (which protect the system from overvoltage), and finally to outgoing distribution lines.

The **distribution system** delivers lower voltage electricity from substations directly to homes and businesses over shorter distances. This system includes pole-mounted equipment, equipment in underground vaults, and aboveground equipment on cement pads that are often in green boxes in the public ROW. This equipment is smaller, but more numerous in terms of the number of units.

Electrical utility equipment and facilities in both the transmission and distribution systems are distributed across the entire Bay Area region. In the past, PCBs were routinely used in electrical utility equipment that contained dielectric fluid as an insulator. This is because prior to the 1979 PCBs ban, dielectric fluid was typically formulated with PCBs due to a number of desirable properties they have (e.g., high dielectric strength, thermal stability, chemical inertness, and non-flammability). Electrical equipment containing dielectric fluid is typically identified as Oil-Filled Electrical Equipment (OFEE). Any OFEE that contained PCBs in the past could still potentially be in use and contain PCBs today. The most common types of OFEE that may contain PCBs are transformers, capacitors, circuit breakers, reclosers, switches in vaults, substation insulators, voltage regulators, load tap changers, and synchronous condensers (PG&E 2000).

In the Bay Area, there are eight electric utility companies operating as of February 2015 (State Energy Commission 2015):

<u>Investor-Owned Utilities (IOUs)</u>

1. Pacific Gas and Electric Company (PG&E)
   77 Beale Street
   San Francisco, CA 94105
   (415) 973-7000 (tel)

<u>Publicly Owned Load Serving Entities (LSEs) and Publicly Owned Utilities (POUs)</u>

2. Alameda Municipal Power
   2000 Grand Street

Alameda, CA 94501-0263
510.748.3905 (tel)

3. CCSF (also called the Power Enterprise of the San Francisco Public Utilities Commission)
1155 Market Street, 4th Floor
San Francisco, CA 94103
209.989.2063 (tel)
4. City of Palo Alto, Utilities Department
P.O. Box 10250
Palo Alto, CA 94303
650.329.2161 (tel)
5. Pittsburg Power Company Island Energy-City of Pittsburg,
65 Civic Drive
Pittsburg, CA 94565-3814
925.252.4180 (tel)
6. Port of Oakland
530 Water Street, Ste 3
Oakland, CA 94607-3814
510.627.1100 (tel)
7. Silicon Valley Power (SVP) - City of Santa Clara
1500 Warburton Avenue
Santa Clara, CA 95050
408.615.2300 (tel)

Community Choice Aggregators

8. Marin Clean Energy (MCE)
781 Lincoln Ave Ste 320
San Rafael, CA 94901-3379
888.632.3674 (tel)

PG&E is by far the largest electrical utility company in the Bay Area. PG&E is an investor-owned company that is not under the jurisdiction of any Bay Area municipality[4]. Three small publicly-owned utilities in the Bay Area (Alameda Municipal Power, City of Palo Alto Utilities Department, and Silicon Valley Power owned by the City of Santa Clara) maintain their own substations and distribution lines. The other public utilities partner with PG&E to deliver energy through PG&E's equipment. PG&E owns and operates several hundred electrical substations in the Bay Area, in addition to the smaller electrical utility equipment that is widely disbursed throughout urbanized areas and along rural corridors (e.g., small transformers on utility poles or in utility boxes). The total number of pieces of equipment that is in use across the Bay Area and that contains PCBs is not known but is likely in the range of tens to hundreds of thousands (see Section 3.3).

[4] PG&E is regulated by the California Public Utilities Commission (CPUC) and the Federal Energy Regulatory Commission (FERC).

3.2 Regulatory Controls on PCBs in Electrical Utility Equipment

In California, both federal and state laws regulate in-use PCBs, PCB wastes, and PCB clean-up. At the federal level, the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA) are used to regulate PCBs and PCB wastes. PCB cleanup sites may also be subject to regulation by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In addition, discharges from electrical utility applications are regulated under the NPDES program authorized by the CWA and implemented through the State and Regional Water Quality Control Boards. State PCB regulations are primarily implemented under the California Health and Safety Code.

TSCA is the primary regulatory tool that addresses most aspects of PCB management and cleanup. Passed into law in 1976, TSCA banned the continued manufacture and commercial distribution of PCBs in the US after July 2, 1979, and prohibited the continued use of PCBs outside of totally enclosed systems. TSCA also governs the ongoing management of PCBs that remain in use that are present at 50 ppm or greater, including labeling, handling, distribution, storage, cleanup of contaminated properties, spill response and disposal (Title 40 CFR Part 761). The federal TSCA regulations are enforced by the US EPA.

In addition to the TSCA regulations, other federal regulations under authority of the Clean Water Act are in place to prevent oil spills from reaching navigable waters, and provide for appropriate and efficient cleanup of any oil spills that do occur (40 CFC part 112). These regulations require Spill Prevention Control and Countermeasure (SPCC) Plans for facilities that could potentially discharge oils to navigable waters (including storm drains and drainage ditches) if the facility also meets one or more of the following criteria: aboveground oil storage > 1,230 gallons; and/or underground oil storage > 42,000 gallons; and/or storage of containerized PCB-contaminated liquid wastes for disposal between 50 and 500 ppm. Electrical utility substations may fall into the category of facilities that require such SPCC plans.

In California, hazardous waste regulations detailed in the California Code of Regulations (CCR) Title 22 are more stringent for PCBs than federal rules. CCR Title 22 designates oils or other liquids containing PCBs concentrations ≥ 5 ppm as non-RCRA hazardous waste requiring special handling and disposal. The California Department of Toxic Substances Control (DTSC) enforces the additional hazardous waste rules that apply to PCBs less than 50 ppm, including spill cleanup, disposal and reporting requirements. DTSC also regulates closure requirements for PCB sites under CERCLA.

3.2.1 PCB Classification and Labeling Requirements

Under both federal and state regulations, all required management of in-use PCBs and PCB-containing equipment, including labeling, disposal, site cleanup, spill response, and reporting is based on classifications of PCB concentrations. Table 3.1 defines the federal and state PCB classifications.

- TSCA regulations apply to PCBs 50 ppm or greater, while California regulations apply to PCBs between 5 and 50 ppm. Under TSCA, PCB concentrations greater than 500 ppm are classified as high PCBs, while PCB concentrations between 50 ppm and 500 ppm are classified as low PCBs. PCB concentrations below 50 ppm are classified by TSCA as non-PCB.

- In California, PCB concentrations in liquids between 5 ppm and < 50 ppm are classified as non-RCRA hazardous waste and governed by state regulations.
- If PCB concentrations are not known, neither federal nor state regulations require testing of in-use equipment or materials for PCB concentrations to determine the appropriate classification. Instead, a number of assumptions are applied to determine the appropriate PCBs classification.

Table 3.1 Current Federal and State Regulatory Classifications of PCBs Concentrations.

PCBs Concentration (known or assumed)	Label	Classification	Regulatory Requirements
Federal Requirements			
≥ 500 ppm (in original source)	PCB	TSCA - High PCB Concentration	Waste remediation required by federal law
50 to < 500 ppm (in original source)	PCB-Contaminated	TSCA - Low PCB Concentration	Waste remediation required by federal law
> 0 to < 50 ppm	Non-PCB	Non-PCB	No waste remediation required
0 ppm	No PCBs	Contains no PCBs, and was manufactured after July 1, 1978	No waste remediation required
State Requirements			
≥ 5 ppm (liquid) ≥ 50 ppm (solids)	PCB-Contaminated	California Hazardous Waste	Waste remediation required by State Law
< 5 ppm (liquid) < 50 ppm (solid)	Non-PCB	California Non-PCB	No waste remediation required

PCB-containing equipment is required to be labeled according to its PCB classification. When removed from service, all transformers, large capacitors (high and low voltage), and voltage regulators that are known or assumed to have PCB concentrations equal to or greater than 500 ppm at the time of manufacture require a “PCB” label. Other electrical equipment known or assumed to contain PCBs between 50 and <500 ppm are labeled according to the federal regulations as “PCB-Contaminated”. In California, equipment determined to have PCBs < 5 ppm can be labeled as “Non-PCB”; however, because federal regulations were enacted prior to state regulations, some “Non-PCB” labels may have been applied to equipment that fit the non-PCB category for federal regulations (< 50 ppm). This lends uncertainty to the “Non-PCB” label if other information is not also available. Electrical equipment that was manufactured after July 1, 1978, and that does not contain any concentration of PCBs can be labeled as “No PCBs”.

3.2.2 Spill Response and Site Cleanup

Both state and federal regulations require cleanup of releases of hazardous materials. As required under both federal and state regulations, the appropriate response to a PCB release is dictated by the known or assumed PCB classification of the equipment responsible for the release. Concentrations are determined based on the source of the release, not on the spilled concentration. For PCBs and PCB-contaminated materials that are 50 ppm PCBs or greater, federal regulations under TSCA govern spill response and cleanup. TSCA requires spill cleanup for releases from equipment or materials that are classified as low or high PCBs (i.e., ≥ 50 ppm PCBs). California hazardous waste regulations require spill cleanup and reporting for releases of PCB-contaminated liquids that fall below the federal regulations (i.e., ≥ 5 ppm but < 50 ppm). Equipment labels are used to identify PCBs and PCB-containing equipment. However, if equipment labels are not present and/or do not provide full information, assumptions about PCB concentrations are often necessary during the initial spill response. For example, any release of untested mineral oil from electrical equipment is assumed to be PCB-contaminated per federal regulations (i.e., ≥ 50 ppm but < 500 ppm).

The first step when a hazardous material release occurs is notification. Under both federal and state rules, the responsible party is required to immediately notify the California Office of Emergency Services (Cal OES) state warning center hotline, and/or 911 when a hazardous material release occurs. This initial reporting is typically a verbal notification (i.e., by telephone). Materials that are 50 ppm PCBs or greater are considered hazardous per federal regulations and liquids that are 5 ppm PCBs or greater are considered hazardous per state regulations. Therefore, any released liquids that are 5 ppm PCBs or greater should be reported to Cal OES.

TSCA hazardous materials spill cleanup requirements (i.e., for releases of PCBs ≥ 50 ppm) are summarized here:

- Low PCB Concentrations (< 500 ppm): excavate all soil within the spill area and backfill with clean soil. Double wash/rinse solid surfaces.
- High PCB Concentration (≥ 500 ppm): notify National Response Center; cordon off the area with a minimum 3-ft buffer and post warning signs; document and record area of visible contamination; excavate all soil within the spill area and backfill with clean soil. Remove all contaminated porous surfaces (e.g., wood asphalt, cement, concrete, etc.). Double wash/rinse non-porous solid surfaces; properly dispose of all PCBs or PCB-contaminated materials from the cleanup site (e.g., soils, solvents, rags, etc.);
- Soils must be remediated to background levels (i.e., detection limits) where practicable.

Federal and state regulations also restrict the allowable concentrations of PCBs remaining in any post-cleanup soils and/or materials, based on the risk categories identified in Table 3.2. For example, in low occupancy areas (i.e., restricted access areas such as electrical substations), PCBs must be below 25 ppm, or the area can have up to 50 ppm PCBs if the appropriate notification is posted at the site. In high occupancy areas (e.g., unrestricted access areas), PCBs must be below 10 ppm. Clean fill used to replace soil removed during the cleanup process must contain less than 1 ppm PCBs. (Note that all of these allowable remaining concentrations are potentially above the thresholds required to meet TMDL goals.) Post cleanup verification sampling is required only for high concentration spills and low-concentration spills involving 1 pound (lb.) or more of PCBs by weight (>270 gallons of untested mineral oil)[5].

Table.3.2 Federal and State Regulatory Classifications of PCB Concentrations and Cleanup Levels.

Risk Category	Allowable PCBs Concentration
PCB waste remediation required	≥ 50 ppm in original source
Low Human health risk from direct exposure	< 50 ppm
High occupancy areas (i.e., non-restricted access areas)	≤ 10 ppm in remaining material
Low occupancy areas (i.e., restricted access areas, such as electrical substations) Low occupancy areas IF the area contains a label or other visible notification of the contamination Low occupancy areas with a cap	≤ 25 ppm in remaining material ≤ 50 ppm in remaining material 25 to < 100 ppm in remaining material
Clean fill	< 1 ppm

In addition, as required by US EPA regulations to prevent oil pollution (40 CFR, Part 112 and 761), utilities must prepare Spill Prevention Control and Countermeasure (SPCC) Plans for facilities that could potentially discharge oils to navigable waters (including storm drains and drainage ditches). SPCC plans are prepared if the facility also meets one or more of the following criteria: aboveground oil storage > 1,230 gallons; and/or underground oil storage > 42,000 gallons; and/or storage of containerized PCB-contaminated liquid wastes for disposal between 50 and 500 ppm. The purpose of the SPCC Plan is to ensure oil spills are minimized, and if any oil spills do occur, to prevent spilled oils from leaving the property and provide maximum cleanup efficiency.

3.2.3 Spill Reporting

In addition to the initial verbal notification, both state and federal regulations may also require submission of follow-up written reports for releases of hazardous materials that are at or above the federal reportable quantities (RQs), or for discharges of oil to navigable waters. For PCBs, the federal RQ is 1 lb. (0.454 kg), while for oil spills, the federal RQ is 42 gallons. Thus, under federal regulations, a follow-up written report must be submitted for any release of 1 lb. or more of PCBs at concentrations ≥ 50 ppm, or for "Non-PCBs" mineral oil spills of 42 gallons or more.

[5] See 40 CFR 761 Subpart G PCB Spill Cleanup Policy for post cleanup verification sampling requirements. EPA provides guidance for sampling in *Verification of PCB Spill Cleanup by Sampling and Analysis* (EPA 560/5-85-026 August 1987), *Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup* (EPA-560/5-86-017 May 1986), and *Wipe Sampling and Double Wash and Rinse Cleanup as Recommended by the Environmental Protection Agency PCB Spill* Cleanup Policy (EPA Revised and Clarified on April 18, 1991).

In California, state regulations only require submission of follow-up written reports if the amount of the hazardous material released is at or above the federal RQ.

Spill reporting requirements for releases of 1 lb. or more of PCBs ≥ 50 ppm are detailed here:

- Identification of the source
- Spill date and time (actual or estimated)
- Clean-up date and time completed or terminated
- Identification of spill locations and contaminated material/surfaces, including identification of restricted access or non-restricted access location
- Pre-clean-up sampling data used to establish spill boundaries, if required
- Description of solid surfaces cleaned
- Depth of soil excavation and quantity of soil removed
- Post-clean-up sampling data
- Estimated cost of clean-up (not required)

3.2.4 Regulation of Utility Vault Discharges

There are additional regulatory requirements for short-term intermittent discharges from electrical utility vaults to surface waters of the U.S. An electrical utility vault is an underground room that provides access to subterranean electrical equipment, which may include PCB transformers or other PCB-containing equipment. These are commonly found throughout the electrical system across the Bay Area. Water may collect in these vaults, requiring utility companies to dewater subsurface vaults and underground structures to protect equipment, and provide safe worker conditions for installation, maintenance, or repair of equipment. Compliance with a general NPDES permit is required for these discharges. In California, the General NPDES permit is issued by the California State Water Resources Control Board (Order WQ 2014-0174-DWQ). To be covered under the general permit, a utility company must submit an application to both the State Water Board and their Regional Water Quality Control Board. The permit application includes a Notice of Intent (NOI) and a Pollution Prevention Plan. PG&E has applied for coverage under the General Permit and PG&E's most recent Pollution Prevention Plan submitted to the San Francisco Bay Regional Water Quality Control Board (Region 2) in compliance with the general permit requirements is available on the State Water Board website (https://www.waterboards.ca.gov/water_issues/programs/npdes/docs/utilityvaults/ppplans/pger2_noi_ppp.pdf). It is estimated that approximately 150 to 200 utility vaults are dewatered in the San Francisco Bay Region each year. The State Water Board's website showing utilities that have applied for coverage under the General Permit did not identify any other electrical utilities, other than PG&E, in the San Francisco Bay Region (Region 2).

Regulation of utility vault discharges is included in this section because unplanned spills or releases from PCBs equipment within a vault may occur due to equipment failure. However, although utility vault discharges could potentially result in release of PCBs, chemical analysis of the liquid in the vault is only required at vaults discharging > 10,000 gallons. Instead, if the vault contains equipment from prior to January 1, 1985 and there is any noticeable oil or sheen, the water is containerized and hauled offsite for analysis and disposal. At all other vaults, liquid samples are collected in a jar, allowed to sit for 5 minutes, and then the appearance (color/opacity) of the liquid in the jar is compared to pictures of three example sample jars that vary in the levels of contamination from green (low contamination) to red (high contamination). The appropriate disposal method for the liquid from the vault is determined by the appearance of the sample. If the sample collected looks similar to the green zone samples, then the liquid from the vault can be discharged through a filter sock into the storm drain or waterway. If the sample collected looks similar to the red zone sample, then the liquid from the vault must be collected and disposed of off-site. This qualitative evaluation provides no information on PCB concentrations that may be present in the liquid.

During the first year of coverage under the general NPDES permit, in compliance with the Notice of Applicability (dated September 22, 2016), PG&E collected samples at fifteen of their utility vault dewatering projects. Samples were analyzed for PCBs using EPA Method 1668. The monitoring results were summarized in an email from Regional Water Board staff. PCBs were detected in 11 out of 15 samples. In samples with detections, PCBs concentrations ranged from 0.5 ng/L to 3.4 ng/L.

3.2.5 Chemical Analysis Methods for PCBs

For compliance purposes, TSCA regulations recommend the use of EPA Method 8082 (i.e., the "Aroclor Method") to determine PCB concentrations with a quantifiable level of detection at 2 ppm. Aroclors are the most common PCB formulations that were produced and used commercially in the US. Aroclors are composed of 1 to 7 primary congeners, plus trace levels of other congeners. EPA Method 8082 identifies and quantifies total PCB concentrations based on comparison with the gas chromatograph patterns (referred to as fingerprints) for known Aroclor formulations. Although widely used for determination of PCB concentrations since the 1970's, this method has a number of limitations.

- First, PCBs in a given sample may not match up well with the Aroclor standards that are used for comparison in the analysis. Typically, a group of five to seven Aroclors are used as technical standards. While these are selected to represent the most commonly used formulations, there were many more Aroclor formulations that were produced and used over the years, including slight variations in the formulations produced from year to year. While Aroclors represent the largest mass of PCBs used commercially in the US, they do not represent all PCB products.
- Second, samples that contain mixed Aroclors or that have undergone weathering are not expected to have the same fingerprint as Aroclor standards. Fitting these samples to a set of standard Aroclor fingerprints may not provide accurate information.
- Third, this method does not detect certain PCB congeners, including some of the most toxic.
- Finally, the Aroclor Method has relatively high method detection limits compared with concentrations of concern for water quality.

TSCA regulations allow the use of an alternative analytical method for PCB determination if it is validated as described in 40 CFR 761, Subpart Q. Alternative analytical methods for PCBs, such as EPA Method 1668, or a revised version of Method 8082 that allows for individual congener analysis provide lower detection and reporting limits, and can be used to detect all 209 individual PCB congeners. However, these methods require more specialized laboratory equipment and expertise to perform, and are therefore considerably more expensive than the "Aroclor" method. Although these improved methods are more appropriate for stormwater control purposes because they are not required, they are unlikely to be used in place of the easier and less expensive “Aroclor” method when responding to mineral oil spills.

3.3 PCBs Remaining in Electrical Utility Equipment

Although use of PCBs is highly restricted currently, McKee et al. (2006) estimated that 12.3 million kilograms of PCBs were used in the San Francisco Bay Area between 1950 and 1990. Roughly 65% (8 million kg) was used in electrical transformers and large capacitors (McKee et al. 2006). How much of this mass was released to the environment and how much remains in electrical equipment distributed across the Bay Area today is unknown. While the 1979 ban of PCBs did not require the immediate removal of PCBs from current applications, electrical utilities have made substantial efforts over the past 35+ years to reduce the amount of PCBs still used in their applications in the Bay Area. According to PG&E, the majority of OFEE containing PCBs in the Bay Area has already been removed or refurbished with dielectric fluids that do not contain PCBs through the following actions:

- Voluntary replacement programs;
- Ongoing removal of PCBs from OFEE as units are serviced or replaced due to routine maintenance programs; and
- OFEE replacement due to unplanned actions (e.g., transformer leaks and fires).

Voluntary actions conducted by PG&E, primarily in the mid-1980s, included the PCBs Distribution Capacitor Replacement Program and the PCBs Network Transformer Replacement Program (PG&E 2000). In addition, in the 1990s, PG&E implemented a program to remove oil-filled circuit breakers and replace them with equipment that contains sulfur hexafluoride gas (PG&E 2000). Current ongoing PG&E efforts to remove PCBs-containing equipment are conducted primarily through maintenance programs. Past maintenance of older equipment may have included draining PCBs-containing oils and refilling the equipment with oils that did not contain PCBs. These refurbished OFEE may still contain PCBs at levels of concern to municipalities due to residual contamination from the original PCB-oil. Currently, as maintenance staff identify older equipment in-use, it is scheduled for replacement. However, PG&E has provided limited documentation of their past and current PCBs removal efforts. There remains much uncertainty on where PCBs transformers, PCBs capacitors, oil-filled circuit breakers, and PCBs-containing distribution system equipment were originally located, and which ones have already been removed or replaced.

Despite the removal efforts described above, PCBs may still be found in older and refurbished OFEE, and particularly OFEE located throughout the distribution system. In a recent meeting with Regional Water Board Staff, PG&E noted that any equipment installed prior to 1985 could contain PCBs, as it would have come from equipment stockpiled prior to the 1979 ban and was installed prior to the voluntary replacement programs (*personal communication*, Sanchez 2016). Because OFEE are not typically tested for PCBs until the fluid is removed during servicing or disposal, or in the event of a spill, the total number of PCBs-containing OFEE that remain in use is unknown. However, in a letter to the Regional Water Board in 2000, PG&E provided information that can be used to make some preliminary estimates, including the following (PG&E 2000):

- There are over 900,000 pieces of OFEE in service in the distribution system;

- In 1999, 22,000 pieces of equipment were serviced at the main PCBs-handling facilities in Emeryville;
- Approximately 10 percent of the units serviced and tested annually contain PCBs at concentrations of 50 parts per million (ppm) or greater, and fewer than 1 percent contained PCBs at concentrations of 500 ppm or greater; and
- The number of pieces of equipment containing PCBs concentrations > 50 ppm has declined over time.

The information above was used to calculate the following:

- Assuming the count of equipment processed in 1999 in Emeryville represents an average annual processing rate throughout the region and that there are at least 900,000 pieces of equipment in PG&E's distribution system it would take over 40 years at a minimum for all of this equipment to be replaced;
- Assuming the 1999 processing rate and 900,000 pieces of equipment in PG&E's distribution system in 1985, approximately 175,000 pieces would not yet have been serviced or replaced as of 2018; and
- Of the approximately 175,000 pieces of equipment remaining in-use in 2018, approximately 17,500 (10%) may contain PCBs concentrations > 50 ppm.

Although based on limited information, the above estimates demonstrate that a potentially large number of pieces of equipment containing PCBs over 50 ppm (i.e., 17,500 as of 2018) may remain in-use in PG&E's electrical utility distribution system. And the remaining 90% (roughly 157,000 pieces of equipment) may contain lower concentrations of PCBs that could still be of concern to Permittees in their efforts to meet TMDL requirements.

3.4 Estimated PCBs Loads from Electrical Utility Equipment to MS4s

McKee et al. (2006) developed a PCBs mass balance model that estimated the total loads to stormwater from all major sources during the peak period of PCBs production and use (i.e., 1950 – 1990), and in the period of the study (i.e., 2005). The mass balance model started with the total mass of PCBs that was used in the region between 1950 and 1990 and apportioned that mass to the major source categories. The largest PCBs-use category was transformers and large capacitors (i.e., oil-filled electrical equipment, OFEE). The total mass used in transformers and large capacitors between 1950 and 1990 was estimated at 7,600 metric tons (MT). Although most of this PCBs mass remains contained within the equipment, a small percentage of PCBs are released each year due to spills and leaks. These releases are the primary source of PCBs to stormwater conveyances from OFEE. Using literature values and the assumptions outlined below, McKee et al. (2006) estimated the following:

- Between 1950 and 1990 (the peak period of production and use of PCBs in the U.S.) 120 – 520 kg of PCBs entered stormwater conveyances due to releases from transformers and large capacitors. On average, this equated to a stormwater load of 8 kg/yr to the San Francisco Bay from electrical utility equipment during that time period.
- In 2005, the mass of PCBs entering stormwater conveyances due to releases from transformers and large capacitors was 1.2 to 4.3 kg/year (average = 2.8 kg/yr). The assumptions and literature data that were used to calculate the 2005 load included the following:

- 0.05% was estimated to leak from transformers and 0.35% from large capacitors each year over an assumed 30-year service life (Harrad 1994, EIP Associates 1997).
- When spills occur, 99% of the spilled PCBs are cleaned up and only 1% of the remaining PCBs are left on erodible surfaces and available for wash off;
- Assumed runoff coefficients based on land-use classifications were used to approximate the fraction of PCBs on erodible surfaces that can enter local storm drains each year; and
- A small fraction (0.3%) of PCBs released to the environment enter the atmosphere (Keeler et al. 1993); McKee et al. (2006) estimated 2% to 6% of these PCBs are subsequently captured in stormwater through wet deposition.

McKee et al. (2006) estimated a stormwater load of 2.8 kg/yr to the Bay from transformers and large capacitors in 2005.

4.0 Desktop Analysis

The purpose of the desktop analysis is to better understand the extent and magnitude of municipally-owned electrical utility equipment as a source of PCBs to urban stormwater runoff, document past and current efforts to reduce PCBs releases from electrical utility equipment during spills or other accidental releases, and document measures already taken or underway to remove PCBs-containing oils and electrical equipment from active service across the Bay Area.

PG&E, the largest electric utility company in the Bay Area, was likely the largest single user of PCBs in the Bay Area, and as such, likely remains the largest current source of PCBs releases to MS4s from electrical utility equipment. However, the project was revised in early 2020 to focus the desktop analysis on information provided by municipally-owned electrical utilities in the Bay Area on their OFEE inventories, and any other readily available data, such as the data provided previously by PG&E on voluntary replacement programs for PCBs-containing OFEE and spill reporting records presented in Sections 3.3 and 3.4, respectively.

The BASMAA project team identified representatives from municipally-owned electrical utilities in the Bay Area and discussed the project information needs with those representatives. The Project team sent the identified representatives a *Request for Information from Municipal Electrical Utilities*. The requested information included a description of the agency's electrical utility transmission and distribution systems, description of OFEE in the systems and PCBs-containing OFEE in the systems, past and current replacement and maintenance programs for OFEE and current and past protocols for OFEE spill response and cleanup.

4.1 Overview of Participating Municipally-Owned Electrical Utilities

In the MRP Area, there are five municipally-owned (public) electrical utilities, including:

1. Alameda Municipal Power
2. City of Palo Alto Utilities
3. Pittsburg Power Company, doing business as (dba) Island Energy – City of Pittsburg
4. Port of Oakland
5. Silicon Valley Power - City of Santa Clara

Three of these public utilities participated in this project and submitted data on their OFEE inventories and spill response protocols for evaluation, including: City of Palo Alto Utilities (CPAU), Pittsburg Power Company dba Island Energy (Island Energy) – City of Pittsburg, and Silicon Valley Power (SVP) – City of Santa Clara.

Additional information about each of the three participating municipally-owned electrical utilities and the information provided on OFEE in their systems is presented below.

4.1.1 City of Palo Alto Utilities

The City of Palo Alto Utilities (CPAU) have been operating a municipal electric power system in that city for over 100 years. CPAU serves the City of Palo Alto with an area of approximately 16,640 acres (including ~11,000 acres of urban area and ~5,500 acres of open space) and a population of approximately 67,082 people.

CPAU provided data on their inventory of OFEE through December 2019, including counts of equipment that are currently active in the system and equipment that have been removed from the system. OFEE counts were provided by the following equipment types:

- Poletop transformers
- Padmount single phase transformers
- Padmount three phase transformers
- Padmount substation transformers
- Underground commercial and residential distribution transformers
- Regulators
- Padmount switches
- Vault/box switches

For each type of equipment, CPAU provided an average volume of oil in each piece of equipment. The OFEE counts were further divided into the following categories:

- All active OFEE (equipment that are currently in active service within electrical transmission or distribution systems);
- Active OFEE that were purchased or installed prior to 1985 (pre-1985 OFEE);
- All inactive OFEE (equipment that have been removed from service);
- Inactive pre-1985 OFEE that were removed from service prior to 2002;
- Inactive pre-1985 OFEE that were removed from service in 2002 or later.

CPAU did not provide any data on measured PCBs concentrations in their OFEE inventory. However, they did identify OFEE that were labeled as "Non-PCBs" by the manufacturer.

4.1.2 Silicon Valley Power

Silicon Valley Power (SVP) has been operating in the City of Santa Clara for more than 100 years. As of December 2019, SVP includes 25 substations, 55 miles of transmissions lines, and 186 miles of overhead distribution lines. The total coverage area is 11,782 acres, and the population served is 129,488 people.

SVP provided data on their inventory of OFEE through December 2019, including counts of equipment that are currently active in the system and equipment that have been removed from the system. OFEE counts were provided by the following equipment types:

- Poletop transformers
- Padmount single phase transformers
- Padmount three phase transformers
- Padmount substation transformers
- Underground commercial and residential distribution transformers
- Regulators
- Padmount switches
- Vault/box switches

For each type of equipment, SVP provided an average volume of oil in each piece of equipment. The OFEE counts were further divided into the following categories:

- All active OFEE (equipment that are currently in active service within the electrical transmission or distribution systems);
- Active OFEE that were purchased or installed prior to 1985 (pre-1985 OFEE);
- All inactive OFEE (equipment that have been removed from service);
- Inactive pre-1985 OFEE that were removed from service prior to 2002;
- Inactive pre-1985 OFEE that were removed from service in 2002 or later.

SVP also provided equipment counts and oil volumes for a number of OFEE that comprised approximately 12% of the oil mass in their inventory, for which no information on equipment status (active or inactive) and no information on equipment age (pre-1985 or post-1985) were available at the time this report was prepared. These data were excluded from the main analysis presented in Section 4.2. However, a sensitivity analysis was conducted in order to understand potential implications of excluding these data. The results of the sensitivity analysis are presented in Section 4.2.3. Based on those results, the unknown data were included in the estimated ranges of PCBs mass and stormwater loads as described further in Section 4.2.3 and Table 4.4.

SVP did not provide any data on measured PCBs concentrations in their OFEE inventory.

4.1.3 Pittsburg Power Company, Island Energy

Pittsburg Power Company is a joint powers authority and department within the City of Pittsburg, California. Since 1997, Pittsburg Power has been operating an electric utility distribution system at Mare Island in Vallejo under the name “Island Energy”. Mare Island was formerly the location of a US Naval shipyard that was decommissioned in 1996. Following decommissioning, the Pittsburg Power Company acquired the electrical utility distribution rights on Mare Island from the US Navy. The distribution system on Mare Island that is operated by Island Energy consists of one substation and approximately 11 miles of distribution lines that serve an area of ~1,200 acres. The Mare Island zip code has a population of approximately 900 people.

Island Energy provided detailed inventories for the transformers that were part of both the historic (US Navy) inventory and the current (Island Energy) inventory of OFEE on Mare Island. The historic inventory documents each piece of OFEE that was part of the US Naval shipyard on Mare Island until 1996. At that time, the US Navy removed the bulk of pre-1985 OFEE and sent them to hazardous waste facilities for proper disposal. However, some pre-1985 OFEE remained on the island. The current inventory identifies each piece of OFEE on Mare Island that has been operated by Island Energy since 1997 through December 2019. The data provided in both the current and historic inventories includes the volume of oil, installation date, and (if applicable) removal date for each transformer in the historic or current system on Mare Island. In addition, measured concentrations of PCBs were provided for most OFEE in these inventories. Island Energy noted that there are gaps in the historic records, and the data provided may be incomplete. The current inventory identifies all OFEE that have been or are currently active and operated by Island Energy on Mare Island between 1997 and 2019 (i.e., since Island Energy began operating the electrical distribution system on Mare Island). The data analysis focused on the PCBs-containing OFEE in the historic and current inventories.

4.2 Analysis of Municipally-Owned Electrical Utility Data

The overall goal of the analysis of municipally-owned electrical utility OFEE inventories was to develop improved estimates of both the load of PCBs to stormwater from OFEE, and the load reductions that have been achieved over time due to ongoing equipment maintenance and replacement programs. The data analysis was also intended to provide data inputs that could be used in the accounting methodology presented in the BASMAA Source Control Load Reduction Accounting for RAA (BASMAA 2020) to calculate the PCBs load reductions achieved since the start of the PCBs TMDL, and the expected PCBs load reductions in the future due to the ongoing removal and proper disposal of PCBs-containing OFEE. To accomplish these goals, the project evaluated the OFEE inventories provided by participating municipally-owned electrical utilities to characterize the magnitude of PCBs-containing OFEE in these systems and document the rate of removal of PCBs-containing OFEE over time. The data were used to calculate the annual average removal rates of PCBs-containing OFEE from participating municipally-owned electrical utility systems since the start of the PCBs TMDL (i.e., 2002). This information was then scaled-up to the larger MRP area in order to provide a rough, first-order estimate of the potential magnitude of the current OFEE load of PCBs to stormwater across the area.

4.2.1 OFEE Inventory Data Analysis Approach and Assumptions

The OFEE inventory data were analyzed to generate estimates of the following:

- The potential mass of PCBs in active OFEE within each municipally-owned electrical utility system at the start of the PCBs TMDL (i.e., 2002) and currently (i.e. 2020).
- The potential mass of PCBs in OFEE that has been removed from each of these systems due to ongoing maintenance and replacement programs before and after 2002.
- The annual average reduction rate achieved since the start of the PCBs TMDL due to removal of PCBs-containing OFEE from these systems.
- The potential PCBs stormwater load from OFEE in these systems at the start of the PCBs TMDL and currently.
- The expected PCBs stormwater load reductions in the future due to continued removal of PCBs-containing OFEE from these systems.

Because information on measured PCBs in these OFEE was limited, the mass of oil in OFEE was used as the primary metric to characterize OFEE within each system, to estimate the magnitude of potentially PCBs-containing OFEE in each system, and to calculate equipment removal rates. The age of the OFEE, based on the purchase or installation date provided, was used as the primary metric to identify potentially PCBs-containing equipment as follows:

- Pre-1985 OFEE. All equipment that was installed prior to 1985 (i.e., pre-1985 OFEE) were assumed to potentially contain PCBs. 1985 was selected as the appropriate cut-off date to identify equipment that may contain PCBs because the installation of PCBs-

containing equipment that had been stockpiled prior to the 1979 PCBs ban continued for several years after the ban[6].
- Post-1985 OFEE. All equipment installed after 1985 (i.e., post-1985 OFEE) were assumed to contain zero PCBs.

The potential mass of PCBs in pre-1985 OFEE was calculated from the mass of oil in these OFEE multiplied by a range of assumed PCBs concentrations in that oil. The PCBs concentrations in all pre-1985 OFEE were based on the following assumptions:

- Measured PCBs concentrations were used, if available.
- If no PCBs measurement data were provided, the range of PCBs concentrations was estimated as follows:
    - Pre-1985 OFEE with “PCBs” labels are assumed to have PCBs concentrations ≥ 500 ppm (i.e., PCBs Transformers). However, because PCBs transformers must be registered with the US EPA transformer registry, and none of the participating municipally-owned utilities have registered any PCBs transformers in this database, all PCBs concentrations in any equipment in the current OFEE inventories were assumed to be less than 500 ppm.
    - Pre-1985 OFEE with “Non-PCBs” on the label have PCBs concentrations < 50 ppm. All OFEE with these labels were assumed to have PCBs between 1 and 49 ppm, unless otherwise noted.
    - Pre-1985 OFEE that were not labeled, or that did not have measured PCBs concentrations were assumed to contain PCBs between 50 and 499 ppm.

Because this report is focused on OFEE that contain or may contain PCBs, the data analysis focused primarily on pre-1985 OFEE.

4.2.2 Data Analysis Methods

Analysis of the OFEE inventory data proceeded through the following seven steps:

1. Calculate the total mass of oil in all active OFEE within each system and the total mass of oil in active pre-1985 OFEE. Use this information to estimate the mass of oil and current abundance of potentially PCBs-containing OFEE within each system.

The total mass of oil in all active OFEE was calculated from the volume of oil in each piece of equipment multiplied by the density of the oil. The OFEE inventories provided by the participating municipally-owned electrical utilities provided either the actual volume of oil in each piece of equipment in their inventory, or the average volume of oil per piece of equipment for each type of equipment and the total counts of active equipment of that type. The density of the

[6] Personal communication, Sanchez 2016. This assumption is based on statements made to Regional Water Board staff at a meeting with PG&E representatives that equipment stockpiled prior to the 1979 ban continued to be put into service after the ban until voluntary replacement programs were instituted around 1985.

oil in all OFEE was based on the density of highly refined mineral oil used as a dielectric fluid in transformers of 0.9 mg/l[7].

Pre-1985 OFEE were identified based on information provided by the municipally-owned electrical utilities on either the installation date for each piece of equipment in their inventory, or the counts of all equipment within each category that were installed before 1985 and are currently active in their system.

2. Calculate the mass of oil in pre-1985 OFEE that has been removed from active service since the start of the PCBs TMDL in 2002.

Only pre-1985 OFEE were included in this calculation because this category comprises all OFEE that may contain PCBs. Each participating municipally-owned electrical utility provided slightly different data on equipment removal dates. Both CPAU and SVP provided direct counts of pre-1985 OFEE within each equipment category that were removed from service in 2002 or later. Island Energy identified all pre-1985 OFEE in their current inventory as either active or inactive as of 2019 but did not provide removal dates for inactive equipment. However, Island Energy's current OFEE inventory only includes OFEE that were active in 1997. At this step in the process, in order to simply this calculation and provide information needed for Step #3, this calculation assumed all equipment in Island Energy's current inventory were active until at least 2002 (i.e., all inactive OFEE were removed from service in 2002 or later).

3. Calculate the overall equipment removal rate and annual average equipment removal rate for pre-1985 OFEE since the start of the PCBs TMDL in 2002. Use this estimate to calculate the future date by which all pre-1985 OFEE will be removed from each participating municipally-owned electrical utility system.

The overall equipment removal rates for pre-1985 OFEE that were achieved between 2002 and 2019 were calculated based on the total mass of oil in pre-1985 OFEE that were removed from each system during that time period, divided by the total mass of oil in all pre-1985 OFEE that were active in 2002. The annual average removal rates were then calculated by dividing the overall removal rate by the number of years between 2002 and 2019 (17 years).

For CPAU and SVP, the overall removal rates since the start of the PCBs TMDL in 2002 were calculated directly from the data provided on removals between 2002 and 2019. However, because of the way the data were provided for Island Energy, an additional step was needed to estimate the overall removal rate since 2002. Island Energy identified all equipment in their current inventory, which spans the time period between 1997 and 2019, as active or inactive in 2019. However, specific removal dates for inactive equipment in the current inventory were not provided. Therefore, in order to estimate the overall removal rate since 2002, first, the annual average removal rate between 1997 and 2019 was calculated by dividing the overall removal rate for this period by the number of years between 1997 and 2019 (22 years). This annual average removal rate was then multiplied by the number of years between 2002 and 2019 (17 years) to estimate the overall removal rate since the start of the PCBs TMDL in 2002.

[7] Based on the reported density of Shell Diala Oil AX manufactured by SOPUS Products. Island Energy identified this as the dielectric oil used in the large transformers at their substation and provided a Material Safety Data Sheet (MSDS) for this product in their Spill Prevention, Control and Countermeasure (SPCC) plan.

Both the annual average removal rates and the overall removal rates since 2002 were compared across participating municipally-owned utilities. These data were also compared with the rates proposed in the accounting methodology for calculating the load reductions due to ongoing removal of PCBs-containing OFEE since the start of the PCBs TMDL and into the future. These removal rates were also used to estimate the future date by which all pre-1985 OFEE will be removed from each system. This calculation assumes the annual average removal rate for each system that has been achieved since 2002 will continue until all pre-1985 OFEE have been removed from each system. The starting point for this calculation was the mass of oil in all pre-1985 OFEE that were active in each system in 2020 (calculated in step #1). This 2020 value was then multiplied by the annual average removal rate for each system to estimate the total mass of pre-1985 OFEE oil removed each year. The number of years to reduce this mass to zero was then estimated by dividing the total mass of oil in active pre-1985 OFEE in 2020 by the mass of oil that would be removed each year.

4. Calculate the potential range of PCBs mass in active OFEE in 2020.

The potential range of PCBs mass (kg) in currently active pre-1985 OFEE was estimated for each system based on the total mass of oil in active pre-1985 OFEE in 2020 multiplied by the measured or assumed PCBs concentrations based on previously described assumptions (see Section 4.2.1).

5. Calculate the 2002 and 2020 loads of PCBs to stormwater from OFEE in the participating municipally-owned electrical utility systems and load reductions achieved over time due to equipment removals.

The starting point for this calculation was the current PCBs mass in active OFEE (step #5 above) for each participating municipally-owned electrical utility system. The following assumptions used by McKee et al., (2006) were then applied to estimate the fraction of PCBs in OFEE that are released to MS4s annually.

- 0.05% was estimated to leak from transformers and 0.35% from large capacitors each year (Harrad 1994, EIP Associates 1997); For this analysis, the value for transformers was used for all OFEE;
- When leaks occur, 99% of the materials leaked are cleaned up and only 1% remain on erodible surfaces and available for wash off.

6. Estimate the stormwater loads from OFEE across the larger MRP area and the potential load reductions that can be achieved through continued equipment removal.

This calculation extrapolated the stormwater loads estimated for the participating municipally-owned electrical utility system OFEE (developed in step #5) to the larger Bay Area.

4.2.3 Data Analysis Results

Summary of Municipally-Owned Electrical Utility Data

Figure 4.1 presents a summary of the distribution of OFEE in each of the participating municipally-owned electrical utility systems' inventories. Additional information about these distributions is provided in the following sections.

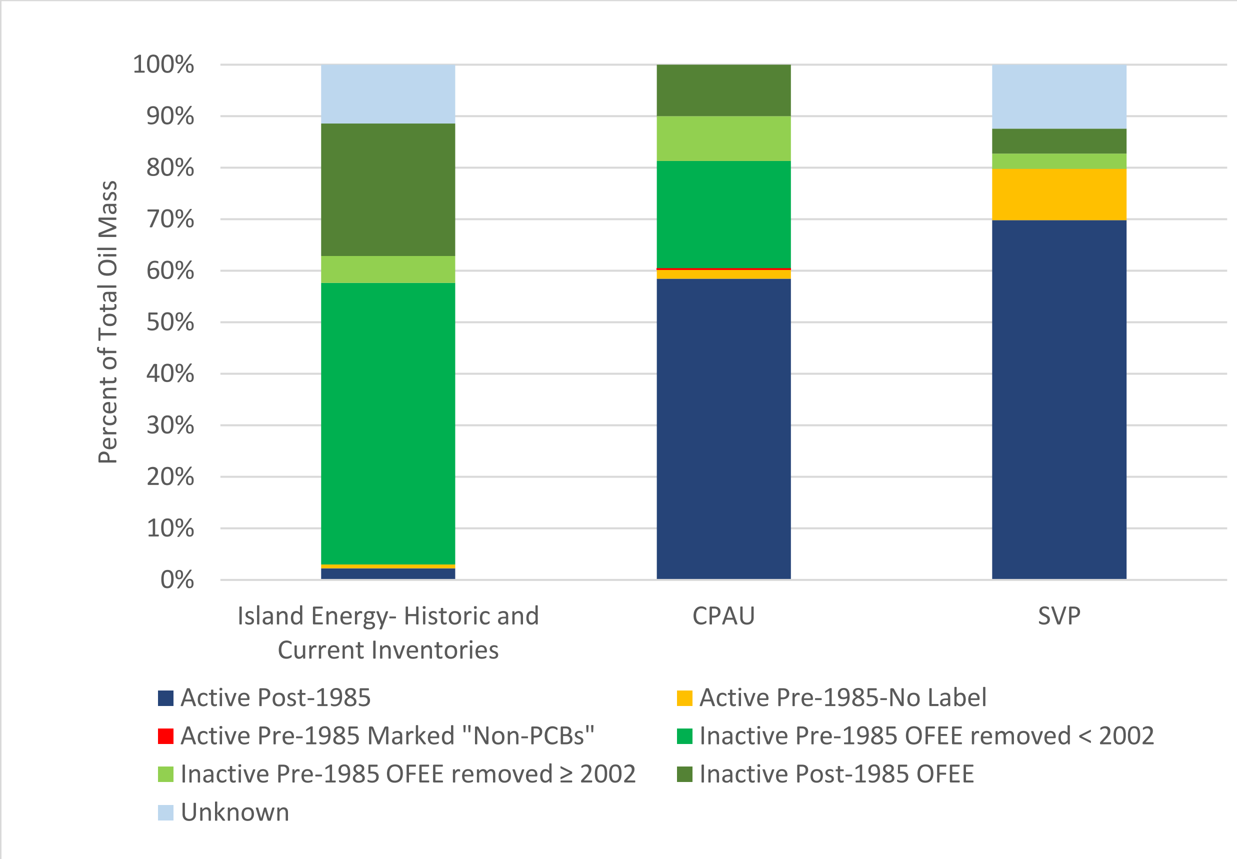

Figure 4.1 Distribution of the mass of oil in oil-filled electrical equipment (OFEE) in three municipally-owned electrical utility systems.

Active Equipment - including both Pre-1985 and Post-1985 OFEE

Table 4.1 presents the mass of oil in all OFEE that are currently active in each participating municipally-owned electrical utility system, divided between pre-1985 OFEE and post-1985 OFEE. Where available, the data are also presented by equipment type. Across all 3 systems, there are more than 4.8 million kilograms (kg) of oil in active OFEE.

Combined, there are nearly 500,000 kg of oil in active pre-1985 OFEE in these systems, which is 10% of the oil in active OFEE (Table 4.1). CPAU has the lowest abundance of active pre-1985 OFEE oil, which comprises 3.4% of their OFEE. Approximately 12% of SVP's active equipment, and 25% of Island Energy's active equipment are comprised of pre-1985 OFEE. Additional pre-1985 OFEE may be active in the system that cannot be verified at this time (see Section 4.1.2 on SVP OFEE identified as "unknown status and age"). Detailed equipment type was not provided by Island Energy, but for both CPAU and SVP, 64% of the pre-1985 OFEE oil is contained in padmount transformers, and about 25% is contained within pole-top transformers. The remainder is either in underground transformers or switches.

Table 4.1 Mass of dielectric oil in oil-filled electrical equipment (OFEE) that are currently active in three municipally-owned electrical utility systems.

Utility System	Equipment Type	Oil in ACTIVE OFEE (kg) Pre-1985 OFEE	Post-1985 OFEE	TOTAL	Percent of Active OFEE that are pre-1985
City of Palo Alto Utilities (CPAU)	Padmount Single Phase Transformer	988	57,798	58,786	1.7%
	Padmount Three Phase Transformer	33,336	609,353	642,689	5.2%
	Poletop Transformer	4,923	121,608	126,531	3.9%
	Regulator	0	920	920	0%
	Underground Commercial Distribution Transformer	0	108,560	108,560	0%
	Underground Residential Distribution Transformer	204	62,584	62,789	0.3%
	Padmount Oil Switch	0	1,090	1,090	0%
	Padmount Vacuum Switch	0	99,038	99,038	0%
	Vault/Box Oil Switch	0	0	0	0%
	Vault/Box Vacuum Switches	0	63,027	63,027	0%
	Subtotal - CPAU	**39,452**	**1,123,977**	**1,163,429**	**3.4%**
Silicon Valley Power (SVP) – City of Santa Clara[1]	Padmount Single Phase Transformer	2,044	23,201	25,245	8.1%
	Padmount Three Phase Transformer	189,333	1,147,357	1,336,690	14%
	Poletop Transformer	111,551	139,338	250,889	44%
	Underground Residential Distribution Transformer	0	1,635	1,635	0%
	Padmount Oil Switch	7,645	9,444	17,089	45%
	Padmount Vacuum Switch	51,880	154,999	206,879	25%
	Padmount Vacuum-Disconnect Switch	0	249,764	249,764	0%
	Padmount Substation Transformer	91,985	1,460,593	1,552,578	6%
	Subtotal - SVP	**454,439**	**3,186,330**	**3,640,76**	**12%**
Island Energy[2]	**Current Inventory of Transformers**	**3,669**	**10,882**	**14,551**	**25%**
	TOTAL (All Systems Combined)	**497,560**	**4,321,189**	**4,818,749**	**10%**

[1]SVP identified incomplete records for OFEE that contain approximately 566,000 kg or oil. The current status of these OFEE (active or removed) and the installation dates were unavailable at the time of this report. Therefore, these OFEE were not included in any of the totals above. See Section 4.1.2 for additional information.
[2]Since 1997, Pittsburg Power Company has been operating the electrical distribution system on Mare Island in the City of Vallejo under the name Island Energy.

Pre-1985 OFEE Removed from Active Service

Table 4.2 presents the total mass of oil in all pre-1985 OFEE that have been removed from service since they were originally installed, divided between the pre-1985 OFEE that were removed before 2002, and those that were removed in 2002 or later (i.e., since the start of the PCBs TMDL). Across the three systems, nearly 1 million kilograms of oil in pre-1985 OFEE have been removed from active service due to ongoing equipment removal and maintenance programs. This represents approximately 67% of the oil from all pre-1985 OFEE in these inventories.

Both CPAU and Island Energy have already removed the bulk of their pre-1985 OFEE from active service (94% and 88%, respectively). When the pre-1985 OFEE in the historic inventory on Mare Island were factored into the calculation, the removal rate on Mare Island increased to over 99% removal of all pre-1985 OFEE. SVP has removed at least 23% of their documented pre-1985 OFEE from active service. Additional removals from the SVP system may have occurred that cannot be verified at this time (see Section 4.1.2 on SVP OFEE identified as “unknown status and age”).

In addition, since the start of the PCBs TMDL in 2002, more than 320,000 kg of oil in pre-1985 OFEE have been removed from service across all three systems (Table 4.2). This represents an overall 39% removal rate, and an average removal rate of 2.3% per year. The overall removal rates for each individual system over this same time period were 81% (CPAU), 68% (Island Energy) and 23% (SVP). These overall removal rates equate to average removals of 4.8% (CPAU), 4.0% (Island Energy), and 1.3% (SVP) per year. Based on these annual average removal rates, the project estimates it will take between 21 and 75 years for all pre-1985 OFEE to be removed from these systems due to continued equipment maintenance and removal programs.

Table 4.2 Mass of dielectric oil in oil-filled electrical equipment (OFEE) that have been removed from active service in three municipally-owned electrical utility systems.

Utility System	Equipment Type or	Pre-1985 OFEE Oil in Inactive/Removed OFEE (kg)			Pre-1985 OFEE Removed Between 2002 and 2019		Pre-1985 OFEE removed since installation	Estimated time to remove all pre-1985 OFEE (years)
		Removed prior to 2002	Removed in 2002 or Later	TOTAL REMOVED	Overall Removal Rate	Annual Average Removal Rate		
City of Palo Alto Utilities	Padmount Single Phase Transformer	2,998	3,475	6,473	**81%**	**4.8%**	**94%**	**21**
	Padmount Three Phase Transformer	98,953	79,431	178,384				
	Poletop Transformer	204,165	47,100	251,265				
	Regulator	0	0	0				
	Underground Commercial Dist.Transformer	39,162	19,879	59,041				
	Underground Residential Dist. Transformer	54,374	17,971	72,345				
	Padmount Oil Switch	0	0	0				
	Padmount Vacuum Switch	0	0	0				
	Vault/Box Oil Switch	0	0	0				
	Vault/Box Vacuum Switches	0	0	0				
	Subtotal - CPAU	**399,651**	**167,856**	**567,508**				
Silicon Valley Power - City of Santa Clara[1]	Padmount Single Phase Transformer	0	1,635	1,635	**23%**	**1.3%**	**23%**	**75**
	Padmount Three Phase Transformer	944	108,642	109,585				
	Poletop Transformer	327	21,801	22,128				
	Underground Residential Dist. Transformer	0	664	664				
	Padmount Oil Switch	0	0	0				
	Padmount Vacuum Switch	0	0	0				
	Padmount Vacuum-Disconnect Switch	0	0	0				
	Padmount Substation Transformer	0	0	0				
	Subtotal - SVP	**1,271**	**132,742**	**134,013**				
Island Energy[2]	**Current Inventory**	**5,276**	**21,161**	**26,437**	**68%**	**4.0%**	**88%**	**25**
	Historic Inventory	**266,192**	**NA[3]**	**266,192**	**NA[3]**		**100%**	
TOTALS (All Systems Combined)		**672,391**	**321,759**	**994,150**	**39%**	**2.3%**	**67%**	**43**

[1]SVP identified incomplete records for OFEE that contain approximately 566,000 kg or oil. The current status of these OFEE (active or removed) and the installation dates were unavailable at the time of this report. Therefore, these OFEE were not included in any of the totals above. See Section 4.1.2 for additional information.
[2]Since 1997, Pittsburg Power Company has been operating the electrical distribution system on Mare Island in the City of Vallejo under the name Island Energy.
[3]NA=not applicable; the historic inventory only covers the period up to 1996.

Sensitivity Analysis – SVP Data

As described in Section 4.1.2, about 12% of the equipment in the SVP inventory did not have information on the status (active or inactive) or age (pre- or post-1985) of the OFEE. In order to evaluate the potential impact of excluding these unknown data, additional analyses were conducted to account for the following three scenarios:

1- All “unknown” OFEE are assumed to be active, pre-1985 OFEE;
2- All “unknown” OFEE are assumed to be pre-1985 OFEE that were removed from service after the start of the PCBs TMDL in 2002;
3- All “unknown” OFEE are assumed to be pre-1985 OFEE that were removed from service prior to 2002.

The results of the sensitivity analysis conducted under each of these three scenarios are shown in Table 4.3. The default scenario excluded all “unknown” oil from all calculations. For each alternative scenario, the mass of “unknown” oil was added to the value for the cell highlighted in blue in the table. The minimum and maximum values calculated for each of the percentage columns are bolded in the table.

This analysis indicates that under Scenario 1, the percent of active OFEE that are pre-1985 increases from 12% to 24%, and the percent of pre-1985 OFEE that have been removed since installation decrease from 23% to 12%.

Under Scenarios 2 and 3, the percent of active pre-1985 OFEE remain the same, but the percent of pre-1985 OFEE that have been removed since installation increases from 23% to 61%, which is more in line with the rates observed for the other two systems. Scenario 3 also increases the annual average removal rate since the start of the TMDL from 1.3% to 3.6% per year.

The primary impacts of these alternative scenarios include the following:

- Under Scenario 1, the pre-1985 OFEE currently in the system more than doubled, which would result in an increase in the current PCBs loads to stormwater from this source;
- Under Scenario 3, the mass of pre-1985 OFEE removed since the start of the TMDL was nearly tripled, which would result in an increase in the PCBs stormwater loads reduced during this time period accordingly. Also under Scenario 3, because of the increased annual removal rate, all pre-1985 OFEE would be removed within 28 years (compared to 75 years in the default scenario).

Because these impacts are potentially large, the results for SVP presented in the next section used the ranges presented in Table 4.3 for Scenario 1 and Scenario 2. The results for these two scenarios provide the upper and lower limits for all values across the default and alternative scenarios.

Table 4.3 Sensitivity analysis conducted to evaluate the impacts of unknown status and age of oil-filled electrical equipment (OFEE) identified in the Silicon Valley Power (SVP) OFEE inventory on the evaluation of pre-1985 as a source of PCBs to urban stormwater.

Scenario	Oil in Active OFEE (kg)		Oil in Inactive/Removed OFEE (kg)			Oil in OFEE with Unknown Status and Age (kg)	Total Oil in OFEE Inventory (kg)	Percent of all Active OFEE that are Pre-1985	Percent of Pre-1985 OFEE Removed Since Installation	Pre-1985 OFEE Removed Between 2002 and 2019	
	Post-1985 OFEE	Pre-1985 OFEE	Pre-1985 OFEE removed before 2002	Pre-1985 OFEE removed in 2002 or later	Post-1985 OFEE					Overall Removal Rate	Annual Average Removal Rate
Default: "Unknown" not included in calculations	3,186,330	454,439	1,271	132,742	221,460	566,026	4,562,268	**12%**	23%	23%	1.3%
1. All "unknown" = Active, Pre-1985 OFEE	3,186,330	1,020,465	1,271	132,742	221,460		4,562,268	**24%**	**12%**	**12%**	**0.7%**
2. All "unknown" = Pre-1985 OFEE Removed in 2002 or Later	3,186,330	454,439	1,271	698,768	221,460		4,562,268	12%	**61%**	**61%**	**3.6%**
3. All "unknown" = Pre-1985 OFEE Removed Prior to 2002	3,186,330	454,439	567,296	132,742	221,460		4,562,268	12%	61%	23%	1.3%

Potential PCBs Mass in Active OFEE and Estimated Stormwater Loads

Table 4.4 provides the calculated PCBs mass in the Island Energy historic and current OFEE inventories, and estimates of the potential PCBs mass in the CPAU and SVP OFEE inventories. Only Island Energy provided data on measured PCBs concentrations in their OFEE oil. Concentrations of PCBs in Island Energy's current inventory of OFEE ranged from 1 to 37 ppm. Concentrations in the historic inventory ranged from <1 up to nearly 900 ppm. About 20% of the OFEE in the historic inventory had PCBs concentrations > 500 ppm. Based on these measured PCBs concentrations and the volumes of oil in each piece of equipment, the historic inventory documents OFEE containing more than 70 kg of PCBs. By comparison, Island Energy's current inventory of both active and inactive OFEE had 0.088 kg of PCBs. Of that total, 0.040 kg of PCBs remain in active OFEE, and 0.048 kg of PCBs were from OFEE that have been removed from active service. This represents a three-order of magnitude decrease in PCBs mass from the historic inventory. One interesting detail about the PCBs concentration data was that nearly one-third of the PCBs in the current inventory were contained in post-1985 equipment. All of these equipment were from 1986 or 1987. PCBs concentrations were generally low in these OFEE, ranging from 1 to 4 ppm. However, the potential contribution from these OFEE could still be important. For example, in the Island Energy current inventory, there is one piece of equipment from 1987 that contains 600 gallons of oil at 1 ppm PCBs, or 2 g of PCBs in total. If this quantity of PCBs were released to the environment, this could have a detrimental impact on stormwater quality.

Because CPAU and SVP did not provide measured PCBs concentrations for OFEE in their inventories, the potential PCBs mass in pre-1985 OFEE was estimated based on the assumptions described in Section 4.2.1. For CPAU, these estimates suggest active pre-1985 OFEE may contain between 1.7 and 17 kg of PCBs, while pre-1985 OFEE that have been removed potentially contained between 28 kg and 284 kg. These estimates suggest an order of magnitude reduction in PCBs mass in the active OFEE inventory. For SVP, active pre-1985 OFEE may contain between 23 kg and 227 kg. If the "unknown" OFEE were assumed to be active pre-1985 OFEE, then the total estimated mass of PCBs in active OFEE doubles to 51 kg to 510 kg. PCBs in pre-1985 OFEE that have been removed were estimated to range from 6.7 to 67 kg, which would increase up to 35 kg to 350 kg if the "unknown" OFEE were assumed to be pre-1985 OFEE that have been removed from service. Across all three systems, the total potential mass of PCBs in active OFEE ranged from 24 kg up to 527 kg. The upper value assumes the "unknown" mass is contained within active, pre-1985 OFEE.

Table 4.4 Estimated potential mass of PCBs in municipally-owned electrical utilities oil-filled electrical equipment (OFEE) inventories

	PCBs (kg)				
OFEE Category	**CPAU**	**SVP**	**Island Energy - Current**	**Island Energy - Historic**	**TOTAL (All Systems)**
All Active	1.7 - 17	23 - 227	0.040		24 - 244
All Removed	28 - 284	6.7 - 67	0.048	70	105 - 421
Removed since 2002	8.4 - 84	6.6 - 66	0.048		15 - 150
Removed prior to 2002	20 - 200	0.1 - 0.6		70	90 - 271
Unknown		28 - 283			28 - 283

Based on the approximate population of the MRP area of ~6 million people, if the active OFEE in all the participating municipally-owned electrical utility systems were representative of the PCBs contained in OFEE across the larger MRP area (i.e., 24 to 527 kg), the estimated mass of PCBs would range from roughly 730 kg up to 16,000 kg of PCBs. Based on acres, the estimated mass of PCBs across the larger MRP area of nearly 3 million acres would range from 2,400 kg up to 53,000 kg of PCBs in active OFEE.

Table 4.5 presents the estimated loads of PCBs to stormwater from active OFEE in the three participating municipally-owned electrical utility systems. Across all three systems, the estimated PCBs stormwater load in 2002 from active OFEE was between 197 mg/yr to 3,390 mg/yr. The low end of this range is the sum of the minimum values for all active OFEE and all OFEE removed since 2002. The upper end of this range is the sum of the maximum values for all active OFEE, all OFEE removed since 2002, and all unknown OFEE. In 2020, the total estimated PCBs stormwater loads from active OFEE were estimated to range from 122 mg/yr up to 2,640 mg/yr. The low end of this range is the sum of the minimum value for all active OFEE. The upper end of this range is the sum of the maximum values for all active OFEE and all unknown OFEE. Scaling these estimates up to the MRP area of roughly 3 million acres gives a stormwater load of between 20,000 mg/yr up to 340,000 mg/yr in 2002, and 12,000 mg/yr up to 260,000 mg/yr in 2020. These estimates are highly uncertain due to all the assumptions that were used in the calculations.

Table 4.5 Estimated range of PCBs loads to stormwater from oil-filled electrical equipment within three municipally-owned electrical utility systems.

OFEE Category	PCBs Stormwater Loads (mg/yr)				
	CPAU	SVP	Island Energy - Current	Island Energy - Historic	TOTAL
All Active OFEE	8.3 - 84	114 - 1,136	0.199	0	122 - 1,220
All Active OFEE - assume "unknown" = active	8.3 - 84	255 - 2,551	0.199	0	264 - 2,636
All Removed OFEE	142 - 1,419	34 - 335	0.241	352	527 - 2,106
Removed since 2002	42 - 420	33 - 332	0.241	0	75 - 752
Removed prior to 2002	100 - 999	0.3 - 3.2		352	452 - 1,354
All Removed OFEE - assume "unknown" = removed	142 - 1,419	175 - 1,750	0.241	352	317 - 3,169
Unknown		142 - 1,415			142 - 1,415

4.3 Spill Response and Cleanup

Although the bulk of PCBs remain contained within OFEE until the equipment is removed from use and transported to proper hazardous waste disposal facilities, releases of PCBs to the environment can and do occur.

4.3.1 Summary of OFEE Release Data for Bay Area

In order to document spills, publicly available data in the California Office of Emergency Services (Cal OES) spill report database (Cal OES 2017), as well as internal spill records (PG&E 2000) supplied by PG&E to the Regional Water Board in September 2000 (that were provided pursuant to a California Water Code §13267 request for information) were reviewed. The Cal OES database and available PG&E spill records were searched for reports of spill releases related to OFEE in the Bay Area between 1994 and 2017. Over 1,200[8] reported release incidents from OFEE in the Bay Area were identified. The information provided by these records and a summary of the important issues identified for water quality concerns are summarized in the remainder of this section. It is important to note that current regulations do not require reporting of all releases from OFEE. The information provided below is based only on the reported releases for which records were available, and likely represents an underestimate of actual OFEE releases during the time period of review. However, these reports clearly demonstrate that PCBs may still be present in the electrical transmission and distribution systems in the Bay Area, and that releases from these systems can and do continue to occur.

Generally, the publicly available spill release records provide information about the spill release date, time, location, chemical, quantity released, actions taken, known or anticipated risks posed by the release, and additional comments. Other information that is sometimes reported for OFEE releases includes a description of the causes of the release and the equipment affected, and the concentrations of PCBs in that equipment (if known). Concentration information reported is likely assumed from equipment labels, as ranges are most often provided rather than specific values. Typically, the reports are limited to the information that was available at the time the spill was initially reported. In some cases, follow-up information such as the results of analytical testing of the spilled materials is also provided, but this is not typical.

Number of Reported OFEE Releases

Between 1994 and 2017, over 1,000 spills from electrical equipment were reported to Cal OES. PG&E records contain information about 200 additional releases that were not reported to Cal OES between 1994 and 2000. A count of these reports by year is presented in Figure 4.2.

[8] The records span 24 years of spill reports, and include PG&E's own record of releases from 1994 thru 1999 and a portion of 2000. The number of reports PG&E submitted in 2000 represents less than half the number of reports for that year. Records did not include all the districts in the Bay Area. District documents submitted reported releases prior to June of 2000, with the exception of one district that submitted a June report. As a result, the number of additional reports from PG&E's records are assumed to be less than half the number of incidents for 2000.

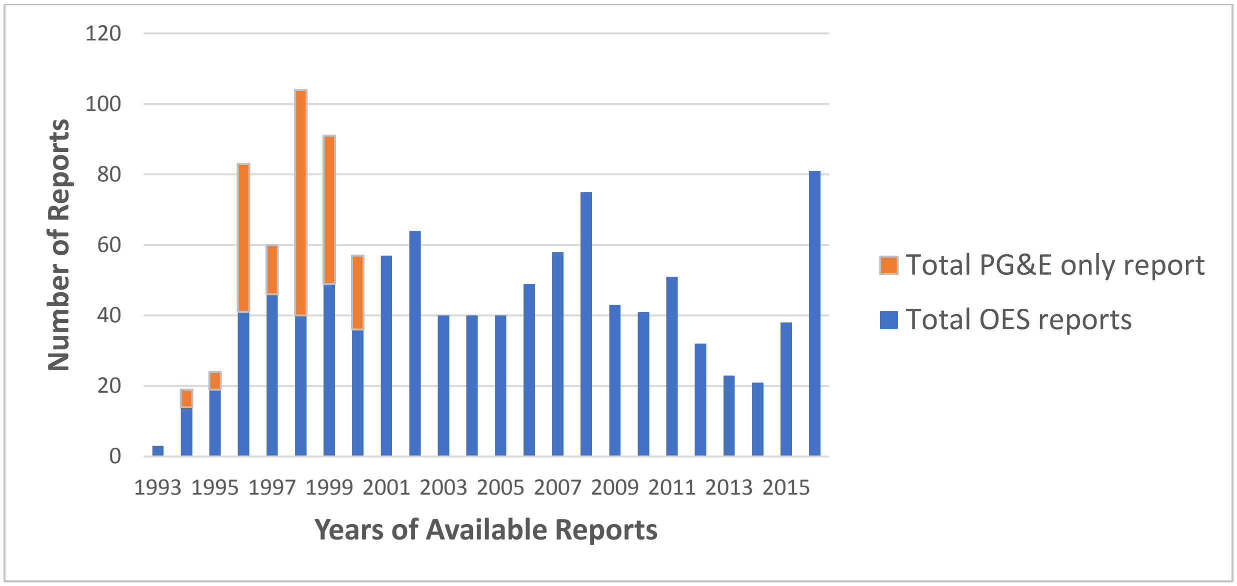

Figure 4.2 Oil-filled electric equipment spills reported to the California Office of Emergency Services (Cal OES) and/or identified through internal Pacific Gas & Electric (PG&E) reports between 1993 and 2017.

Volume of OFEE Releases

The total volume of material released from all reported OFEE spills in a given year in the Bay Area is presented in Figure 4.3. Mineral oil or transformer oil are the substances identified in over 99% of reported releases from OFEE in the Cal OES spill report database. In a phone conference with Regional Water Board staff in 2012, PG&E said they submit written reports to Cal OES for all PCBs spills that meet or exceed the mineral oil federal reportable quantities (RQ) of 42 gallons (*personal communication*, Jan O'Hara 2012). However, the reports reviewed indicate written reports are sometimes submitted for spills that are much less than 42 gallons.

The reported volumes of oil released during a single incident range from less than one gallon up to 5,000 gallons. Nearly half of all OFEE spill reports identify the volume of oil spilled as 5 gallons or less, and more than 90% of all spill reports identify the volume of fluid spilled as less than 100 gallons. Releases as large as 500 gallons from the distribution system and 5,000 gallons from the transmission system have been reported. Only five incidents reported releases that exceeded 1,000 gallons of oil. Nearly all (~99%) of reports provided information on the volume of oil released.

The reported volumes released do not necessarily equate to the volume of the oil that may have reached storm drains or local creeks. Estimates of those volumes were not available.

Location of OFEE Releases

Cal OES and PG&E records show releases occurred in all Bay Area counties. Leaks and spills of PCBs from electrical equipment have occurred onto roads, sidewalks, pervious areas, vegetation, structures, vehicles, and even people (Cal OES 2017). Most releases occurred in the distribution system, often from equipment installed in the public ROW such as pole-mounted transformers installed along roadways.

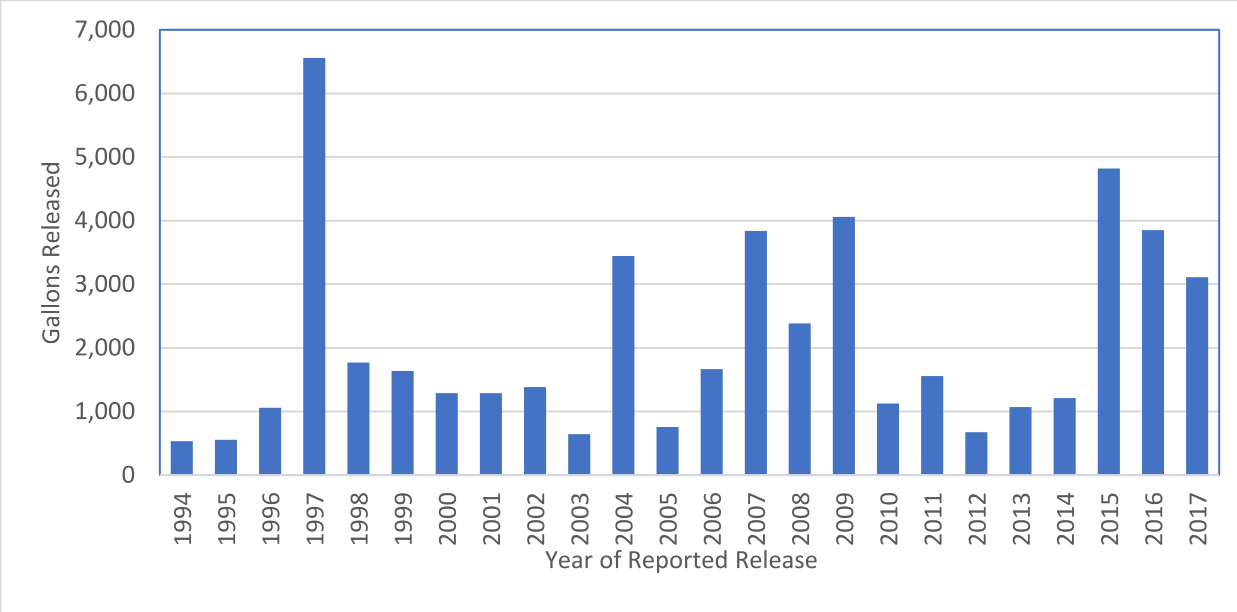

Figure 4.3 Total reported gallons of oil released each year (1994 – 2017) from spills from PG&E electrical utility equipment in the Bay Area.

A number of reports document direct releases from OFEE to the MS4, and potentially a downstream waterbody (e.g., creek). There are at least 17 incidents identified during the past 15 years that involved direct releases from OFEE directly to a waterbody or to storm drains that discharge to local creeks (Table 4.6). The majority of these releases were reported as having unknown PCBs concentrations, and no reports provide any follow-up information on the concentration of PCBs in the spilled materials based on chemical analysis.

It is important to note that in addition to the incidents identified in Table 4.6, materials spilled during any of the numerous other incidents may (or may not) have entered the MS4 and/or receiving waters such as local creeks directly or been washed into the MS4 and/or creeks by stormwater or irrigation runoff. Generally, the spill reports lack any details regarding this type of information.

Table 4.6 Examples of Information Reported on Releases of PCBs to Bay Area Storm Drains and Creeks.

Date	Gallons	Reported Concentration	Water Body	Municipality
1/24/2016	Unknown	<50 ppm	Coyote Creek	San José
2/17/2016	Up to 18	Unknown	Los Gatos Creek	Los Gatos
3/7/2016	10	Unknown	Culvert	Concord
8/16/2016	Unknown	<50 ppm	Guadalupe River	San José
11/17/2015	Unknown	Unknown	Cerrito Creek	Richmond
10/4/2015	5	Unknown	Creek	Los Gatos
5/3/2015	30	<2 ppm	Cerrito Creek	Richmond
3/2/2011	30	Unknown	Unknown Marsh	Menlo Park
6/2/2007	40	Unknown	Pond, Marsh Area	Vallejo
2/28/2006	20	<50 ppm	Calara Creek	Pacifica
5/27/2006	1	Unknown	Unknown Creek	Orinda
10/10/2005	Unknown	Unknown	Coyote Creek	San José
7/23/2005	<15	Unknown	Nearby Creek	Walnut Creek
12/8/2004	Small amount	<50 ppm	Moraga Creek	Orinda
3/7/2004	Unknown	Unknown	Blossom Creek	Calistoga
7/14/2003	8	< 50 ppm	Coyote Creek	San José
2/16/2002	15	Unknown	Napa River	Napa

Causes of OFEE Releases

Cal OES release reports and PG&E records document a number of causes of PCBs releases from OFEE. Most releases can be attributed to one of the following:

- **Equipment Failure**. This is the cause of the majority of the reported releases. Equipment failure in utility vaults has additional potential as an important source of PCBs because OFEE in these vaults may contain more than 100 gallons of oil. More than 50 release incidents were reported for equipment contained in electrical utility vaults during the time period reviewed. A number of these reports noted the presence of water in the vaults in addition to the PCBs oil released. Releases from equipment failure in utility vaults are mostly contained, but Cal OES spill reports document releases of PCBs oil that breached containment, including discharges that reached water bodies.

- **Accidents**. Approximately 20% of reported releases resulted from equipment knocked over by accident. In the distribution system, reports document 50 to 500 gallons released from poles knocked over during car accidents, by construction equipment, and during tree trimming. On rare occasion PCBs releases have occurred during accidents while equipment is in transport.

- **Storms, Fires, and Overheating from High Summer Temperatures**. These factors are the reported cause of more than 10% of the releases from the distribution system.

- **Field Repairs and Fluid Replacement**. The Cal OES database contains records that indicate draining fluids in the field may have been ongoing as recently as 2007, when a report documented that a valve left open from draining a transformer in the field caused a release. In 2016, Daniel Sanchez, who at the time was PG&E's Manager of Hazardous Materials and Water Quality Environmental Management Programs, informed Regional Water Board staff that PG&E does not drain and refill pole mounted PCB transformers in the field any longer; however, it is unclear when this practice ceased, and/or if it still occurs with equipment not mounted on poles.

- **Vandalism**. Between 1997 and 2015, there were at least 25 separate reported incidents of vandalism that resulted in PCBs releases. For example:
    - In 1997, gunshot damage caused the release of 5,000 gallons of oil from a substation transformer and regulators in San Mateo County;
    - In 2011, copper theft at a substation released 750 gallons of oil in Contra Costa County;
    - In 2013, vandalism of pad-mounted transformers resulted in the release of possibly 1,000s of gallons of oil before discovery in San José.

PCBs Concentrations in OFEE Releases

Of the more than 1,200 spill reports that were reviewed, approximately one-third identified the PCBs concentration as unknown or did not provide any information on the PCBs concentration of the spilled material (Figure 4.4). Releases with high PCBs concentrations (> 500 ppm) were infrequently reported, accounting for only 1% of reported spills. Concentrations above 50 ppm represent about 8% of the reported spills. As recently as 2016, failure of a pole-mounted transformer resulted in release of mineral oil with 280 ppm PCBs to surrounding soils and brick structures. For approximately 44% of the reported releases, the PCBs concentration was identified as less than 50 ppm, based primarily on assumptions associated with a "Non-PCB" label. For these 44% of reports, no additional information was provided on PCBs concentrations other than a designation of "< 50 ppm". According to labeling requirements, a "Non-PCB" label indicates the PCBs concentrations in the oil are assumed to be below hazardous waste thresholds of 50 ppm (federal regulations, see Section 3.2.1). However, in most cases, no additional information was provided in the spill reports to indicate how the "Non-PCB" category was arrived at, or whether the federal (> 50 ppm) or state (> 5 ppm in liquid) "Non-PCB" category was assumed.

For the vast majority of these reports, no follow-up chemical analysis results were provided that confirmed the "Non-PCB" designations. In a limited number of reports, follow-up PCBs analysis results were provided for materials that were identified as "Non-PCB" during initial reporting. Generally, these results found PCBs concentrations between 5 and 49 ppm, suggesting that the labels were correctly applied. However, any concentration of PCBs in electrical equipment oils is potentially significant in terms of water quality impacts and implementation of the PCBs TMDL. These results clearly demonstrate that the "Non-PCB" designation represents a threshold that is far too high to necessarily be protective of water quality.

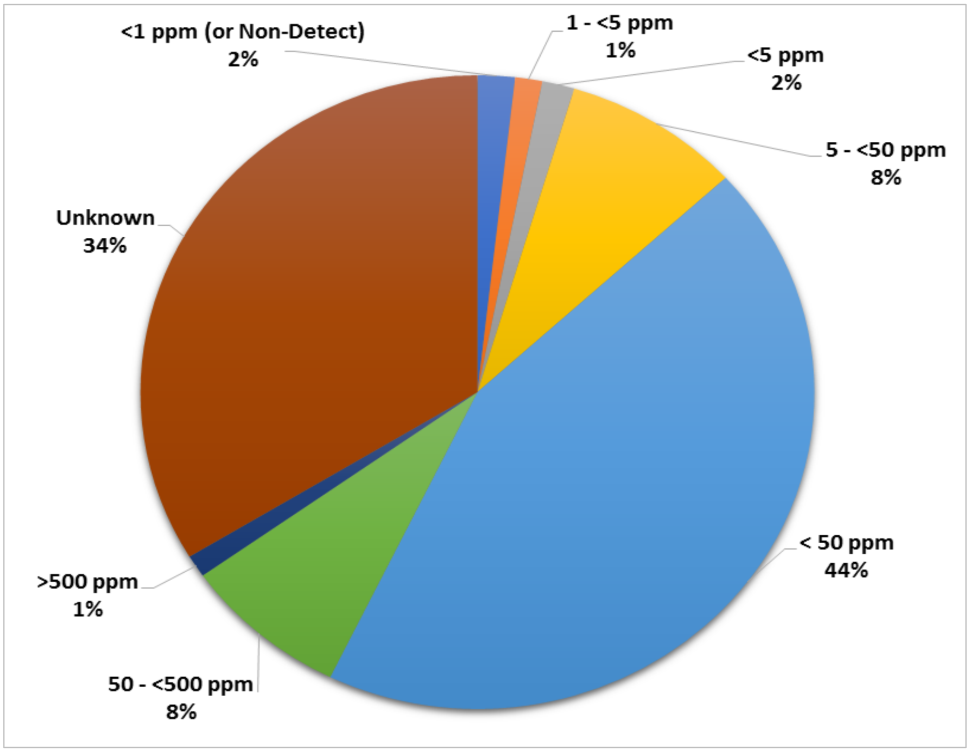

Figure 4.4 PCB Concentration data reported for releases from PG&E electrical equipment between 1993 and 2016. Each category identified above is independent (e.g., the "< 50 ppm category" does not include reports that provided more specific concentration data that was < 50 ppm).

Only 1% of the reported releases identified the PCBs concentrations as either below 1 ppm, or below detection limits. Although the quality of the PCBs concentration data in the release reports varies widely, these results clearly demonstrate that electrical equipment in the Bay Area can still contain PCBs at concentrations of concern for water quality protection programs.

Recommendations

Based on review of reports in the Cal OES database, while they meet the current regulatory notification requirements, the current spill notification and reporting procedures are not adequate to address TMDL goals, and do not provide the Regional Water Board or Bay Area MS4s with the information needed to better quantify and control releases to the MS4.

Review of two municipally-owned utilities' procedures for spill response indicates that all spills, even those of a low PCBs concentration or low volume release, are internally documented even if there is no OES notification requirements. Given that PG&E provided spill reports (pursuant to a 2000 California Water Code §13267 request for information) that were not submitted to OES indicates PG&E also internally documents spills even if they do not need to be reported. Therefore, it is likely that the municipally-owned utilities already have procedures for documenting and recording all spills.

More stringent requirements to address PCBs TMDL goals should include spill response and reporting for all spills/releases from municipally-owned utility OFEE unless there is clear and sufficient evidence available when the spill is initially discovered that unequivocally identifies the equipment involved as having been installed after 1985. This more stringent requirement will ensure that all releases from equipment that could potentially contain PCBs will be reported.

In addition, the information reported in Cal OES database typically captures only the data that were available at the time the spill occurred. Although these reports may provide some preliminary information on the mass of PCBs released (i.e., volume and concentration spilled), these reports rarely provide any corroborating measurement data or any follow-up information on the effectiveness of cleanup activities. This information is needed to quantify PCBs from OFEE releases, or to track where PCBs remain in use in the system. As discussed in Section 3.2.5, any chemical analysis methods should follow the recommendations of the Regional Water Board for congener analysis at sufficiently low reporting levels to capture all concentrations of concern and congeners of concern to address water quality issues (SFBRWQCB 2016).

Bay Area MS4s do not receive timely notification of releases from OFEE. Even for releases that must be reported to Cal OES, electrical utilities do not typically notify local agencies directly. Instead, Bay Area MS4s are responsible for reviewing Cal OES reports in order to identify spills or releases that have occurred in their jurisdictions. This delay is problematic because clean-up actions have likely been completed by the time reports are submitted to Cal OES. Bay Area MS4s should be notified of releases within their jurisdiction as soon as possible so they can provide oversight during initial cleanup efforts, as well as any follow-up that is needed to ensure cleanup was completed to the desired levels. The appropriate local agency staff understand their municipal storm drain systems and how storm drain inlets connect to creeks and water bodies in their jurisdictions. Better communication between utilities and municipal stormwater programs can result in more efficient responses and less impact to waterways.

In summary, to better quantify the amount of PCBs released from OFEE spills, and to help ensure that adequate cleanup actions are being implemented, the following improvements to current reporting and notification requirements could be made:

- Notify Bay Area MS4s of releases within their jurisdiction as soon as possible so they can provide oversight during initial cleanup efforts, as well as any follow-up that is needed to ensure cleanup was completed to the desired levels.
- Respond and report to Bay Area MS4s for all spills/releases from OFEE unless there is clear and sufficient evidence available when the spill is initially discovered that the equipment involved was installed after 1985.
- Any chemical analysis methods should follow the recommendations of the Regional Water Board for congener analysis at sufficiently low reporting levels to capture all concentrations of concern and congeners of concern to address water quality issues.

4.3.2 Spill Response Protocols

Electrical utility companies typically address spills or leaks from their OFEE with Standard Operating Procedures (SOPs) that should conform to both TSCA requirements and the more stringent California hazardous waste rules. The SOPs describe the steps to be taken by field crews in the event of an OFEE leak or spill, which should generally include the following:

- Notify Supervisor or compliance Manager
- Stop and contain the leak
- Determine the spill area (i.e., the area with visible traces of oil plus 1 foot beyond)

- Determine the PCB classification
- Notify property owner
- Notify Cal OES when required

Response to a specific release incident is determined by the PCBs classification of the responsible equipment. The state response level (5 to <50 ppm PCBs) requires immediate clean-up by next business day. The federal response level requires immediate clean-up until clean for spills of 50 to < 500 ppm, and the additional use of all resources to clean the spill immediately for spills > 500 ppm.

The disposal of all materials removed from a cleanup site or used to clean the site are handled according to the TSCA hazardous waste classifications (50 to <500 ppm; and ≥500 ppm in solids or liquids), or the state non-RCRA hazardous waste classification (5 to <50 ppm PCBs in liquids). The allowable post-cleanup concentrations of remaining soils and other surface materials typically range from 10 to 25 ppm, depending on site-specific evaluations of human health risk. As a result, current efforts to control and cleanup PCBs releases from electrical utility equipment are focused on these thresholds.

By comparison, Bay Area municipalities are concerned with much lower concentrations of PCBs. For example, currently Bay Area municipalities generally designate a site as a *potential* PCBs source to stormwater runoff if soil or sediment concentrations are ≥0.5 ppm and designate a site as a *confirmed* PCBs source to stormwater runoff if soil or sediment concentrations are ≥1.0 ppm. Control of PCBs sources at these substantially lower concentrations has been deemed necessary to make progress towards meeting the stringent stormwater runoff wasteload allocations called for in the PCBs TMDL. In addition, post cleanup verification sampling is only required for high concentration spills or high volume spills.

The Cal OES reports provide almost no information on actions taken to stop active spills, or the methods used to cleanup spilled materials from surrounding surfaces, storm drain infrastructure, or creeks. Municipalities need this type of information to better understand any potential risks that remain following initial cleanup. Because of the challenges with achieving the stormwater runoff wasteload allocation in the PCBs TMDL, additional remedial actions may be warranted in some cases.

According to information supplied to the Regional Water Board (PG&E 2000), PG&E spill response is guided by internal documents, including:

- ***Utility Operations Standard D-2320*** - for PCB spills in the distribution system;
- ***PCB Management at Substations -*** for PCB spills in the transmission system.

These documents were not available for review. However, PG&E staff presented the basic elements of their spill response protocol during a public presentation to CCCWP in 2013. PG&E's spill response protocol, as described during this presentation, is summarized here. First, PG&E's spill response is based on the following three guiding principles:

1. Personnel and public safety: isolate or barricade the area from the public; do not do anything to put yourself and others in harm's way.
2. Reporting: report the incident to electric operations.
3. Containment: prevent the spill from spreading using diking or applying absorbents.

Two municipally-owned utilities provided spill response procedures for review. The procedures followed the general guidelines discussed above. In one procedure the cleanup activities included double wash/rinse affected area of the pole and associated equipment. The other procedure expanded this to all solid surfaces such as walls, sidewalks, streets, cars, etc. One procedure called for removing all *visibly* contaminated soil plus one foot buffer zone or to a depth where there are no detectible PCBs. The other procedure called for removing all visibly contaminated soil but only included a one foot buffer for Federal low concentration PCB spills (50-499 ppm). One procedure called for collecting a sample after cleanup activities were completed for all categories of spills but there were no guidelines provided for the sample methods or results. The other procedure only called for cleanup sampling of Federal high concentration PCBs spills (>500 ppm) for comparison with the regulatory cleanup levels. The procedures do discuss containing spills, however, there was no discussion about specific procedures when the spill enters a storm drain system.

Recommendations

Bay Area MS4s need access to all electrical utility spill cleanup procedures to review and provide suggested revisions to ensure all necessary measures and precautions are included to achieve consistency across spill cleanups. Additional spill cleanup procedures suggested by MS4s may also depend on the location and type of spill (e.g., impervious surface vs soil; public right of way vs utility property; proximity to storm drain). Clean-up investigations should not only determine the spill area but determine if soils may have migrated off-site. In addition, samples for cleanup sites should be required for all spills unless there is clear and sufficient evidence available when the spill is initially discovered that the equipment involved was installed after 1985. The samples collected should be compared to thresholds identified by MS4s for *confirmed* PCBs source to stormwater runoff (e.g., soil or sediment concentrations are ≥ 1.0 ppm) in addition to the federal and state post cleanup levels required.

Improved notification of spills/releases to Bay Area MS4s discussed in Section 4.3.1 would also allow municipal stormwater program staff to field verify appropriate spill cleanup procedures as needed.

5.0 Source Control Framework

The overall approach for this SSID Investigation was to conduct a desktop analysis to evaluate electrical utility equipment in municipally-owned electrical utility systems in the Bay Area and propose a source control framework for electrical utility equipment to reduce ongoing PCBs loads to the Bay in stormwater runoff. The elements of the proposed source control framework include development of a new regional Electrical Utilities Management Program which identifies specific actions to reduce the release of PCBs to MS4s, estimates of PCBs loads to stormwater from electrical utility equipment, and development of data inputs that can be used to calculate the PCBs loads reduced through implementation of the new program. This section describes each element of the proposed source control framework for electrical utility equipment. This framework is consistent with MRP Provision C.8.e.iii.(3)(a) requirements for SSID project closure. Implementation of this source control framework will prevent or reduce the discharge of PCBs from electrical utility equipment in the Bay Area.

5.1 Electrical Utilities Management Program

Electrical utility applications present special challenges for source identification and abatement[9] due to the quantity of equipment and facilities, their dispersed nature, and difficulty in sampling discharges when they occur. In addition, municipalities lack control over the vast majority of these properties and equipment. Permittees have no jurisdiction over many large electrical utilities, including PG&E, and therefore no control over the cleanup of PCBs-containing spills (e.g., dielectric fluids from transformers), or prompt notification when they happen. To date, neither Permittees nor the Regional Water Board have been able to verify that a sound and transparent cleanup protocol is used consistently by all electrical utilities for PCBs spills from their electrical equipment across Bay Area cities. Moreover, current state and federal regulatory levels for reporting and cleanup of PCBs spills (e.g., cleanup goals for soils) are higher than cleanup levels recommended by the Regional Water Board to meet the objectives of the PCBs TMDL (SFBRWQCB 2016). There are currently potential missed opportunities to account for load reductions that have been and continue to occur due to the removal of PCBs-containing OFEE through ongoing equipment removal and replacement programs. Furthermore, there are missed opportunities to cleanup spills to the stringent levels that would be more consistent with the PCBs TMDL requirements, and to reduce the loads of PCBs from MS4s to the Bay. Given these constraints and the potential opportunities to reduce PCBs loads from electrical utility equipment, a new regional control measure program is proposed to manage the release of PCBs from OFEE. The Electrical Utilities Management Program described here identifies actions that address OFEE as a source of PCBs to stormwater at a regional level. The Program includes components that can address both municipally-owned and non-municipally-owned electrical utility OFEE in the Bay Area. However, the Regional Water Board will need to use their authority to compel non-municipally-owned electrical utilities (i.e., PG&E) to participate in the Program.

[9] Source identification and abatement is one type of stormwater control measure that Permittees use to reduce loads of PCBs in urban runoff. This control measure involves investigations of properties with elevated PCBs in stormwater or sediment to identify sources that contribute a disproportionate amount of PCBs to the MS4, and cause the properties to be abated, or refer the properties to the San Francisco Bay Water Board or other regulatory authority for follow-up investigation and abatement. This control measure is described in more detail in the BASMAA Source Control Load Reduction Accounting for RAA (BASMAA 2020).

Actions under the new Electrical Utilities Management Program would include the following:

- Action 1: Electrical utilities will document the removal of PCBs-containing OFEE since the start of the TMDL and in the future until all PCBs-containing OFEE have been removed from active service. The documentation should include data to support calculations of the associated stormwater load reductions due to these efforts;
- Action 2: Electrical utilities will implement enhanced spill response and reporting protocols, as needed, to further reduce the mass of PCBs released to stormwater due to accidental releases from PCBs-containing OFEE. The enhanced spill response and reporting protocols should include data gathering requirements that will support calculations of the associated stormwater load reductions due to these efforts.

Implementation of these actions would provide the following benefits: (1) document PCBs loads that have already been avoided due to removal of PCBs-containing OFEE, (2) reduce PCBs loads released to stormwater when spills do occur, and (3) provide information that can be used to determine when this potential source of PCBs to stormwater has been eliminated due to removal of all PCBs-containing equipment from service.

5.2 Estimated PCBs Loads to Stormwater from Electrical Utility Equipment

The starting point for documenting the load reductions that have been and will continue to be achieved through implementation of the new program is an estimate of the PCBs loads to stormwater from electrical utility equipment at the start of the PCBs TMDL. As described in more detail in Section 3.4, McKee et al. (2006) developed a PCBs mass balance model that estimated the total loads to stormwater from all major sources during the peak period of PCBs production and use (i.e., 1950 – 1990), and in the period of the study (i.e., 2005).

The estimated stormwater load of 2.8 kg/yr to the Bay from transformers and large capacitors in 2005, developed by McKee et al. (2006) as part of their PCBs mass balance model described in detail in Section 3.4, is the starting point for estimating load reductions that have been achieved since the PCBs TMDL was established. As shown in Table 5.1, the McKee et al. (2006) mass balance model presents the best estimate for the total PCBs stormwater load from all sources in 2005 as 52 kg/yr. The PCBs TMDL for the San Francisco Bay identifies the total stormwater load at that time as 20 kg/yr (SFBRWQCB 2008). For consistency with the TMDL, the McKee et al. (2006) best estimate for stormwater loads from various sources were normalized to a total stormwater load of 20 kg/yr (Table 5.1). As shown in Table 5.1, the TMDL-normalized PCBs load to stormwater conveyances in 2005 from electrical utility equipment is assumed to be 1.1 kg/yr. This value is one to two orders of magnitude larger than the estimated stormwater loads that were developed in this project based on extrapolation of the municipally-owned electrical utility data presented in Section 4.0 to the larger Bay Area (0.02 – 0.34 kg/yr). However, the stormwater load estimates extrapolated from the participating municipally-owned electrical utility data have some important limitations. There is currently no information available to determine if these estimates, representative of electrical utilities operating across small service areas, would be appropriate as representative of the OFEE and associated PCBs mass across the much larger MRP area. These utility systems service a population of less than 200,000 people, again a tiny fraction (about 3%) of the larger MRP area population of nearly 6 million people. These utility systems also serve an area of less than 30,000 acres, which is (1%) of the entire MRP area of nearly 3 million acres. Almost all of the remaining area is served by PG&E, a large private company that may not be well-represented by data from the three small municipally-owned electrical utilities that participated in this project. There are likely substantial differences between PG&E equipment, operations, and practices, especially in the past, that preclude extrapolating the municipally-owned utility data from this project to PG&E service areas across the Bay Area. The number, type and range of transmission and distribution OFEE that make up a small service area system may not be representative or scalable to the number, type and range of transmission and distribution OFEE that make up a large service area system where electricity must be delivered over larger distances.

There was also considerable variability in the quality and quantity of the OFEE inventory data provided across the three participating municipally-owned utility systems that was used to develop the load estimates in Section 4.0. Island Energy provided complete information on their current inventory but acknowledged there were gaps in the historic data and they could not verify the accuracy or completeness of those data. Neither CPAU nor SVP had information on measured PCBs concentrations in any of their OFEE. SVP, the largest among the three participating utilities, had large uncertainty in their data because of the “unknown” OFEE category. SVP indicated it may be possible in the future to resolve some of these uncertainties. However, within the time frame of this project, SVP provided the data they were able to access. One of the limitations was that compiling these data, especially during the COVID-19 pandemic and shelter-in-place orders, was extremely challenging for the utility staff. This was especially true for data that were limited to hard copies or available only on computer servers located at the electrical utility offices. Under these conditions, SVP was still able to provide useful data on a large portion of their OFEE inventory.

Given the limitations described here, the use of the municipally-owned electrical utility OFEE inventory data to represent OFEE beyond the boundaries of each of the participating systems may not be appropriate. The McKee et al. (2006) TMDL-normalized stormwater load estimate of 1.1 kg/yr remains the best currently available estimate of the PCBs load from electrical utility equipment to the Bay at the start of the PCBs TMDL.

Table 5.1 PCBs mass input to stormwater conveyances in the San Francisco Bay Area from all sources based on the mass balance model presented in McKee et al. (2006). Transformers and Large Capacitors represent the oil-filled electrical utility equipment source.

Source	McKee et al., (2006) PCBs Load (kg/yr)	PCBs Load Normalized to TMDL Stormwater Load (kg/yr)
Watershed Surface Sediment Erosion	30	12
Building Demolition and Remodeling	4.1	1.6
PCBs Still in Use	4	1.5
Bed and Bank Erosion	2.9	1.1
Transformers and Large Capacitors	**2.8**	**1.1**
Atmospheric Deposition	2.8	1.1
Identified Industrial Contaminated Areas	2	0.77
Plasticizers	1.1	0.43
Railway Lines	1.1	0.43
Small Capacitors	0.5	0.19
Auto-Recycling	0.4	0.15
Other Dissipative Uses	0.06	0.023
Lubricants	0	0
Landfills	0	0
Total Stormwater Load (kg/yr)	**52**	**20**

5.3 Data Inputs to Calculate PCBs Loads Reduced

The proposed new Electrical Utilities Management Program identifies actions to document PCBs load reductions that have occurred since the start of the TMDL and will continue to occur in the future due to removal of PCBs-containing OFEE, until all of these equipment have been removed from active service in electrical utility systems in the Bay Area (Action 1). The new Program also identifies actions to document PCBs load reductions due to implementation of enhanced spill response and reporting procedures (Action 2). One of the objectives of the analysis of the municipally-owned electrical utility system OFEE inventory data was to provide information and data inputs that could be used to calculate PCBs loads reduced due to implementation of the Electrical Utilities Management Program. These data inputs are presented below.

5.3.1 Data Inputs to Calculate PCBs Loads Reduced for Action 1

For Action 1 (PCBs-containing equipment removal), the accounting methodology described in the BASMAA Accounting (2020) calculates the PCBs loads reduced by multiplying the PCBs load to stormwater from electric utility equipment by the assumed rate of load reduction achieved over a given period of time due to equipment removals. The data inputs needed for this calculation include the following two terms:

Term 1.1 (L_0) = Estimated annual load of PCBs that enters MS4 from OFEE in the starting year of the time period of interest (i.e., the year that accounting begins, kg/yr).

Term 1.2 (R_1) = Estimated annual average percent of PCBs loads prevented from entering the MS4 due to OFEE removal (percent per year).

Term 1.3 (Y_i) = Number of years in the time period of interest.

The values that are recommended for each of these terms are presented in Table 5.2.

Table 5.2 Recommended values for each of the terms required to account for the PCBs load reductions achieved through implementation of Action 1, removal of PCBs-containing equipment from active service, between 2005 and 2020..

Term	Description	Value	Units	Source
1.1	Annual PCBs Stormwater Load in 2005 (i.e., the assumed load at the start of the PCBs TMDL)	1.1	kg/yr	McKee et. al. (2006)
1.2	Annual average % of loads prevented from entering MS4 due to equipment removals.	1.3 to 4.8 (average = 2.3)	%	Section 4.2.3 (this report)
1.3	Number of years in the time period of interest.	varies	years	N/A

For Term 1.1 the estimated PCBs load of 1.1 kg/yr in 2005 (described in Section 5.2) is the recommended starting value for the annual load of PCBs to stormwater at the start of the PCBs TMDL. This value is currently the best available estimate of PCBs loads to the Bay from electrical utility equipment at that time.

For Term 1.2, the recommended value for the annual average percent of PCBs prevented from entering the MS4 due to OFEE removal ranges from 1.3 % to 4.8 % per year, with an average value of 2.3 % per year (Table 5.2). These values represent the annual average equipment removal rates for the participating municipally-owned electrical utilities presented in Section 4.2.3. These annual average equipment removal rates were calculated based on the mass of oil in pre-1985 OFEE that was removed from service between 2002 and 2019. Use of these values for Term 1.2 assumes the rate of load reduction achieved over the time period of interest is approximately equivalent to the equipment removal rate achieved during that same time period. Further, these values also assume the equipment removal rates for the municipally-owned electrical utilities (Section 4.2.3) reasonably represent the equipment removal rates at other Bay Area electrical utilities (i.e., PG&E). As a check on these assumptions, the load reduction rate between 1990 and 2005 based on the estimate in the McKee et al (2006) mass balance models presented in section 3.4 was compared with the equipment removal rates calculated for municipally-owned electrical utilities that were reported in Section 4.2.3.

The McKee et al. (2006) mass balance models provide PCBs stormwater load estimates for electrical utilities in 2005, and during the peak period of PCBs production and use (1950 – 1990). Based on these estimates, the PCBs load to stormwater from OFEE in 2005 was 65% lower than the average annual load in1990. That equates to a PCBs load reduction of 4.33%

per year during the fifteen-year period between 1990 and 2005. This annual average PCBs load reduction rate compares well with the equipment removal rates at the participating municipally-owned electrical utilities reported in Section 4.2.3. This finding supports the assumption that the equipment removal rates at the participating municipally-owned electrical utilities reasonably approximate the load reduction rates over time. This finding further supports the assumption that most of this load reduction was likely the result of the removal and proper disposal of PCBs-containing OFEE. As described in Section 3.3, during the late 1980s and 1990s, electrical utilities implemented voluntary equipment replacement programs specifically designed to remove PCBs-containing OFEE. Past statements provided to the Regional Water Board by PG&E support the assertion that the majority of PCBs-filled equipment had been replaced by the early 2000’s (PG&E 2000). Additional removals have continued to occur, albeit at a slower pace, due to routine maintenance programs that replace older electrical equipment that is more likely to contain PCBs with newer equipment that does not contain PCBs. Information provided to the Regional Water Board by PG&E on maintenance records from their Emeryville processing facility supports this assertion (PG&E 2000). Those data indicate that in 1999, approximately 10% of the 22,000 pieces of OFEE that were dismantled and disposed of at the Emeryville site had PCBs at concentrations at or above 50 ppm. This information further supports the assertion that a large mass of PCBs that were in use during the peak period have since been removed. However, this information also indicates there are still large numbers of equipment that contain PCBs at high concentrations in active service across the Bay Area. Although no information was provided on the percent of equipment that contained PCBs at lower concentrations (i.e., below 50 ppm), equipment with these lower concentrations are also potential sources to stormwater. Current spill reports in Cal OES records further corroborate that PCBs-containing equipment are still in use across the Bay Area, both at concentrations above and below 50 ppm (see Section 3.4.1).

The value for Term 1.3 will vary, depending on the number of years during the time period of interest. For example, to calculate the PCBs loads that have already been reduced due to equipment removals since the start of the PCBs TMDL and the current date (i.e., between 2005 and 2020), the value for Term 1.3 is 15 years.

Assuming the annual average PCBs-containing equipment removal rate remains constant over time, then the current (2020) and future stormwater loads of PCBs from electrical equipment can be estimated along with the associated timeframe to achieve removal of all PCBs-containing equipment. The results are presented in Table 5.3. The calculation starts with the assumed TMDL baseline load of 1.1 kg/yr, multiplied by the annual average load reduction rates presented in Table 5.2 and the 15-year period since the TMDL baseline load estimates in 2005. The results of this calculation demonstrate PCBs loads to stormwater have been reduced by **0.215 kg/yr to 0.792 kg/yr (average = 0.380 kg/yr)**. The resulting Bay Area PCBs stormwater loads from electrical equipment in 2020 ranges from 0.308 kg/yr to 0.886 kg/yr (average = 0.721 kg/yr). Based on these current loading estimates, it will take between 20 and 80 years before all of the PCBs-containing OFEE in the Bay Area have been removed from service.

Table 5.3 Estimated PCBs loads to Stormwater from PCBs-containing oil-filled electrical equipment (OFEE) in the San Francisco Bay Area in 2005 and 2020, based on assumed load reduction rates, and the additional time before all PCBs-containing OFEE are removed from active service.

Equipment Removal Scenario	Estimated PCBs Load to Stormwater in 2005 (kg/yr)	Average Load Reduction Rate per Year (%/year)	Estimated PCBs Loads Reduced since 2005 (kg/yr)	Estimated PCBs Load to Stormwater in 2020 (kg/yr)	Time to Remove all PCBs-containing OFEE from active service (Years)
Low Reduction Rate	1.1	1.3%	0.215	0.886	77
Average Reduction Rate	1.1	2.3%	0.380	0.721	43
High Reduction Rate	1.1	4.8%	0.792	0.308	21

5.3.2 Data Inputs to Calculate PCBs Loads Reduced for Action 2

PCBs loads reduced due to enhanced spill cleanup and reporting (Action 2) can be calculated by multiplying the current annual mass of PCBs released to MS4s due to spills by an enhanced cleanup efficiency rate. The data inputs needed for this calculation include the following 3 terms:

Term 2.1(M_{sp}) = Average annual mass of PCBs released in spills (kg/yr).

Term 2.2 (SW_i) = Estimated percent of spilled PCBs mass that enters the MS4 without the enhanced spill cleanup and reporting protocols.

Term 2.3 (E_f) = Efficiency of the enhanced spill cleanup and reporting protocols to reduce spilled PCBs released to MS4s (percent).

The recommended values for each of the terms above are presented in Table 5.4.

Table 5.4 Recommended values for each of the terms required to account for the PCBs load reductions achieved through implementation of Action 2, enhanced spill cleanup and reporting.

Term	Value	Units	Source
2.1	2.3	kg/yr	Section 5.3.2 (this report)
2.2	1	%	McKee et. al. (2006)
2.3	10	%	Section 5.3.2 (this report)
	25		
	50		

The values in Table 5.4 were developed as described here. First, the ten most recent years of Cal OES spill reports for OFEE in the Bay Area from the 1993-2017 reports discussed in

Section 3.4.1 were reviewed. Between 2008 and 2017, a total of 507 spills of electrical equipment oils were reported. The reports document the total volume of oil spilled as approximately 24,300 gallons. However, most of the reports provided limited or no information on PCBs concentrations. Nearly 50% of the reports identified the PCBs concentration as unknown, and 40% of the reports identified PCBs concentrations as < 50 ppm based on equipment labels. Only 9% of the reports provided information on measured PCBs concentrations in the spilled oils. The reported concentrations spanned a range from 1 ppm up to 720 ppm, with an average of 110 ppm. Given the limited data on concentrations of PCBs in the spilled oils, the mass of PCBs released in these spills is uncertain. Using the average measured PCBs concentration of 110 mg/kg, the average annual mass of PCBs released in spills was calculated as 0.9 kg/yr. However, not all spills are reported to Cal OES. Review of internal PG&E spill reports that were provided to the Regional Water Board for a 7-year period from 1994 to 2000 (PG&E 2000) showed that only 40% of the spills identified in internal records had also been reported to Cal OES during that time period. For the spills not reported to Cal OES, ~30% had measured PCBs concentrations ranging from 1 ppm to 700 ppm, with an average of 113 ppm. Based on this information, the Cal OES reports between 2008 and 2017 represent only 40% of spills, and accordingly increase the estimated total mass of PCBs released during spills to 2.3 kg/yr.

Applying the McKee et al. (2006) assumption that 99% of PCBs released during spills are successfully cleaned, and 1% remain in the environment, then 0.023 kg/yr of spilled PCBs remain in the environment and available for removal in stormwater. Enhanced cleanup protocols that increase the cleaning efficiency by 10%, 25%, and 50% would result in additional removal of between **0.002 and 0.012 kg/yr** of PCBs. These estimates are summarized in Table 5.5. This project did not identify any additional information that could be used to further refine or improve the data inputs shown in Table 5.4 that were used to calculate the potential load reductions due to implementation of enhanced cleanup protocols shown in Table 5.5.

Table 5.5 Estimated annual PCBs load reduction for implementing enhanced spill response and reporting for oil-filled electrical equipment (Action 2).

Scenario	Annual Mass of PCBs released in spills (kg/yr)	Current cleanup efficiency	Current PCBs Load to Stormwater due to spills (kg/yr)	Assumed Improved Cleanup Protocol Efficiency	Annual Load Reduction Due to Improved Cleanup Protocol (kg/yr)
Low	2.3	99%	0.023	10%	0.002
Mid	2.3	99%	0.023	25%	0.006
High	2.3	99%	0.023	50%	0.012

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APPENDIX F
Load Reduction Credit for PCBs in Roadway and Storm Drain Infrastructure Management Program

F.1 BACKGROUND

The BASMAA study *Evaluation of PCBs in Caulk and Sealants in Public Roadway and Storm Drain Infrastructure* (BASMAA, 2018) sampled caulk and sealant materials from public roadway and storm drain infrastructure around the Bay Area. The overall approach to the sampling program was to work cooperatively with multiple Bay Area municipal agencies to identify public right-of-way locations where PCBs were potentially used in caulk or sealant applications on roadway and storm drain infrastructure. These locations were identified primarily based on the time period that the infrastructure was originally constructed and/or repaired, with a focus on the 1970's - the most recent time period PCBs were still in widespread use. The project team collected 54 caulk or sealant samples from public infrastructure in these locations; 11 of these were collected from concrete bridges or overpasses. The Project Team then reviewed the information collected about each sample to determine how to group the samples for compositing prior to PCBs analysis. A total of 20 composite samples were then analyzed for PCBs concentrations. Ten of these composites were associated with concrete roadways, sidewalks, or bridges.

F.2 TOTAL ESTIMATED PCBS LOAD IN OLDER BRIDGES

The U.S. Department of Transportation Federal Highway Administration National Bridge Inventory (USDOT, 2019) was used to estimate the total potential PCBs load contained in older bridges located within the jurisdictions subject to the MRP.

F.2.1 Equations Used to Estimate PCBs Load

The equation used to estimate the total PCBs load contained in bridges built and/or reconstructed prior to 1981 within the jurisdictions subject to the MRP is as follows:

$$\text{Total Load}_{\text{PCBs, Bridges}} = \text{Density}_{\text{sealant}} * \text{Concentration}_{\text{PCBs}} * \sum \text{Volume}_{\text{sealant, bridges}}$$

Where:

$\text{Density}_{\text{sealant}}$ = average sealant density [kg/m^3]

$\text{Concentration}_{\text{PCBs}}$ = empirically derived concentration of PCBs [mg/kg]

$\sum\text{Volume}_{\text{sealant, bridges}}$ = Volume of sealant in all applicable bridges [m^3]

The volume of joint sealant was calculated using an assumed cross-section of sealant, multiplied by the assumed length of applied sealant:

$$\text{Volume}_{\text{sealant, bridges}} = \text{Cross-Section}_{\text{sealant}} * \text{Length}_{\text{sealant}}$$

Where:

$\text{Cross-Section}_{\text{sealant}}$ = Cross-section of applied sealant

$\text{Length}_{\text{sealant}}$ = Length of applied sealant

F.2.2 Data Used to Estimate Load

Data used to estimate load were obtained from BASMAA, 2018; a study of Bay Bridge sealant summarized by Hardeep Takhar of the California Department of Transportation (Caltrans) in 2013; and bridge dimensional information available from the National Bridge Inventory (USDOT, 2019). A summary of the data inputs is provided in Table F-1 below.

Table F-1: Bridge Load Calculation Data Inputs

Input	Result	Units	Source
Density of Sealant	1,100	kg/m^3	Takhar, 2013
Cross-Section of Sealant	1	square inch	Caltrans, 2007
PCBs Concentration	184	mg/kg	See Section 2.2.1

The derivation of the representative concentration of PCBs in sealant applied to bridges is described below.

F.2.2.1 <u>PCBs Concentration</u>

In order to compute a reasonable estimate of the expected PCBs concentration in caulking material in bridges in the MRP area, a data set consisting of 20 composite samples from BASMAA (2018) and four grab samples from the demolition of the Bay Bridge (Takhar, 2013) was analyzed.

Of the 20 BASMAA composite samples, 10 were identified as representative of caulking used on bridges based on the location from which the samples were taken (i.e., five of the composite samples were taken from bridges and five were from concrete roadway surfaces, sidewalks, and curbs and gutters). The remaining composite samples were judged to be non-representative, as they were taken from storm drain structures, asphalt roadways, metal pipes, and electrical utility poles and boxes. Table F-2 below summarizes the BASMAA study results for the concrete roadway, sidewalk, and bridge composite samples (BASMAA, 2018). Table F-3 summarizes the Bay Bridge caulk measurements (Takhar, 2013).

Table F-2: Sample Descriptions and PCBs Concentrations for Roadway and Bridge Composite Samples from the BASMAA Regional Infrastructure Caulk and Sealant Sampling Program (BASMAA, 2018)

Composite ID	Total PCBs (mg/kg)	Type of Structure(s) Sampled	Caulk/Sealant Application	Sample Appearance (Color/ Texture)	# of samples in composite	Sample ID's in composite	Structure Construction Date
A	4,967	Concrete Bridge	Caulk between expansion joints	Black Pliable Foam	2	10	1960-70's
						13	<1960
B	4,150	Concrete Bridge	Caulk between expansion joints	Black Pliable	3	9	1960-70's
						30	1960-70's
						31	<1960

Composite ID	Total PCBs (mg/kg)	Type of Structure(s) Sampled	Caulk/Sealant Application	Sample Appearance (Color/ Texture)	# of samples in composite	Sample ID's in composite	Structure Construction Date
C	0.78	Concrete Bridge	Caulk between expansion joints	Brown Fibrous	2	20	1960-70's
						26	1960-70's
D	0.70	Concrete Bridge	Sealant between concrete surfaces or between concrete and wood surface	Black Hard/Brittle	3	27	<1960
						29	1960-70's
						32	<1960
E	ND	Concrete Roadway Surface	Caulk between expansion joints	Black Hard/Brittle	5	35	<1980
						36	<1980
						37	<1980
						38	<1980
						39	<1980
F	ND	Concrete Sidewalk	Caulk between expansion joints	Black Hard/Brittle	3	2	<1960
						7	<1960
						46	<1980
G	ND	Concrete Sidewalk	Caulk between joints	Brown Fibrous	2	16	1960-70's
						17	1960-70's
H	ND	Concrete Sidewalk /Curb/Gutter	Caulk between joints	White/Gray Hard/Brittle or Pliable	3	1	<1980
						8	1960-70's
						18	1960-70's
I	0.06	Concrete Sidewalk /Curb/Gutter	Crack Sealant	White Hard/Brittle or White Pliable	2	23	<1980
						24	<1980
S	2.5	Concrete Bridge	Prefabricated joint filler	Black Pliable	1	12	<1960

A photo log of the samples taken from concrete bridges is provided in Attachment 1.

Table F-3: Concentrations of PCBs in Caulks Measured from the Bay Bridge

Description	Result (mg/kg)
PCBs Concentration (Bay Bridge Upper Roadway Sample)	1.01
PCBs Concentration (Bay Bridge Upper Roadway Sample)	1.65
PCBs Concentration (Bay Bridge Upper Roadway Sample)	0.705
PCBs Concentration (Bay Bridge Roadway Barrier Wall)	3.71
Bay Bridge Average Concentration	1.77

Source: Takhar, 2013

The complete dataset (i.e., results summarized in Table F-2 and F-3 and other non-representative samples) contains 10 non-detect (all in the BASMAA (2018) dataset) and 14 detected values.

After removing the 10 data points considered unrepresentative of bridges, the representative dataset contains 4 non-detect and 10 detected values (i.e., Table F-2 and Table F-3 summarized values). For the purposes of this analysis, both the complete and the presumed representative subset of the PCBs-in-caulk datasets were analyzed independently.

The non-detect values were imputed using a regression-on-order statistics method prior to estimating summary statistics using a maximum likelihood estimation approach as described in the sections below.

F.2.2.2 Handling Censored (Non-Detect) Results

Since estimation of common descriptive statistics of censored datasets can be heavily biased with simply substituted values, a robust regression-on-order statistics (ROS) method, as described by Helsel and Cohn (1988), was utilized to provide probabilistic estimates of non-detects (NDs). When applying the ROS method, ND values are imputed based on their plotting positions relative to the probability distribution estimated from the detected data. Imputed values are always less than their detection limits, but if the dataset includes multiple detection limits, some imputed values may be larger than some of the detected values. For the PCBs-in-caulk dataset, method detection limits (MDLs) for individual samples were not reported, but an overall MDL of 0.05 μg/kg was included in the BASMAA report and NDs are only reported for samples when every individual congener was not detected.

Maximum Likelihood Estimation

The lognormal probability distribution is often used to represent positively skewed contaminant concentrations (Singh et al., 1997). As such, the PCBs-in-caulking dataset has been assumed to arise from a population that is lognormally distributed, which implies that the standard deviation is proportional to the mean and the data are bounded by zero. A random variable, x, is said to be lognormally distributed if the distribution of $y = \ln(x)$ is normally distributed with a mean, μ_y, and variance, σ_y^2. The mathematical equation for lognormal distribution is:

$$f_x(x) = \frac{1}{\sqrt{2\pi}\sigma x} \exp\left[-\frac{1}{2}\left(\frac{lnx-\mu}{\sigma}\right)^2\right] \quad x > 0 \qquad \textbf{Equation 1}$$

Where:

- μ is mean of the untransformed random variable x,
- σ^2 is the variance of the untransformed random variable x, and
- x is the variable of interest.

The lognormal distribution parameters of x are related to the normal parameters of y with the following equations:

$$\mu_x = \exp\left(\mu_y + 0.5\sigma_y^2\right) \qquad \textbf{Equation 2}$$

$$\sigma_x{}^2 = \mu\sqrt{\exp(\sigma_y^2) - 1} \qquad \textbf{Equation 3}$$

When a dataset is a random sample from a lognormal distribution, the Maximum Likelihood Estimate (MLE) of the parameter, μ_y, is simply the sample mean of the log-transformed data

(Singh et al., 1997). Similarly, the MLE of the parameter, σ_y^2, is the sample variance of the log-transformed data. However, for small sample datasets with a few extreme values, such as the PCB-in-caulk dataset, severe transformation bias can occur when estimating the arithmetic mean, μ_x, and arithmetic standard deviation, σ_x. Because of this, an alternative method for computing the expected value is needed as described below.

Advancing the assumption that the sample data arise from a lognormal distribution, a probability weighted mean can be computed as:

$$\hat{\mu}_x = \frac{\sum_{i=1}^{n}(x_i * w_i)}{\sum_{i=1}^{n} w_i} \qquad \textbf{Equation 4}$$

Where:

- $\hat{\mu}_x$ is probability-weighted mean of the untransformed random variable x;
- x_i is the ith sample value; and
- w_i is weight of the ith sample value, which is assumed equal to the probability of occurrence, $p(x_i)$, and can be computed by fitting the data to a lognormal probability density function (PDF).

The lognormal PDF can be constructed by computing the theoretical percentiles and plotting against the probability of a standard lognormal PDF. Any percentile, P_k, of x can be computed using the parameters of y as follows:

$$P_k = \exp(\mu_y + z_k\sigma_y) \qquad \textbf{Equation 5}$$

Where:

- z_k is the kth percentiles of the standard normal distribution.

Results and Conclusions

As stated above, the available data was evaluated in two separate dataset configurations:

1. All data including the potentially unrepresentative values (*N = 24)*
2. Roadway and bridge-only data excluding the potentially unrepresentative values (*N = 14)*.

In both configurations, lognormal distributions were fit to datasets where the non-detect values had been imputed with ROS. Figure F-1 below shows lognormal probability plots along with a best-fit line demonstrating the lognormality of the data.

Table F-4 provides summary statistics after applying ROS to the datasets. As shown, the data mean and data median are significantly different, which again supports the lognormal distribution assumption. The arithmetic mean values computed from Equation 2, however, are unrealistic considering the values are larger than any of the sample values – this is a result of transformation bias. The probability weighted mean values are believed to be the most accurate representation of the central tendency of PCBs in caulk for bridges in the MRP area based on the two datasets because this adjusts for the likely probability of occurrence of the extreme values observed in the data while preserving all sample data in the calculation.

Figure F-2 and Figure F-3 show the PDFs of the best-fit lognormal distributions. Each observed or imputed value drawn along the PDF is used to indicate the probabilities of occurrence, which were used to determine the weights for the probability weighted mean values.

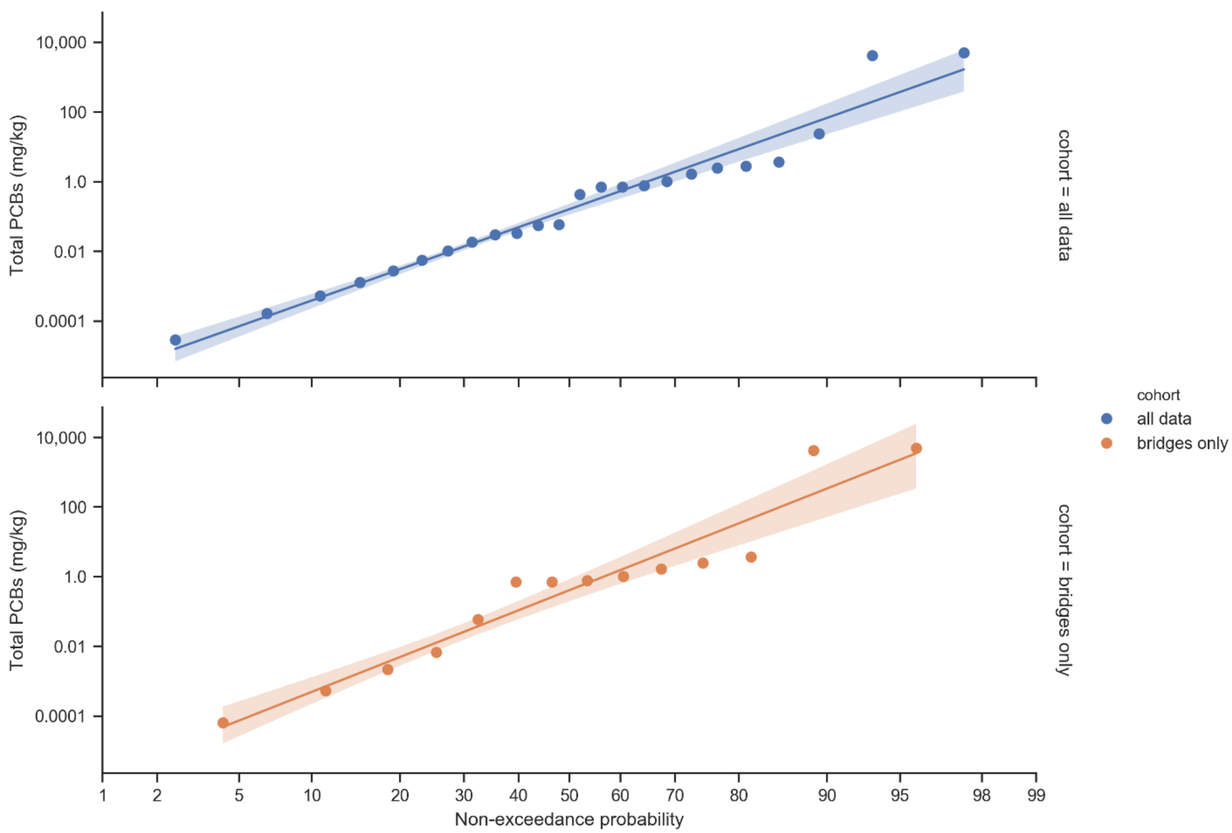

Figure F-1 - Lognormal probability plots. The shaded bands indicate the 95% confidence interval around the best-fit lines.

Table F-4: Summary Statistics

Statistic	Dataset	
	All Data	Roadway/Bridge Only
Sample Count (Total; NDs)	24; 10	14; 4
Data Mean, mg/kg	381	652
Data Standard Deviation, mg/kg	1292	1663
Data Median, mg/kg	0.25	0.74
Lognormal Mean (μy)	-1.82	-0.891
Lognormal Standard Deviation(σy)	4.57	5.02
Arithmetic Mean (μx), mg/kg	8,927	334,514
Probability Weighted Mean ($\hat{\mu}_x$), mg/kg	49.5	184

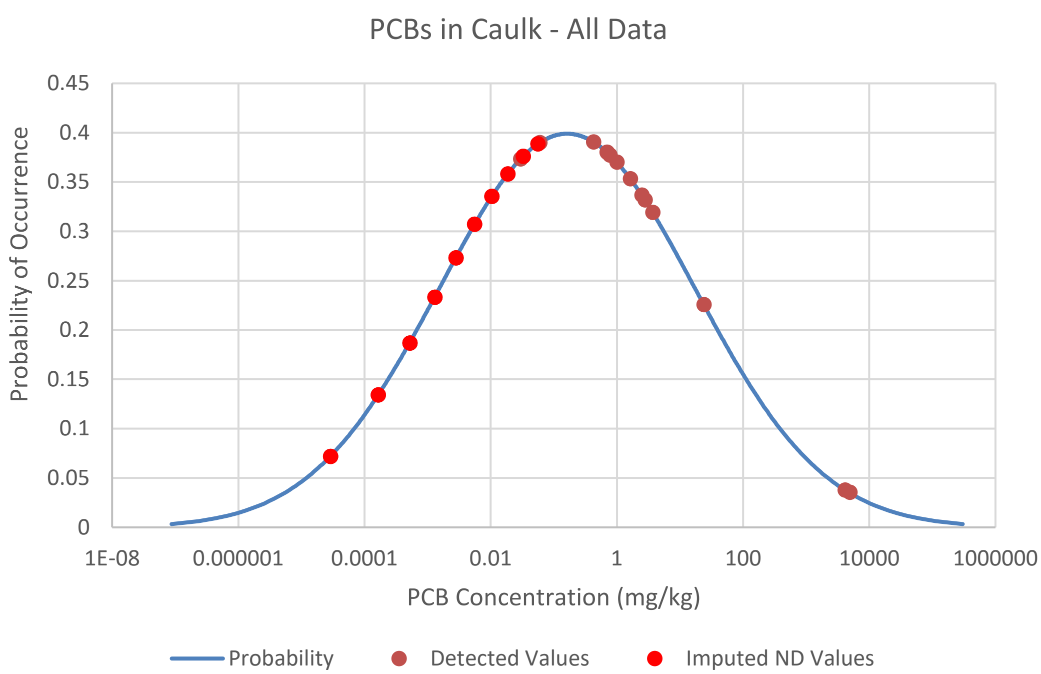

Figure F-2: Lognormal distribution plot for all available Total PCBs data, showing the weights of the detected and imputed values

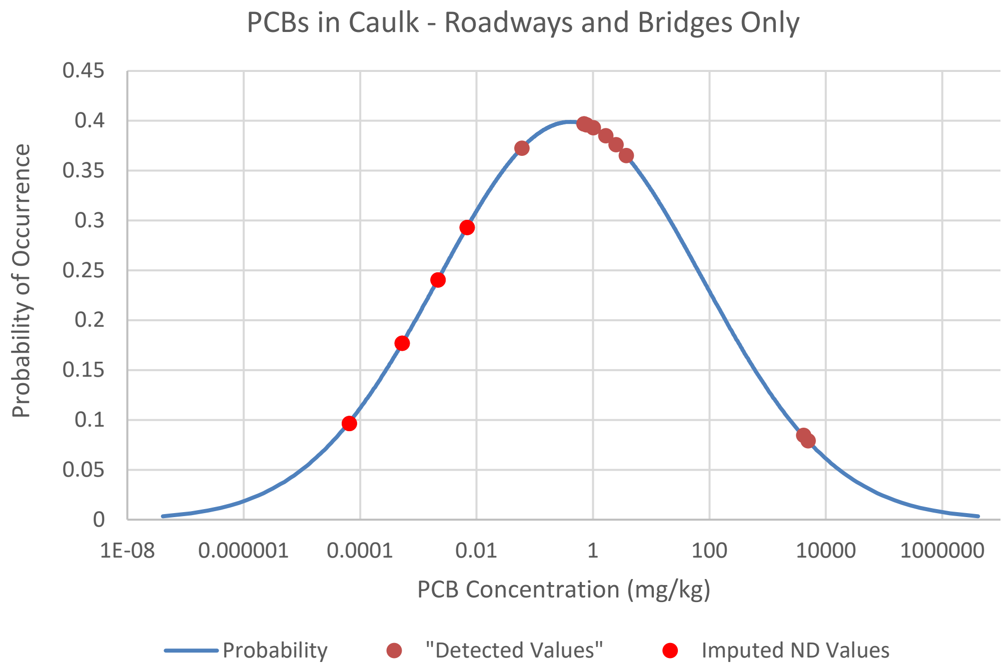

Figure 3: Lognormal distribution plot for Total PCBs data from roadways and bridges only, showing the weights of the detected and imputed values

F.2.2.2 Length of Applied Sealant

While it is evident from the BASMAA (2018) study photos that sealant may be applied to many concrete connections within any given bridge, this estimate focuses on the locations most exposed to weather and traffic and therefore most likely to leach into the environment. The sealant application locations of focus in this study include the bridge expansion joints (e.g., at connections between bridge spans), and the longitudinal seam between the bridge deck and the sidewalk and/or bridge side rail.

The federal bridge database used for this analysis contains information about dimensions of bridges located within the MRP jurisdictions. The length of sealant used to calculate total potential PCBs mass was estimated using database values as follows:

$$Length_{sealant,\ joints} = (N_{span} + 1) * Width_{deck}$$

Where:

N_{span} = The number of bridge spans

$Width_{deck}$ = Bridge deck width

Assuming there are seams along either side of the bridge at the sidewalk or wall, the longitudinal seam was calculated as:

$$Length_{sealant,\ longitudinal\ seam} = 2 * Length_{bridge}$$

F.2.3 Total Estimated PCBs Load in Bridges

A summary of the total calculated loads for bridges within the MRP coverage boundary, built and/or reconstructed prior to 1981, and specific bridge types[11], per the Nation Bridge Inventory, is provided in Table F-5.

Table F-5: Total Calculated Loads for Bridges within the MRP Area, Built and/or Reconstructed Prior to 1981

County	Total Sealant PCBs Mass - Joints Only (kg)	Total Sealant PCBs Mass - Joints and Longitudinal Seal (kg)	Number of Bridges
Alameda	3.8	11.2	340
Contra Costa	1.7	7.3	277
San Mateo	2.5	7.2	254
Santa Clara	3.7	10.1	473
Solano	0.9	3.2	133
Total	**12.6**	**39.0**	**1,477**

The average mass of PCBs in MRP bridges with the characteristics described, based on the calculation, is approximately 8.5 grams, accounting for joint sealant only, and 26 grams, accounting for both joint and longitudinal sealant.

F.3 LONG TERM LOAD REDUCTION ESTIMATE

F.3.1 Methodology

To estimate the load reduction associated with long-term bridge or expansion joint replacement, it is assumed that an ongoing PCBs release rate from bridge joints is mitigated through bridge joint maintenance and whole bridge replacement projects. The load reduction estimation is based on the assumption that PCBs in caulk are leaching from bridge joints and longitudinal seals over their lifetime. When that PCBs-containing caulk is replaced or removed through maintenance or replacement projects, the source of PCBs release is removed, and the associated annual released load is also removed. PCBs leaching from the material could occur through incremental wear or through larger damage (e.g., pieces of caulk torn out) over the lifetime of the caulk.

While volumetric or mass-based losses of joint seals over time were not found in literature, publications that describe joint maintenance and failure were reviewed to justify the assumption of leaching over time. Compression and strip seal type joints, which could potentially be expected to consist of PCBs-containing material, have an expected lifetime of 8 to 16 years, according to a survey conducted for an NCHRP study on bridge joints (NCHRP, 2016). Despite this recommended lifetime, an extrapolated rate of joint replacement in the Bay Area demonstrates that joints are being replaced at a much lower frequency. According to three

[11] 0 – Other; 01 – Slab; 02 – Stringer/Multi-beam or Girder; 03 – Girder and Floorbeam System; 04 – Tee Beam; 05 – Box Beam or Girders – Multiple; or 06 – Box Beam or Girders – Single or Spread.

Permittee preventative maintenance plans available on Caltrans' Highway Bridge Program funding website (Caltrans, 2019), approximately 3% of bridges meeting the characteristics described above are scheduled for joint replacement over the next five-year funding period. An additional 1.5% of bridges are scheduled for replacement over the same five-year period (presumptively replacing the joints). At this rate, replacing the joints via joint maintenance or bridge replacement projects in all 1,477 bridges would take over 110 years.

The concept that older, likely PCBs-containing joints persist in the older MRP bridges is borne out through the findings of the BASMAA (2018) study, which found very high PCBs concentrations in composite samples from a random selection of representative bridge infrastructure. This outcome is also consistent with a finding from a 2003 NCHRP report (NCHRP, 2003), which found through interviews with transportation agencies that "agencies indicated that they tend not to respond to joint problems unless there is a safety hazard or when the deck is being rehabilitated or replaced. Other than reactive efforts, joint repair and rehabilitation, in most agencies, is associated with deck rehabilitation." Additionally, while guidance documents typically define joint replacement needs in terms of visual degradation of the joint, along with other factors, the NCHRP study stated that agencies often defined failure of a deck joint as leakage, physical damage, or traffic hazard. These conditions could be taken to interpret that agencies are only replacing severely damaged or degraded joints (NCHRP, 2003).

Older joints could be considered more likely to leach into the environment, as the sealant material accumulates damage over time. Typical types of joint seal damage described by the Wyoming Department of Transportation, Aeronautics Division Airport Pavement Management Program (2020) include: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack or absence of sealant in the joint. These damage types are also consistent with those described in NCHRP (2016). Most of these damage types either directly refer to stripping of the sealant from the joint or create a condition in which the sealant is more likely to be released from the joint when subjected to traffic loads (i.e., conditions such as extrusion, hardening/becoming more brittle, loss of bond). Examples of damaged joint seals from this source are provided in Attachment 2.

F.3.2 Load Reduction Calculation

Lacking a literature-based release rate of sealant over time, two potential annual release rates are provided for the load reduction calculation. Based on the assumption that the joint seal may become degraded over time, it is possible that the sealant releases little during the initial operation period and more as the joint sealant ages. Another possible release pathway is through leaching into surrounding concrete and subsequent degradation of the concrete. Two potential average annual release rates (i.e., average over the life of the seal) were assumed to calculate an estimated load reduction from removing the joint seal – 1% and 0.5%. These average annual release rates were applied to the estimated mass for the 1,477 bridges meeting the identified age criteria (Table F-6). These releases would be eliminated through removal of the joint seal through joint replacement or bridge replacement.

Table F-6: Long-Term Load Reduction (i.e., Replacement of PCBs-Containing Joints in All Older Bridges)

County	Total Sealant PCBs Load Reduced - Joints Only (g/year)		Total Sealant PCBs Load Reduced - Joints and Longitudinal Seal (g/year)	
	1% annual loss rate over life	0.5% annual loss rate over life	1% annual loss rate over life	0.5% annual loss rate over life
Alameda	38	19	112	56
Contra Costa	17	8	73	37
San Mateo	25	12	72	36
Santa Clara	37	19	101	50
Solano	9	5	32	16
Total	126	63	390	195

This is the assumed load reduction by 2080, based on the assumption that all older joints will be removed/replaced within 100 years of installation (this is consistent with recent Caltrans replacement frequency calculated above).

F.4 REFERENCES

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Attachment 1: BASMAA Bridge Sample Photos

Composite A

Composite B

Composite S

Composite C

Composite D

Attachment 2: Images of Joint Seal Damage

Joint sealant damage is any condition that enables soil or rocks to accumulate in the joints or allows significant infiltration of water. Accumulation of incompressible materials prevents the slabs from expanding and may result in buckling, shattering, or spalling. A pliable joint filler bonded to the edges of the slabs protects the joints from accumulation of materials and also prevents water from seeping down and softening the foundation supporting the slab. Typical types of joint seal damage are: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack of absence of sealant in the joint..

Source: Wyoming Department of Transportation, Aeronautics Division Airport Pavement Management Program (https://www.appliedpavement.com/hosting/wyoming/pavement-inspection/pci-review/distresses-pcc/joint-sealant-damage.html)

Severity	Distress Example	Description
Low		Joint sealer is in generally good condition throughout the sample. Joint seal damage is at low severity if a few of the joints have sealer which has debonded from but is still in contact with the joint edge. This condition exists if a knife blade can be inserted between sealer and joint face without resistance.
Medium		Sealant needs replacement within two years. Joint seal damage is at medium severity if a few of the joints have any of the following conditions: (a) joint sealer is in place, but water access is possible through visible openings no more than 1/8 in (3 mm) wide. If a knife blade cannot be inserted easily between sealer and joint face, this condition does not exist; (b) pumping debris are evident at the joint; (c) joint sealer is oxidized and "lifeless" but pliable (like a rope), and generally fills the joint openings; or (d) vegetation in the joint is obvious, but does not obscure the joint opening.

Severity	Distress Example	Description
High		Joint sealer is in generally poor condition over the entire surveyed sample. Sealant needs immediate replacement. Joint seal damage is at high severity if 10% or more of the joint sealer exceeds limiting criteria listed above, or if 10% or more of sealer is missing.

APPENDIX G

Enhanced Inlet Cleaning Efficiency Factor Data Analysis for Storm Drain Inlets with and without Inlet-based Full Trash Capture Devices

G.1 PURPOSE AND APPROACH

The purpose of this appendix is to document findings of analysis conducted to determine the enhanced efficiency factors (EE_f) for sediment removal associated with enhanced storm drain inlet maintenance, including increasing the frequency of storm drain inlet cleaning, and the use of small (inlet-based) full trash-capture (FTC) devices, that are expected to capture larger amounts of trash, sediment and vegetation. First, the pollutant removal efficiency was calculated for the baseline control measure, which was assumed to be annual cleanout of storm drain inlets without FTC devices. The efficiency factors were then developed for the following enhancements: (1) increased frequency of cleanouts at inlets without FTC devices; and (2) twice yearly cleanouts at inlets with FTC devices.

Based on a review of available literature, there are limited data available on the reductions of pollutants (including sediment) associated with different storm drain inlet maintenance frequencies. No studies were found that assessed the reduction of either PCBs or mercury due to enhanced inlet cleaning frequencies. Two studies in particular, Woodward Clyde (1994) and Caltrans (2003), however evaluated the increase in the removal of material (i.e., sediment, vegetation, and trash) from inlets under different cleaning frequencies. Results from both studies indicated that the annual volume of material removed from inlets increased with cleaning frequency.

The Caltrans (2003) *Drain Inlet Cleaning Efficacy Study* was designed to measure the potential increases in material volume/mass and water quality benefits due to increased inlet cleaning frequencies on freeways. The study was conducted from 1996 through 2000. The volume and mass of material removed under annual, biannual, and three times per year cleaning frequencies at 55 to 90 inlets, depending on the year, were measured.

The Woodward Clyde (1994) *Storm Inlet Pilot Study* was conducted in Alameda County in 1993. This study was also designed to measure the potential increases in material volume and mass due to increased inlet cleaning frequencies. A total of 15 inlets draining residential, industrial, or commercial land uses were monitored. The volume and mass of material removed under annual, biannual, quarterly, and monthly cleaning frequencies were measured.

None of the inlets in the two studies identified above were equipped with FTC devices. To evaluate pollutant reductions associated with cleanouts of storm drain inlets equipped with small FTC devices, a recent study (SCVURPPP, 2016) documented cleanout volumes of materials removed from inlets equipped with FTC devices. The SCVURPPP (2016) *Storm Drain Trash Monitoring and Characterization* study focused on litter/trash, but also removed and measured other debris (defined as sediment and vegetation) from 119 inlets equipped with small FTC devices. These devices typically require cleaning frequencies of at least twice per year. Each of the 119 inlets was initially cleaned at the start of the project. The volume of trash and debris that accumulated within the inlets was removed and measured during two subsequent monitoring events. The accumulation period between each monitoring event ranged from four to five months. The data were used to estimate the annual average volumes of trash and debris captured in each inlet. The annual volume of debris removed was converted to a mass using the average density of debris removed from inlets during the Woodward Clyde (1994) study, which was 38 pounds per cubic foot.

The percent increase of annual mass of debris removed from storm drain inlets during cleanouts, as measured in each of the three studies described above, is presented in Figure G-1. Caltrans removals for inlet cleaning without FTC devices appear to be much greater than removal efficiencies measured during the Woodward Clyde study, and therefore may not be realistic for the purposes of developing conservative efficiency factors for load reduction accounting. The Woodward Clyde study results were used to represent the enhanced efficiency due to increased cleanout frequency of storm drain inlets without FTC devices. The results of the SCVURPPP (2016) study indicate that the use of inlet-based FTC devices, combined with an increased cleaning frequency of twice annually, appears to substantially increase the annual mass of debris that is captured and removed from these storm drain inlets during cleanouts.

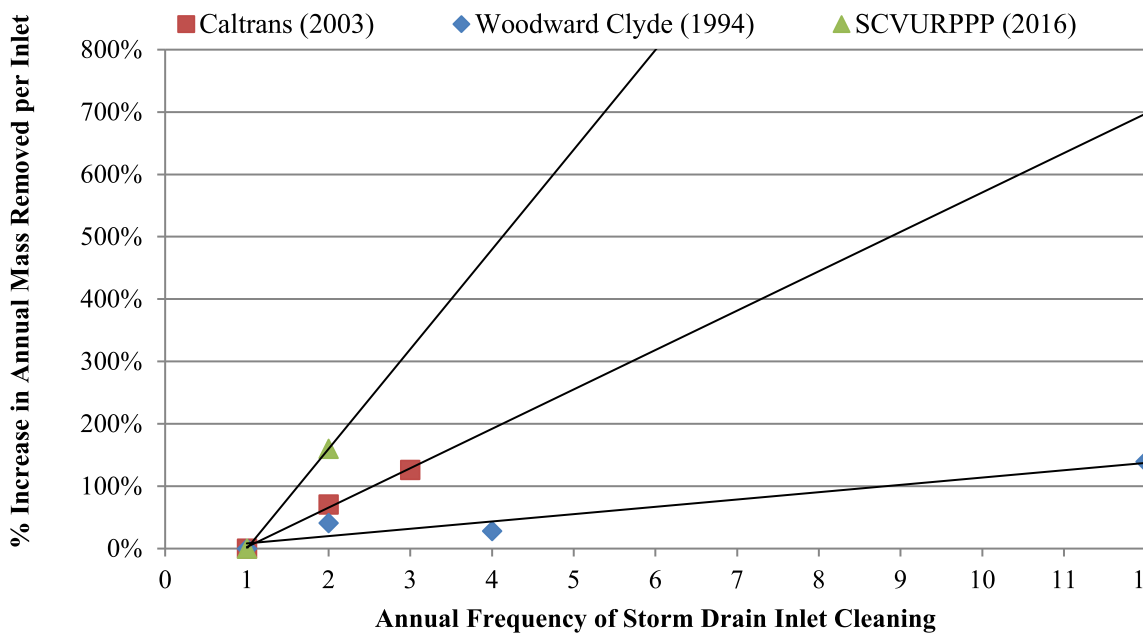

Figure G.1: Reported results of increases in annual mass of debris (e.g., sediment and vegetation) removed as a result of increased cleaning frequency for storm drain inlet with and without small full trash-capture (FTC) devices.

Based on the above findings, Table G-1 presents a conservative estimate of the enhanced efficiency factors for more frequent cleaning of storm drain inlets without FTC devices, and the enhanced efficiency factors for cleaning storm drain inlets equipped with inlet-based FTC devices at least twice per year. For the purposes of load reduction accounting, the method assumes the following:

- Based on an analysis of 36 Alameda County and San Mateo Permittee storm drain inlet cleaning datasets from 1996 through 2009, on average, municipalities clean their inlets once per year (annually);

- Based on the same dataset, an average of 100 kg of material (sediment, vegetation, and litter) is removed from each inlet annually (see descriptive statistics below);

Statistic	Mass (Kg) of Material Removed Annually per Inlet
Maximum	4,049
90th Percentile	476
75th Percentile	284
Mean	268
Geometric Mean	100
Median	91
25th Percentile	41
10th Percentile	21
Minimum	5
# of Municipalities in Dataset	36

- Each inlet (on average) receives drainage from a catchment of 1 acre (BASMAA, 2014), equating to a unit material removal rate of 100 kg per acre per year;
- The mass fraction of material associated with PCBs and mercury yields (i.e., sediment <63um) is approximately 15% on average (McKee et al., 2006);
- The annual suspended sediment load to each inlet is roughly 134 kg per year on average based on the modeled value for Old Urban land use (Paradigm Environmental, 2020, see attachment to Appendix A); and
- Based on the assumptions above, roughly 15 kg of sediment associated with PCBs and mercury is removed from each inlet cleaned on an annual frequency, equating to about a 11% reduction of PCBs and mercury via annual cleaning (i.e., 15 kg / 134 kg). This is the control measure effectiveness of annual cleaning of storm drain inlet without FTC devices.

Assuming the baseline control measure effectiveness for annual cleaning of 11%, data from the studies cited above were used to calculate the enhanced efficiency factors for storm drain inlet cleaning at increasing frequencies for inlets without FTC devices, and twice-yearly cleaning of inlets that have been equipped with small FTC devices, as shown in Table G-1.

Table G-1: Enhanced efficiency factors (EE_f) for increased storm drain inlet cleaning frequencies for storm drain inlets both with and without small full trash-capture (FTC) devices.

		Enhanced Cleaning Frequency for Inlets without FTC devices				Enhanced Cleaning Frequency for Inlets with FTC Devices
		Annually	Biannually	Quarterly	Monthly	Biannually
Original Cleaning Frequency	No Cleaning or New Inlet	0.11	0.16	0.16	0.27	0.29
	Annually		0.05	0.05	0.16	0.18

E.2 References

BASMAA (2014). San Francisco Bay Area Stormwater Trash Generation Rates - Final Technical Report. Bay Area Stormwater Management Agencies Association. Prepared by EOA, Inc. Oakland. June.

Caltrans (2003). Drain Inlet Cleaning Efficacy Study. California Department of Transportation. CTSW-RT-03-057.36.1. June.

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SCVURPPP (2016). Storm Drain Trash Monitoring and Characterization Project. Santa Clara Valley Urban Runoff Pollution Prevention Program. Prepared by EOA, Inc. August.

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APPENDIX H
Enhanced Street Sweeping Efficiency Factors

H.1 DESCRIPTION OF THE ANALYSIS

The Clean Watersheds for Clean Bay (CW4CB)[12] Task 4 pilot projects evaluated enhancements of municipal operation and maintenance activities that remove sediments and associated pollutants, including PCBs and mercury. This objective coincided with Municipal Regional Stormwater NPDES Permit (MRP, Order R2-2009-0074) Provision C.12.d, which required MRP Permittees to evaluate at the pilot scale in five drainages, ways to enhance existing sediment removal and management practices such as municipal street sweeping, curb clearing parking restrictions, inlet cleaning, catch basin cleaning, stream and stormwater conveyance system maintenance, and pump station cleaning via increased effort and/or retrofits. MRP Provision C.12.d also required Permittees to evaluate existing information on high-efficiency street sweepers, with the goal of evaluating the cost-effectiveness of high-efficiency street sweeping relative to reducing pollutant loads.

Appendix B-1 of the CW4CB Final Report summarizes the results of the Task 4 enhanced street sweeping pilot project that occurred in four pilot study areas (two sites in Richmond and one each in San Jose and Sunnyvale). This study entailed collecting monitoring data in each pilot study area representative of the baseline sweeping condition. The monitoring data were then used to calibrate the Windows Source Loading and Management Model (WinSLAMM) to evaluate sediment, PCBs, and mercury in the pilot study areas. Once WinSLAMM calibrated using the pilot study data, it was used to model street sweeping performance in the pilot study areas during the baseline condition for sediment, PCBs, and mercury. WINSLAMM was also used to model the effectiveness of various street sweeping scenarios for the pilot study areas for removing sediment, PCBs, and mercury. The modeled scenarios included (1) different sweeper types, (2) sweeping frequencies, and (3) street roughness values. The modeled scenarios assumed parking controls were in effect.

The results of the scenario analysis are presented in Tables H-1 and H-2 below for PCBs and mercury, respectively.

[12] For more information, see: http://basmaa.org/Clean-Watersheds-for-a-Clean-Bay-Project.

Table H-1: Change in PCBs Mass Removal Efficiency (%) from Initial Street Sweeping Scenario to Final Scenario

				Final Scenario							
			Sweeper Type	Vacuum							
			Street Roughness	Rough	Intermediate	Rough	Intermediate	Rough	Intermediate	Intermediate	Rough
Initial Scenario	**Sweeper Type**	**Street Roughness**	**Frequency**	Once per 4 weeks	Once per 4 weeks	Once per 2 weeks	Once per 2 weeks	Once per week	Once per week	Twice per week	Twice per week
	None	None	None	9.9%	14%	15%	18%	19%	21%	21%	22%
	Vacuum	Intermediate	Once per week	-11%	-7%	-6%	-3%	-2%	0%	0%	1%
		Intermediate	Once per 2 weeks	-8%	-4%	-3%	0%	1%	3%	3%	3%
		Intermediate	Once per 4 weeks	-4%	0%	1%	4%	5%	7%	7%	8%
		Intermediate	Twice per week	-11%	-7%	-6%	-3%	-2%	0%	0%	1%
		Rough	Once per week	-9%	-5%	-4%	-1%	0%	2%	2%	2%
		Rough	Once per 2 weeks	-5%	-1%	0%	3%	4%	6%	6%	6%
		Rough	Once per 4 weeks	0%	4%	5%	8%	9%	11%	11%	12%
		Rough	Twice per week	-12%	-8%	-6%	-3%	-2%	-1%	-1%	0%

Notes:

1. Change in efficiency resulting from change in sweeping scenario shown in red (reduction in efficiency) and blue (increase in efficiency).

Table H-2: Change in Mercury Mass Removal Efficiency (%) from Initial Street Sweeping Scenario to Final Scenario

				Final Scenario							
			Sweeper Type	Vacuum							
			Street Roughness	Rough	Intermediate	Rough	Intermediate	Rough	Intermediate	Intermediate	Rough
Initial Scenario	**Sweeper Type**	**Street Roughness**	**Frequency**	Once per 4 weeks	Once per 4 weeks	Once per 2 weeks	Once per 2 weeks	Once per week	Once per week	Twice per week	Twice per week
	None	None	None	9.1%	10%	10%	10%	10%	11%	11%	11%
	Vacuum	Intermediate	Once per week	-1%	0%	0%	0%	1%	2%	2%	2%
		Intermediate	Once per 2 weeks	0%	0%	0%	0%	1%	2%	2%	2%
		Intermediate	Once per 4 weeks	0%	0%	1%	1%	1%	2%	2%	2%
		Intermediate	Twice per week	-1%	0%	0%	0%	1%	2%	2%	2%
		Rough	Once per week	-2%	-2%	-2%	-2%	-1%	0%	0%	0%
		Rough	Once per 2 weeks	-2%	-2%	-2%	-2%	-1%	0%	0%	0%
		Rough	Once per 4 weeks	-1%	-1%	-1%	-1%	0%	1%	1%	1%
		Rough	Twice per week	-2%	-2%	-2%	-2%	-1%	0%	0%	0%

Notes:

Change in efficiency resulting from change in sweeping scenario shown in red (reduction in efficiency) and blue (increase in efficiency).

APPENDIX I
Large Trash Capture Device Unit Efficiency Factor Data Analysis

I.1 Purpose and Approach

The purpose of this appendix is to document findings of studies and analyses conducted to determine the effectiveness for removing total suspended solids (TSS), PCBs, and mercury by large (non-inlet-based) trash capture devices, including hydrodynamic separator (HDS) units, gross solids removal devices (GSRDs), and baffle boxes. Other types of non-inlet-based trash capture devices, such as trash netting devices and trash booms, are assumed to remove negligible amounts of sediment, PCBs, and mercury, so are not included in this appendix. Inlet-based devices, including inlet baskets and connector pipe screens, are discussed in Appendix G. For the purposes of load reduction accounting, the method assumes that HDS units, GSRDs, and baffle boxes reduce PCBs and mercury concentrations in direct proportion to TSS reduction.

I.2 HDS Units

Percent Removal of TSS. Percent removal of TSS in HDS units was calculated from the BASMAA Clean Watersheds for a Clean Bay (CW4CB) Task 5 Leo Avenue pilot project data (BASMAA 2017a). For this project, a prefabricated Contech HDS unit called the Continuous Deflective Separator (CDS) was retrofitted into the existing storm drain system in the Leo Avenue Watershed in San Jose.

Influent and effluent water quality was sampled at four events as summarized in Table I-1 below. The CDS unit removed an average of 30% of TSS coming into the unit.

Table I-1: Percent Removal of TSS at Leo Ave CDS Unit

Event	Date	Sample Location	TSS (mg/L)	% Removal
1	28-Feb-14	Inflow	110	17%
		Outflow	91	
2	29-Mar-14	Inflow	230	17%
		Outflow	190	
3	31-Oct-14	Inflow	62	88%
		Outflow	7.5	
4	02-Dec-14	Inflow	82	-3%
		Outflow	84.5	
Average				**30%**

The International Stormwater BMP Database (http://bmpdatabase.org/) was evaluated for potentially useful studies. Twenty studies of manufactured devices were identified as useful for analysis. These studies had a total of 334 paired inflow/outflow data points for TSS. Percent removal was calculated for each paired data point and then averaged for the BMP. The results for these studies along with descriptions of land use type and watershed size and imperviousness are presented in Table I-2 below. Average percent removal ranged from -85% (i.e., an increase in TSS concentration in outflow compared to inflow) to 73% and averaged 19% across all studies (including the City of San Jose's Leo Avenue unit).

The dataset was also analyzed by removing BMPs that were treating just roads or highways, parking lots, or college campuses. In this scenario, ten studies remained that had mixed, other, or unknown land use type. The average percent removal of TSS from the BMPs evaluated in this group of studies was slightly higher at 22%.

Table I-2: Percent Removal of TSS for Studies in BMP Database

Site and BMP	Device Model	Land Use Type	Watershed % impervious	Watershed Area (ac)	Average TSS % Removal[1]
OP Soccer Complex: PMSU56_40_40	Contech CDS, Model PMSU56_40_10	Parking lots adjacent to soccer fields.	90	3.98	-85%
NW Birch Place CDS unit: Continuous Deflective Separation unit	CDS Unit	Low Density Residential: 47.4% Office Commercial: 42.2% Multi-Family Residential: 10.3%	--	45.0	-14%
Broadway Outfall: CDS Unit	CDS			132	-6%
University of New Hampshire F3: Continuous Deflective Separation	CDS	College Campus: 100%	100	0.32	-5%
Lake O Sediment Demo: CDS Unit	PSW56_53		--	--	-3%
I-210 / Orcas Ave: Orcas	CDS	Roads/Highway: 100%	100	1.11	-3%
USGS_WI_HSD_DD: Hydrodynamic Settling Device	Downstream Defender®, manufactured by Hydro International.		84	1.90	-1%
I-210 / Filmore Street: Filmore CDS	CDS	Roads/Highway: 100%	100	2.50	2%
University of New Hampshire F2: Environment 21 V2B1	Environment 21 V2B1	College Campus: 100%	100	0.32	5%
University of New Hampshire F1: Vortechnics	Vortechnics	College Campus: 100%	100	0.32	13%
USGS_WI_HSD: HSD	Hydrodynamic Settling Device, Contech	The HSD treats a 0.25-acre deck section of the westbound I–794 freeway	100	0.25	26%
Harrisburg Public Works Yard: PAYardTerreKleene	Terre Kleen	--	90	3.21	28%
SC_StructBMP3: BMP3	Vortechnics	BMP3 is located along the westbound lane of S.C. Highway 802	--	--	29%

Site and BMP	Device Model	Land Use Type	Watershed % impervious	Watershed Area (ac)	Average TSS % Removal[1]
Indian River Lagoon CDS Unit: CDS Unit	CDS	Open Space: 38% Light Industrial: 32% Office Commercial: 19%	11	61.5	30%
Leo Avenue: HDS Unit[2]	Contech CDS	--	--	--	30%
SC_StructBMP1&2: BMP2	CDS Technologies	BMP2 is located along the southbound lane of U.S. Highway 21	100	1.11	39%
University of New Hampshire E1: Aqua Swirl	Aqua Swirl	College Campus: 100%	100	0.99	40%
Timothy Edwards Middle School: Vortechs No 5000	Vortechs	--	80	1.95	45%
VC: VC	Vortcapture	Residential area with lots of organic matter/leaf litter loading	--	--	53%
Marine Village Watershed: VortechsTM Stormwater Treatment System	Vortechs	Office Commercial: 50% Medium Density Residential: 45% Unknown: 5%	95	9.34	72%
NJ Manasquan Bank: NJManasquanCDS	High Efficiency Continuous Deflective Separator (CDS), Model 20_25	--	79	0.89	73%

Notes: -- indicates information was not provided.

1. Based on analysis of paired inflow/outflow results.
2. Leo Ave CW4CB study. Not a BMPDB Study.

The manufacturer's removal efficiency claims and the tested removal efficiencies of six of the BMPs evaluated in the studies were summarized as reported in the Massachusetts Stormwater Technology Evaluation Project (MASTEP) clearinghouse database (Table I-3).

Table I-3: Percent Removal of TSS for Six Manufactured Devices from MASTEP

Product (BMP)	Manufacturer	Manufacturer's Removal Efficiency claim	Tested Removal Efficiency
Aqua-Swirl	Aqua Shield	85%	84-87%
CDS	Contech	70%	65-95%
Vortechs	Contech	35-85%	35-64%
Downstream Defender	Hydro International	90%	70%
V2B1	Environment 21	80%	65%

Product (BMP)	Manufacturer	Manufacturer's Removal Efficiency claim	Tested Removal Efficiency
Terre Kleen	Terre Hill	78%	17-50%
Average[1]			56%

Notes: 1. Average based on low end of reported efficiency range.

Based on the above findings, 20% is a conservative estimate of the average percent removal of TSS by HDS units.

Percent Removal of PCBs and Mercury. To further evaluate the pollutant removal performance of HDS units, BASMAA (2019) conducted a combined monitoring and modeling study in 2017 and 2018 based on the removal of solids captured within HDS unit sumps. The Project collected samples of the solids captured and removed from eight different HDS unit sumps during cleanouts. The solid samples were analyzed for PCBs and mercury concentrations. Maintenance records and construction plans for these HDS units were reviewed to develop estimates of the average volume of solids removed per cleanout and the typical number of cleanouts per year. This information was combined with the measured pollutant concentrations to calculate the annual mass of PCBs and mercury captured in the sumps and removed during cleanouts. Next, the annual pollutant loads discharged from each HDS unit catchment were estimated using two different load calculation methods. Method #1 used the land use-based pollutant yields described in the BASMAA Interim Accounting Methodology (BASMAA 2017b) to estimate catchment loads. Method #2 used the Regional Watershed Spreadsheet Model (RWSM, Wu et al. 2017) to estimate runoff volumes and stormwater concentrations and calculate catchment-specific loads. Finally, HDS unit performance was evaluated for both catchment load estimates by calculating the average annual percent removal of PCBs and mercury due to the annual mass removal of solids from the HDS unit sumps. Results are presented in Table I-4.

For catchment loads calculated using Method #1 (land use-based yields), the median percent PCBs removal across all eight units ranged from 5% to 10%, while the mean ranged from 17% to 28%. For catchment loads calculated using Method #2 (RWSM runoff volume x concentration), the median percent PCBs removal ranged from 15% to 32%, while the mean ranged from 23% to 36%. Variability in removal rates was high between individual units, ranging from almost no removal to 100% removal of the estimated loads. For mercury, across all eight units, the median percent removal for catchment loads calculated using Method #1 (land use-based yields) ranged from 3% to 4%, while the mean ranged from 5% to 8%. For all units under Method #1, the removal rates were lower for mercury than for PCBs. For catchment loads calculated using Method #2 (RWSM runoff volume x concentration) the median removal ranged from 13% to 19%, while the mean ranged from 28% to 35%. Similar to PCBs, removal rates for mercury in individual HDS units were highly variable (Table I-4).

Table I-4. HDS Unit Performance - Annual Percent Removal Calculated for Two Catchment Load Estimates.

HDS Unit ID	PCBs Removal				Mercury Removal			
	Method #1		Method #2		Method #1		Method #2	
	Low	High	Low	High	Low	High	Low	High
1	80%	100%	100%	100%	26%	40%	100%	100%
2	8%	18%	10%	22%	4%	6%	65%	98%
3	4%	9%	21%	45%	2%	3%	8%	12%
4	38%	83%	27%	59%	5%	7%	17%	26%
5	0.06%	0.13%	0.21%	0.46%	0.1%	0.2%	1.1%	1.6%
6	5%	11%	20%	43%	0.01%	0.02%	0.1%	0.2%
7	0.6%	1.4%	0.5%	1.1%	0.06%	0.09%	2%	3%
8	1.4%	3.1%	7%	16%	3%	4%	27%	41%
Median	5%	10%	15%	32%	3%	4%	13%	19%
Mean	17%	28%	23%	36%	5%	8%	28%	35%

The BASMAA study results were highly variable and limited by the small sample size. However, pollutant load reductions achieved by HDS units, on average, approach or even exceed 20%, the value identified as a conservative estimate of TSS removal by HDS units in the analysis presented previously. These results support the continued use of a 20% efficiency factor for calculating the annual average PCBs and mercury loads reduced by HDS units.

I.3 Gross Solids Removal Devices

Caltrans conducted the Gross Solids Removal Devices (GSRDs) Pilot Program to develop and evaluate the performance of non-proprietary, full trash capture devices that could be retrofitted into existing highway drainage systems or incorporated into new highway projects (Sobelman et al.). The GSRD Pilot Program consisted of multiple phases with each phase representing one pilot study. The pilot studies consisted of one or more devices that were developed from concept through design and installation, with two years of pilot testing of overall performance. Five phases were constructed and monitored covering eleven designs. Four general types of GSRDs were developed and studied: linear, inclined screen, baffle box, and v-screen. Of the many configurations tested, the most promising devices, based on considerations of particle capture, clogging, passing design flow, drainage, stage capacity and maintenance requirements, were the Linear Radial (louvered modular well casing), the Inclined Screen (parabolic wedgewire screen) and the Inclined Screen (sloped flat wedge-wire screen). The linear radial and inclined screen devices have been certified by the Los Angeles Regional Water Quality Control Board as being full capture devices. Standard designs were developed for these screen systems that provided the best solids removal performance in the pilot tests.

The results of the first phase of the pilot program, which tested the linear radial and inclined screen devices, are summarized in Table I-5 below.

Table I-5. GSRD Unit Performance Observed by Caltrans (2003)

Device Type	Gross Solids Capture Efficiency by Wet Weight (%)	
	2000 – 2001	2001 – 2002
Linear Radial 1 (I-10)	100[1]	100
Linear Radial 2 (I-210)	97	87
Linear Radial 2 (I-5)	94	100
Inclined Screen 1 (SR-170)	100	100
Inclined Screen 2 (I-210)	83[2]	100
Inclined Screen 2 (US-101)	86[2]	73[2]
Average	**93%**	**93%**

Notes:

1 Material collected in the bypass bag was presumed to be windblown.

2 GSRD overflowed. Gross solids escaped the overflow structure and were unaccounted for. As a result, the calculated capture efficiencies are overstated.

Source: Caltrans, 2003.

Based on the above findings and assuming that the mass fraction of material associated with PCBs and mercury yields (i.e., sediment <63 µm) is approximately 15% on average of the captured debris (McKee et al., 2006), then the percent removal of PCBs and mercury by GSRDs is approximately 14% (93% gross solids removal x 15% of captured debris that is associated with PCBs and mercury).

I.4 Baffle Boxes

Baffle boxes are subsurface rectangular vaults that are placed inline in the stormwater system to reduce pollutant loadings by capturing sediments, gross solids, and associated pollutants. Treatment mechanisms typically include filtration, hydrodynamic separation, and adsorption. Several different types of baffle boxes are available commercially and have footprints that vary in size from approximately 10 square feet to over 200 square feet. These subsurface vaults are commonly subdivided into a series of chambers by vertical baffles that interrupt the stormwater flow and promote capture of suspended particles by sedimentation.

The treatment effectiveness of the Nutrient Separating Baffle Box ® (NSBB) by Suntree Technologies has been recently evaluated by the manufacturer to assess the suspended sediment removal efficiency under controlled conditions (Suntree Technologies, 2018). The NSBB contains an additional basket screen that is located above the top of the chamber baffles. The screen captures floating and suspended solids and holds them out of the water column during nonflow periods (Suntree Technologies, 2018). The performance evaluation was conducted on the NSBB model 3-6-72, which has an effective sedimentation area (i.e., footprint) of 18 square feet (6 feet by 3 feet). Additional details of this and other models can be found on the Suntree Technologies, Inc. website. Influent suspended sediment concentrations were measured at 200 mg/L with a median particle size of 100 µm; influent flow rates ranged from 0.35 to 1.75 cfs. Resulting annualized TSS removal efficiency ranged from approximately 51 to 68 percent, with a weighted annualized TSS removal efficiency of 62.9%. The annualized TSS removal efficiency for different flow rates is shown in Table I-6 below.

Table I-6: Nutrient Separating Baffle Box (Model 3-6-72) TSS Removal Efficiency

Mean Flow Rate Tested (cfs)	Measured Removal Efficiency	Annual Weighting Factor	Weighted Removal Efficiency
0.35	67.9%	0.25	16.98%
0.70	65.8%	0.3	19.74%
1.05	63.1%	0.2	12.62%
1.40	56.4%	0.15	8.46%
1.75	50.6%	0.1	5.06%
Weighted Annualized TSS Removal Efficiency			**62.9%**

Source: Suntree Technologies, Inc., 2018

A similar baffle box, the Debris Separating Baffle Box, is sold by Bio Clean. It is assumed that the unit processes in the two proprietary baffle box devices are similar, thus the expected removal efficiencies would be the same.

Based on the above study and assuming that the mass fraction of material associated with PCBs and mercury yields (i.e., sediment <63 µm) is approximately 63% of the captured sediment, then the percent removal of PCBs and mercury by baffle boxes is approximately 40% (63% TSS removal with a median particle size of 100 µm x 63% of material that is associated with PCBs and mercury). Given the limited data available on the effectiveness of baffle boxes in reducing PCBs and mercury, however, and the similarity of the baffle box to the mechanistic removal processes used in HDS systems, a conservative estimate is being used for PCB and mercury reduction for baffle boxes. The pollutant removal efficiency that will be used for baffle boxes is 20%, the same as HDS systems.

I.5 References

Bay Area Stormwater Management Agencies Association (BASMAA), 2017a. Clean Watersheds for a Clean Bay Project Report, Final Report May 2017. Bay Area Stormwater Management Agencies Association. Accessed at: http://basmaa.org/Clean-Watersheds-for-a-Clean-Bay-Project.

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APPENDIX E

ACCWP RAA Modeling Report & Peer Review

REASONABLE ASSURANCE ANALYSIS PEER REVIEW PACKAGE

Alameda Countywide Clean Water Program and Contra Costa Clean Water Program

Municipal Regional Stormwater Permit
NPDES Permit No. CAS612008
Order No. R2-2015-0049

Prepared by

Geosyntec Consultants, Inc.

1111 Broadway, 6th Floor

Oakland, California 94607

Project Numbers: LA0542 and LA0540

December 11, 2019

Table of Contents

Peer Review Matrix: Attached File:
RAA_PeerReviewMatrix_ACCWP_CCCWP_120419_RTC.xlsx

PR-1: Peer Review Component Descriptions

0. INTRODUCTION

This Peer Review package is intended to provide descriptions and back-up references associated with each model component identified for review in the Peer Review for SF Bay PCBs and Mercury Reasonable Assurance Analyses (RAAs) for Green (Stormwater) Infrastructure Instructions/Guidance to Peer Reviewers (Peer Review Instructions) and "FINAL_RAA_PeerReviewMatrix_Template_8_1_19.xlsx" (Peer Review Matrix), provided by BASMAA (2019). The descriptions herein are repeated or expanded from those included in the Peer Review Matrix, which includes fields that are requested to be populated by the peer reviewer. The descriptions provide summary information regarding the model inputs and/or reference other reports and documentation attached to this Peer Review Package that provide more extensive detail.

The Alameda Countywide Clean Water Program Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions Report (ACCWP, 2018) [PR-2] and the Contra Costa Clean Water Program Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions Report (CCCWP, 2018) [PR-3] (i.e., GI Quantitative Relationship Reports) are frequently referenced throughout this Peer Review package. Note that both GI Quantitative Relationship Reports are very similar, as the same RAA modeling methodology was used for both Counties; often reading one of the two reports will provide the referenced information.

1. BASELINE CONDITION MODELING

1.A Model Selection

Refer to Section 2.1 and 2.2 of the GI Quantitative Relationship Reports [PR-2; PR-3] for an overview of the model selected for the CCCWP and ACCWP RAA baseline condition models.

Rationale: The approach used for modeling hydrology is to use a hydrologic response unit (HRU) approach. An HRU is a unique combination of land surface features (imperviousness, underlying soil characteristics, slope, etc.) which is expected to give a consistent runoff response to rainfall, no matter where that unique combination is found. The HRU approach involves modeling thousands of combinations of land surface features present within the area of analysis, for a generic unit area drainage catchment, and then storing these results in a database. These HRU results can been be scaled geospatially across the entire area of analysis without developing a detailed hydrologic model and this method is appropriate for estimating average annual runoff and pollutant loading. This method is consistent with the *Bay Area RAA Guidance Document* (BASMAA, 2017).

Spatial/Temporal Resolution: Generic HRUs, characterized by varying the values of specific identified parameters within a defined range, are modeled using USEPA's Stormwater Management Model (SWMM). Continuous simulation HRU models are run on an hourly timestep for the identified baseline period of record (water year [WY] 2000 – 2009). An average annual runoff volume per acre is obtained for each HRU. The average annual runoff volume per acre associated with a specific HRU can then be multiplied by the area represented by that HRU within the entire area for analysis. The resulting volumes associated with each represented HRU within the area of analysis can then be added together to estimate the total average annual runoff volume.

Alignment with Information/Needs/Data Available: The HRU approach is consistent with the *Bay Area RAA Guidance Document* and the precision of the methods used to develop the TMDLs. As the TMDL WLA and MRP requirements are in terms of annual load reduction, event-specific modeling results are not needed. Additionally, long-term continuous simulation modeling allows for effects such as those relating to antecedent conditions (e.g., soil saturation resulting from back-to-back storms) to be incorporated into the results. Finally, detailed storm drain information is not currently available for all areas within the area of analysis, so it is not possible to develop a detailed routing model at this time.

A flow chart representing the Baseline Loading Model is provided:

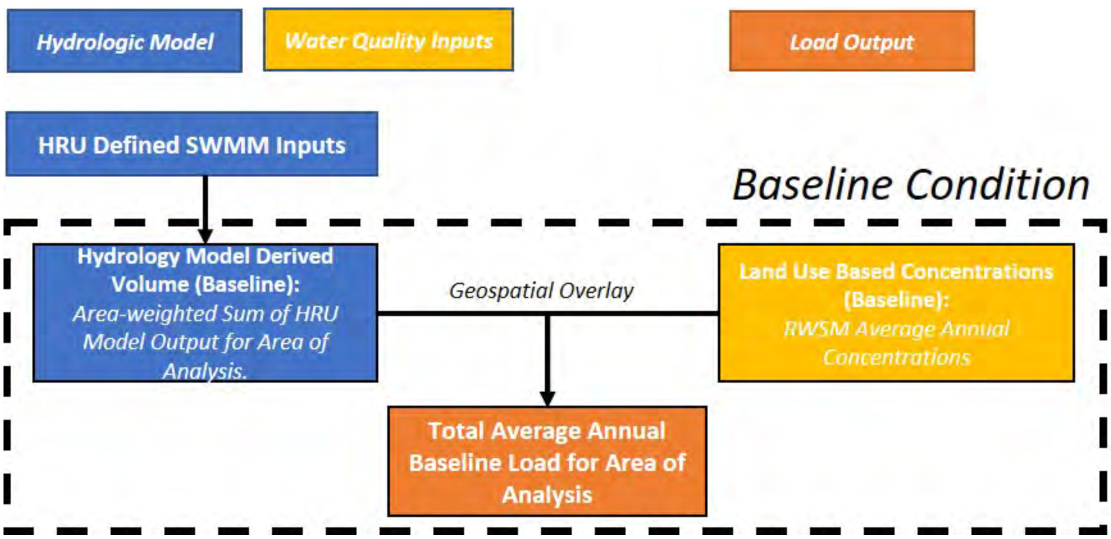

Figure 1-1: Baseline Condition Model Flow Chart

1.B Geographic Area of Analysis

The geographic area of analysis includes the entire area within Contra Costa and Alameda Counties, as shown in Exhibits 1 through 6 of the GI Quantitative Relationship Reports [PR-2; PR-3]. Note that the Counties are not labeled in PR-2 and PR-3; Contra Costa County is north of Alameda County. While the entire area is modeled, baseline results are ultimately subdivided based on regulatory (i.e., MRP covered areas vs. Phase II and Industrial General Permit covered areas) and jurisdictional boundaries. Modeled areas and jurisdictional boundaries are shown in Figure PR-1A and Figure PR-1B for Alameda and Contra Costa Counties, respectively.

1.C Period of Time

Baseline period of record is WY 2000 – 2009 (i.e., October 1, 1999 through September 30, 2009), as documented in the GI Quantitative Relationship Reports [PR-2; PR-3], see section 3.1.1. As included in the RAA Guidance Document (BASMAA, 2017), “For the purposes of RAA analyses, the baseline period for both PCBs and mercury analyses is recommended to be water years 2000

– 2009 (for long-term continuous simulation), or water year 2002 (for representative year simulation). These baseline period options are generally representative of the period during which much of the data were collected for mercury and PCBs.” Also see additional detail in item 1.I “Meteorology”.

1.D Flows and Pollutant Load Simulation

Section 2.2 of the GI Quantitative Relationship Reports [PR-2; PR-3] describes flow and pollutant load simulation. Refer to Section 2.2.2. of the GI Quantitative Relationship Reports [PR-2; PR-3] specifically for information regarding the water quality model.

1.E Rainfall/Runoff Processes

Rainfall/runoff processes are modeled using USEPA SWMM Version 5.1. A summary of the computational methods employed within SWMM to simulate runoff is provided in Section 3.4 of the USEPA SWMM Manual (USEPA, 2015) [PR-4].

1.F Pollutant Loading Variability

Land use variability is accounted for using SFEI’s Regional Watershed Spreadsheet Model (RWSM) output, as described in the “Regional Watershed Spreadsheet Model Version 1.0 Results Summary” memo (Geosyntec, 2019a), provided by BASMAA. The results were developed using Wu et al (2017). Also refer to Section 2.2.2. of the GI Quantitative Relationship Reports [PR-2; PR-3] specifically for information regarding the water quality model.

1.G Watershed Characteristics

See Section 3.1.1 and Table 3 of the GI Quantitative Relationship Reports [PR-2; PR-3] for the watershed characteristics that were varied and the ranges of inputs; also see Table 1.H-1 below, which summarizes SWMM parameter input values.

1.H Watershed Hydrology Parameterization

The output of each uniquely parameterized HRU is matched to those geospatial areas with the unique combination of parameter values, as identified with geospatial data. The geospatial data used to develop the ranges of parameters and match geospatial area to the unique HRUs are shown in Exhibits 1 through 6 of the GI Quantitative Relationship Reports [PR-2; PR-3]. Geospatial data sources associated with each parameter are provided within the text of Section 3.1.1 of the reports (also refer to footnotes). Table 1.H-1 below provides SWMM input values not summarized in Table 3 of the GI Quantitative Relationship Reports [PR-2; PR-3].

Table 1.H-1: SWMM Parameter Input Values

Parameter	Description & Source[1]	Unit	Value
Infiltration Model	Controls how infiltration of rainfall into the upper soil zone of subcatchments is modeled in SWMM.	--	Green Ampt, see parameters in Table 1.H-2
Routing Method	Determines the method used to route flows through the system in SWMM.	--	Kinematic Wave
Reporting Time Step	*Model time step input.*	Minutes	5
Dry Weather Time Step	*Model time step input.*	Minutes	240
Wet Weather Time Step	*Model time step input.*	Minutes	5
Routing Time Step	*Model time step input.*	Seconds	30
Flow Path Length	Overland flow path length assumed for sheet flow runoff. Selected default inputs represent typical overland sheet flow path lengths for undeveloped/open space areas and developed/urban areas, respectively.	Feet	500 (Existing non-developed condition; development footprint)
			250 (Proposed developed condition; development footprint)
N-Imperv	Manning's roughness for impervious or pervious surfaces.	--	0.012 (corresponds to smooth concrete)
N-Perv		--	0.25 (corresponds to dense grass)
Dstore-Imperv	Depth of depression storage (i.e., the maximum surface storage provided by ponding, surface wetting, and interception) for impervious and pervious surfaces.	Inches	0.1, 0.075, and 0.05 for slopes of 3%, 7.5%, and 15%, respectively
Dstore-Perv		Inches	0.2, 0.15, and 0.1 for slopes of 3%, 7.5%, and 15%, respectively
%Zero-Imperv	Percent of the impervious area with no depression storage.	%	25
Groundwater	--	-	Not simulated
Snowmelt	--	-	Not simulated

[1] Source of description and selected model input values obtained from USEPA, 2015 unless otherwise indicated.

Soil parameter model input values are provided in Table 1.H-2.

Table 1.H-2: Green-Ampt Soil Parameters

Hydrologic Soil Group	Prevalent Soil Texture Class	Saturated Soil Conductivity (in/hr)		Suction Head[1] (in)	IMD[1] (in/in)
		Existing Condition[1]	Developed Condition[2]		
A	Sand, Loamy Sand	2.5	1.88	2.61	0.34
B	Sandy Loam	0.3	0.23	6.02	0.22
C	Loam	0.15	0.11	10.4	0.13
D	Clay	0.1	0.08	7.4	0.17

[1] HSG A and B estimated based on texture class from Rawls, et al., (1983); HSG C and D estimated through calibration, see the "Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation" Memo [PR-5].

[2] Determined based on an assumption of 25% reduction of conductivity due to compaction.

The varied input characteristics resulted in a total of 586 unique pervious HRU models, which are defined by the combinations of rainfall zone, ET zone, HSG, and slope. Additionally, a total of 74 impervious HRU types were modeled, defined by the combinations of rainfall zone, ET zone, and slope. The top 15 most dominant pervious HRU's account for about 50% of the study area. The two most dominant pervious HRU types represent 14% of the total study area, and are both <1% developed (developed includes urbanized and agricultural areas).

1.I Meteorology

Rainfall files used for hydrologic model are documented in Table 1 and Evaporation data inputs are documented in Table 2 of the GI Quantitative Relationship Reports [PR-2; PR-3].

1.J Drainage System Representation

Storm drain system routing was not modeled, as an HRU approach was used, as described above. However, large-scale drainage routing was accounted for when conducting model calibration and validation. Model calibration and validation is further described in the "Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation Memo" (Geosyntec, 2019b) [PR-5].

1.K Model Calibration

Refer to the "Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation Memo" (Geosyntec, 2019b) [PR-5].

1.L Model Validation

Refer to the "Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation Memo" (Geosyntec, 2019b) [PR-5].

2. GREEN INFRASTRUCTURE LOAD REDUCTION MODELING

A flow chart showing the development and components of the future condition model is provided.

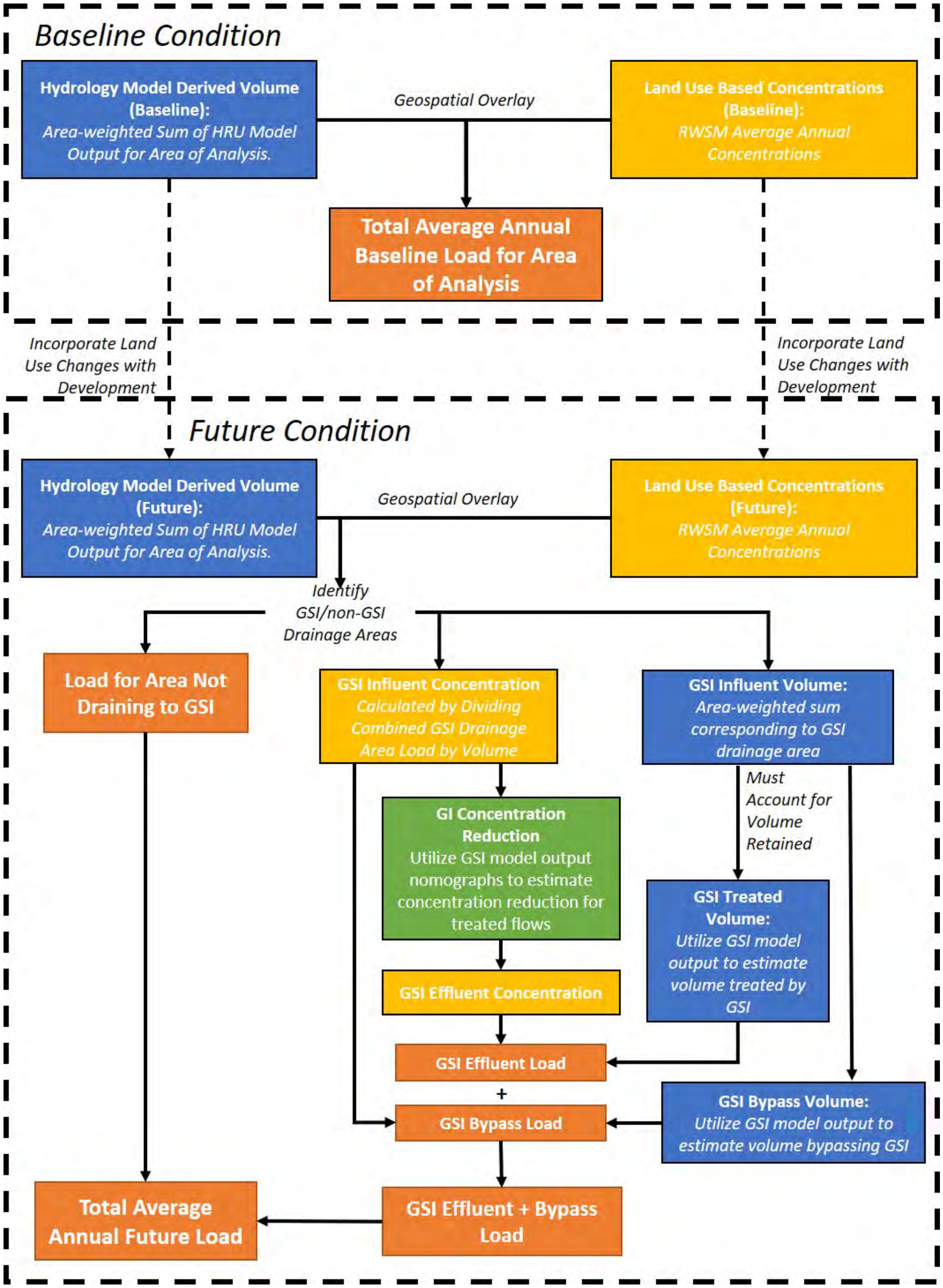

Figure 2-1: Future Condition Model Flow Chart

2.A Load Reduction Goal

The mercury load reduction required to be achieved through GI by 2040 per the MRP is 10 kg/yr MRP area-wide, or 3.1 kg/yr for Alameda County, and 1.7 kg/yr for Contra Costa County.

Calculations were conducted to develop the PCBs load reduction goals as described in the *Bay Area RAA Guidance Document* (BASMAA, 2017). The calculation methodology is summarized below.

2.A.1 TMDL Attainment Load Reduction (2030)

LR_{goal} = Baseline – WLA (kg/yr)

Where:

LR_{goal} = The load reduction goal (kg/yr)

Baseline = The baseline pollutant loading as calculated through the RAA

WLA = The population-based wasteload allocation

The TMDL population-based wasteload allocations for Alameda County and Contra Costa County are provided Table 2.A-1.

Table 2.A-1:TMDL Population-Based Wasteload Allocations for Alameda County and Contra Costa County

Stormwater Improvement Goal	PCBs (kg/yr)
Alameda County	0.5
Contra Costa County	0.3

2.A.2 RAA Calculated Baseline Load - PCBs

The results of the RAA baseline modeling are presented for Alameda County and for Contra Costa County in Table 2.A-2, below. The baseline countywide load used to establish the PCBs load reduction goal for the Permittee area is shown in bold. Refer to the RAA Guidance Document Section 2 and Section 3.5 (BASMAA, 2017) for details on the calculation methodology.

Table 2.A-2: RAA Model Baseline Loading Estimates – PCBs

RWQCB Region	Above/Below Dam	Permit	Baseline Load Alameda County (kg/yr)	Baseline Load Contra Costa County (kg/yr)
Region 2	**Below Dam**	**MRP**	**3.6**	**1.6**
		NPDES	0.2	0.8
		Phase 2	0.5	<0.1
	Above Dam	MRP	<0.1	<0.1
		NPDES	0.0	<0.1
		Phase 2	0.0	0.0
Region 5	Below Dam	MRP	<0.1	0.1
		NPDES	0.0	<0.1
		Phase 2	0.0	<0.1
	Above Dam	MRP	0.0	<0.1
		NPDES	0.0	0.0
		Phase 2	0.0	0.0
		Total	4.3	2.6

Using the preliminary RAA-calculated baseline load[1] of PCBs for each County, the load reduction goal is estimated to be 3.1 kg/yr for Alameda County and 1.3 kg/yr for Contra Costa County.

2.A.3 MRP Load Reduction through GI by 2040

The PCBs load reduction required to be achieved through GI by 2040 (i.e., 3 kg/yr MRP area-wide or 0.9 kg/yr for Alameda County and 0.5 kg/yr for Contra Costa County) must be adjusted to reflect the RAA-calculated baseline load (i.e., 3.6 kg/yr and 1.6 kg/yr for Alameda and Contra Costa Counties, respectively). The MRP load reduction requirement for GI for all permittees (3 kg/yr) represents 20.8% of the overall required TMDL load reduction. Therefore, the adjusted countywide load reduction through GI can be calculated as:

$$LR_{MRP,\ GI,\ 2040} = LR_{goal} * 20.8\%$$

The adjusted countywide PCBs load reduction goal through GI by 2040 are calculated as summarized in Table 2.A-3.

Table 2.A-3: Adjusted Countywide PCBs Load Reduction Goals through GI by 2040

County	PCBs Load Reduction Goal through GI (kg/yr)
Alameda County	0.6
Contra Costa County	0.3

2.B Overall Methodology to Account for GI Load Reductions

Refer to Sections 2.3, 3.2, and 3.3 of the GI Quantitative Relationship Reports [PR-2; PR-3].

[1] As of the May 2019 draft model run; the final baseline load is subject to change per peer review comments

2.C Load Reduction Calculation Method

The load reduction is calculated based on the difference between the baseline PCBs and mercury load and the PCBs and mercury load accounting for GI. The baseline model produces a PCBs and mercury load for each County, along with a "load production" GIS layer that estimates the load corresponding with each parcel and ROW segment within each County (note that individual parcel loadings should be considered representative of the 'average tendency' of loading for similar parcels). This "load production" layer is revised for the future condition based on land use changes, then combined in GIS with planned green infrastructure projects to estimate the resulting parcel load, assuming standard bioretention treatment. The estimated load reduced per acre using this approach is calculated and presented in Sections 4 and 5 of the GI Quantitative Relationship Reports [PR-2; PR-3].

The sum of the revised and treated parcel loads, across each County, provides the load under the future estimated condition. This future estimated load is then subtracted from the baseline estimated load to estimate loads reduced.

3. REFERENCES

ACCWP, 2018. Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions. September 28.

BASMAA, 2017. Bay Area Reasonable Assurance Analysis Guidance Document. Prepared by Geosyntec Consultants and Paradigm Environmental. June.

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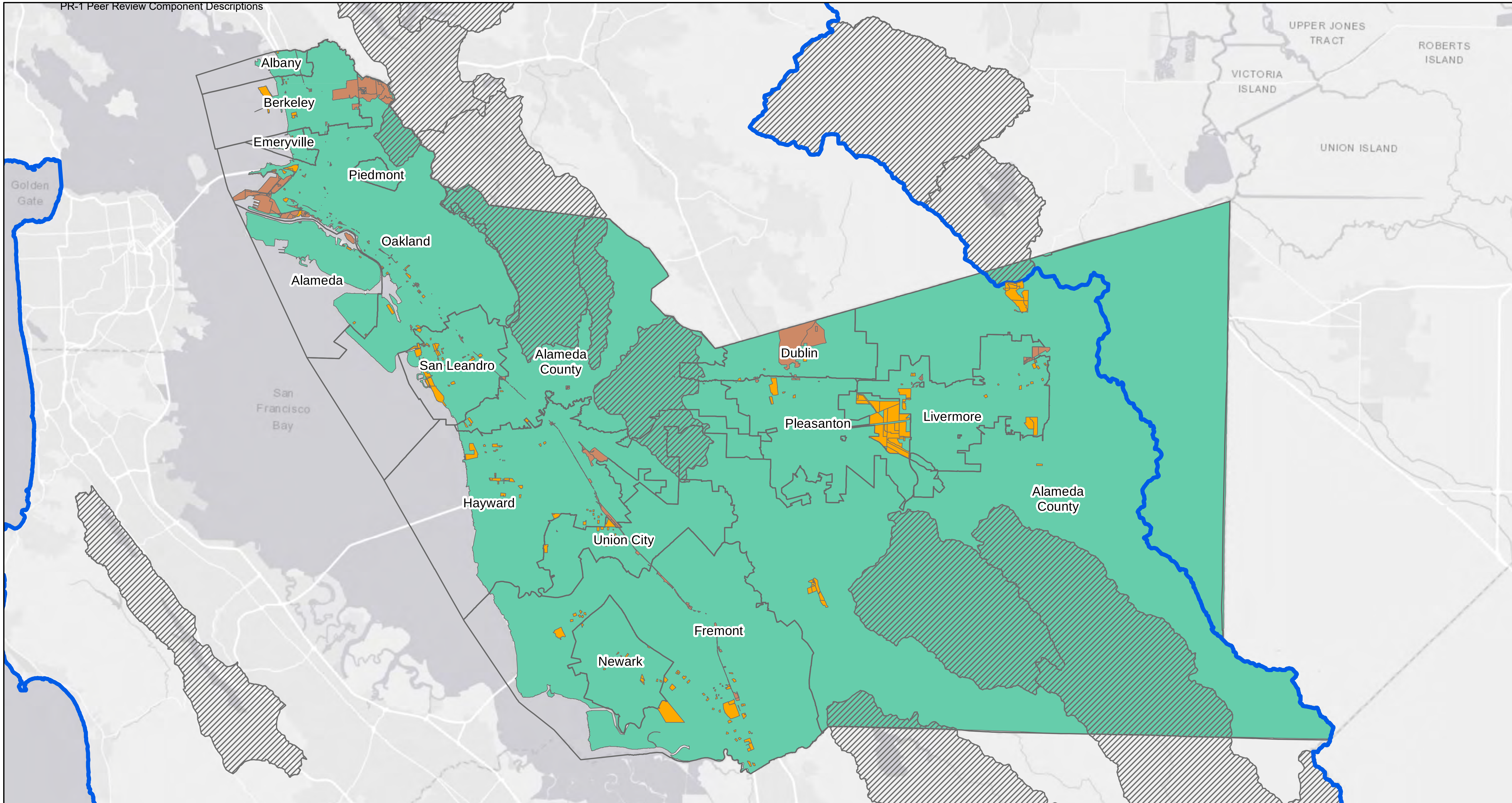
CCCWP, 2018. Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions. August 22.

Geosyntec Consultants, 2019a. Regional Watershed Spreadsheet Model Version 1.0 Results Summary Memorandum. April 30.

Geosyntec Consultants, 2019b. Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation Memorandum. August 7.

USEPA, 2015. Storm Water Management Model User's Manual Version 5.1. September.

Wu, J., Gilbreath, A.N., McKee, L.J., 2017. Regional Watershed Spreadsheet Model (RWSM): Year 6 Progress Report. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 811. San Francisco Estuary Institute, Richmond, California.



Legend

- Municipalities
- Area Above Dams[1]
- RWQCB Region 2 Boundary
- RWQCB Region 5

Stormwater Permit Coverage

- Individual Stormwater NPDES Permit
- Phase II General Stormwater Permit Water Quality Order 2013-0001-DWQ
- MS4

Notes:
1. Areas above Dams are not included in baseline load estimated for Municipal Regional Stormwater Permittees. Areas covered under different stormwater permits (i.e., individual NPDES permits, Phase II permit) are not included in baseline load estimates for Municipal Regional Stormwater Permittees.

Alameda County RAA
Baseline Loading Analysis Area

Alameda County
California

Geosyntec consultants

Oakland | October 2019

Figure 1A

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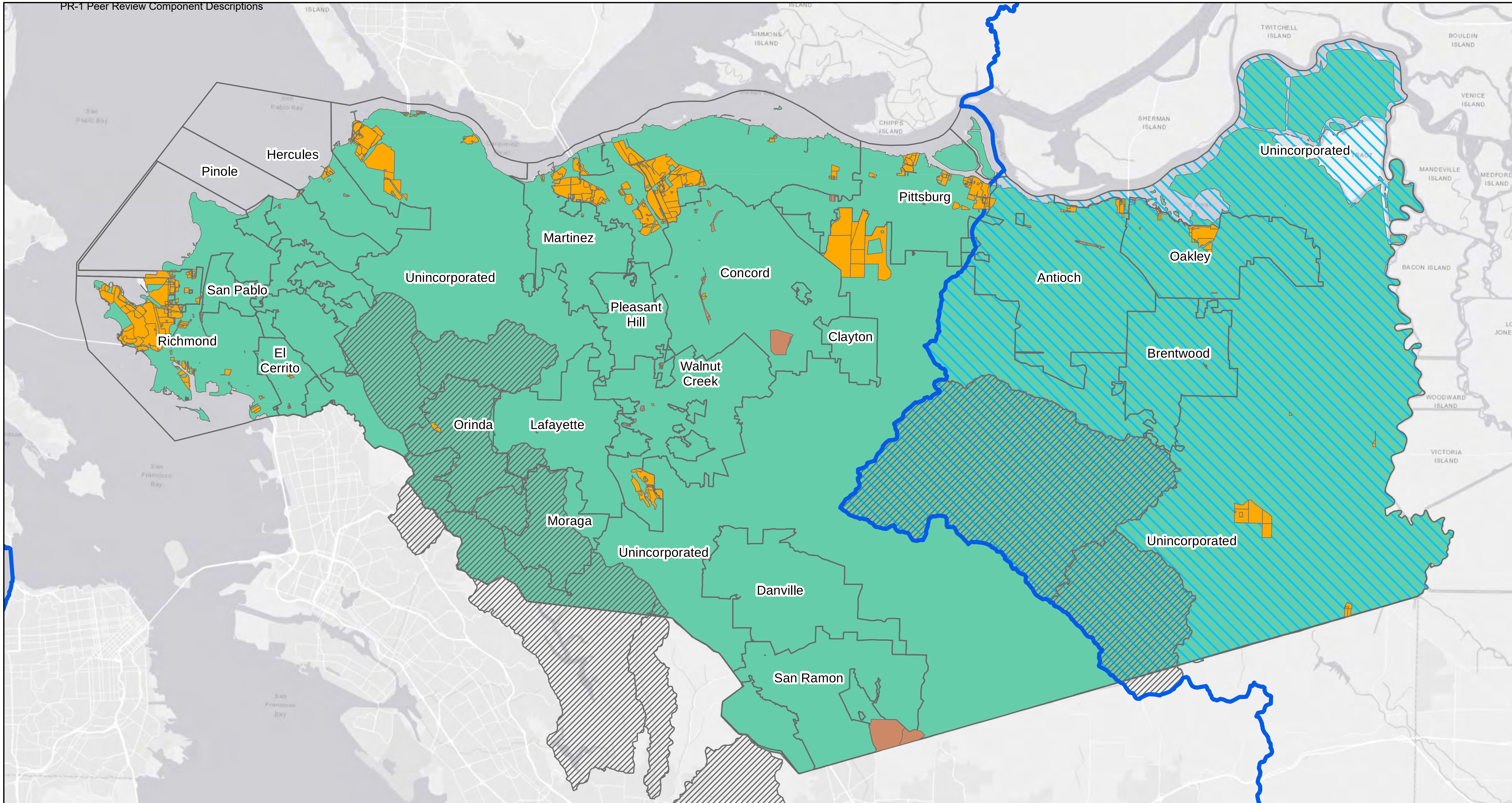

Legend

- Municipalities
- Area Above Dams[1]
- RWQCB Region 2 Boundary
- RWQCB Region 5

Stormwater Permit Coverage

- Individual Stormwater NPDES Permit
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Notes:
1. Areas above Dams are not included in baseline load estimated for Municipal Regional Stormwater Permittees. Areas covered under different stormwater permits (i.e., individual NPDES permits, Phase II permit) are not included in baseline load estimates for Municipal Regional Stormwater Permittees.

Contra Costa County RAA Baseline Loading Analysis Area

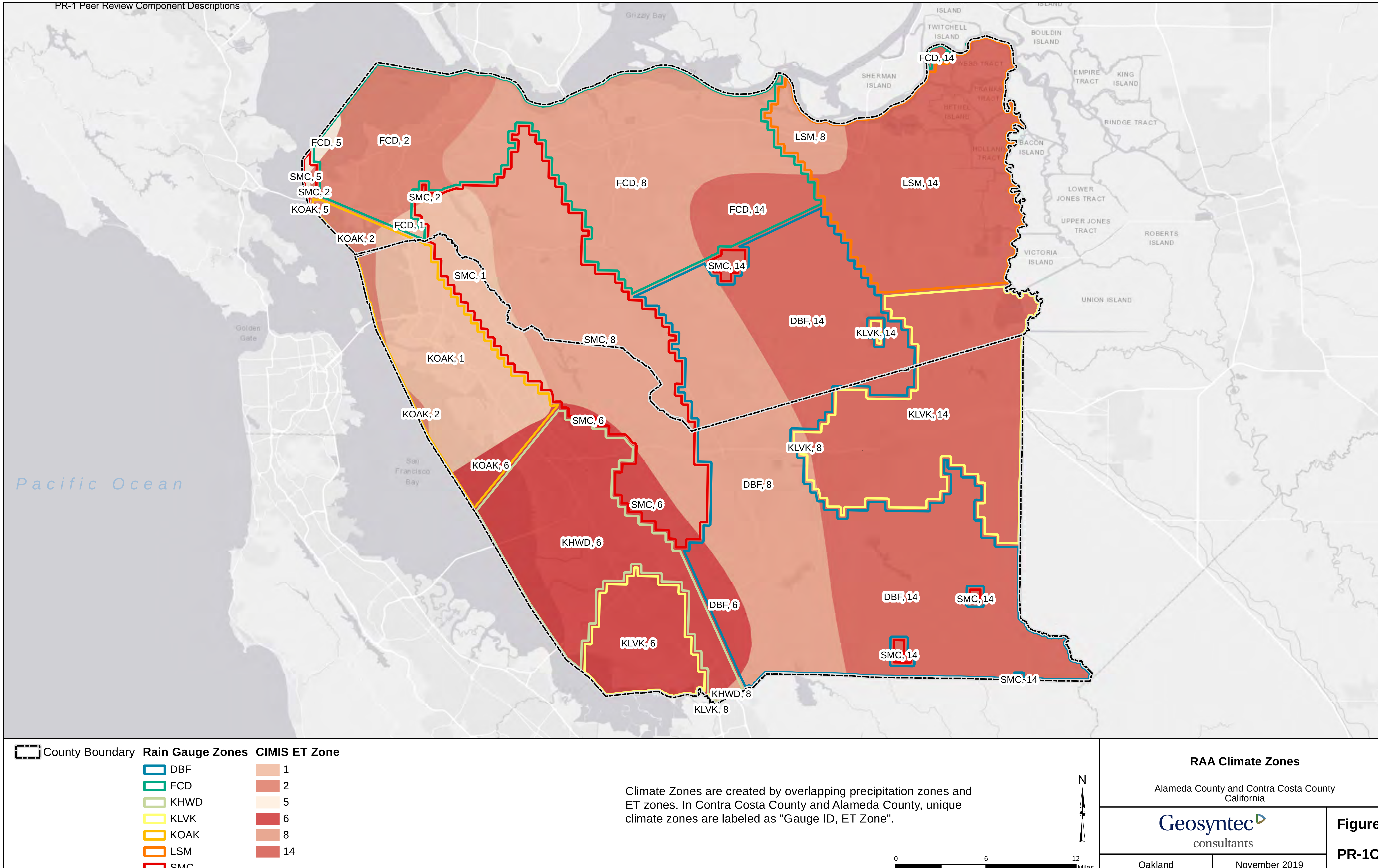
Contra Costa County
California

Geosyntec consultants

Oakland | October 2019

Figure 1B

P:\GIS\Bay_Area_RAA\Project\Peer_Review_Documentation\PR_Figure_1B_Baseline_Loading_Map_ContraCosta.mxd 10/1/2019 2:49:36 PM



Climate Zones are created by overlapping precipitation zones and ET zones. In Contra Costa County and Alameda County, unique climate zones are labeled as "Gauge ID, ET Zone".

RAA Climate Zones Alameda County and Contra Costa County California	
Geosyntec consultants	Figure PR-1C
Oakland / November 2019	

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PR-2 Alameda Countywide Clean Water Program GI Quantitative Relationship Report

ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM

QUANTITATIVE RELATIONSHIP BETWEEN GREEN INFRASTRUCTURE IMPLEMENTATION AND PCBS/MERCURY LOAD REDUCTIONS

MEMBER AGENCIES:

Alameda
Albany
Berkeley
Dublin
Emeryville
Fremont
Hayward
Livermore
Newark
Oakland
Piedmont
Pleasanton
San Leandro
Union City
County of Alameda
Alameda County Flood Control and Water Conservation District
Zone 7 Water Agency

Report prepared by:

Alameda Countywide Clean Water Program
399 Elmhurst Street
Hayward, California 94544

Submitted to:

California Regional Water Quality Control Board, San Francisco Bay Region

September 28, 2018

Acknowledgements

This report was prepared in cooperation with the Contra Costa County Clean Water Program. Geosyntec Consultants contributed substantially to the writing and preparation of this report.

Preface

This *Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions* was prepared by the Alameda Countywide Clean Water Program (ACCWP) per the Municipal Regional Permit (MRP; NPDES Permit No. CAS612008; Order No. R2-2015-0049) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board. This report fulfills the requirements of MRP Provisions C.11.b.iii.(3), C.11.c.iii.(1), C.12.b.iii.(3), and C.12.c.iii.(1) to submit refinements to the measurement and estimation methodologies for assessing mercury and PCBs load reductions in the next permit term and the quantitative relationship between green infrastructure implementation and mercury and PCBs load reductions that will be used for the reasonable assurance analyses.

This report is submitted by ACCWP on behalf of the following Permittees:

- The cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City;
- Alameda County;
- Alameda County Flood Control and Water Conservation District; and
- Zone 7 of the Alameda County Flood Control and Water Conservation District (Zone 7 Water Agency).

LIST OF ACRONYMS

ASOS	Automated Surface Observation System
BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practices
CCCWP	Contra Costa Clean Water Program
CIMIS	California Irrigation Management Information System
GI	Green Infrastructure
GIS	Geographic Information System
HRU	Hydrologic Response Unit
KTRL	Kendall-Theil Robust Line
MAD	Median Absolute Deviation
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
ng/kg	nanogram per kilogram
NPDES	National Pollutant Discharge Elimination System
PCBs	Polychlorinated Biphenyls
RAA	Reasonable Assurance Analysis
RMSE	Root Mean Square Error
ROW	Right-of-Way
RWSM	Regional Watershed Spreadsheet Model
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SWMM	Stormwater Management Model
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
WY	Water Year

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Appendix A: Modeling Inputs and Data Exhibits

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1. INTRODUCTION

1.1 Purpose

This *Quantitative Relationship between Green Infrastructure Implementation and PCBs/Mercury Load Reductions* report was prepared by the Alameda Countywide Clean Water Program (ACCWP) per the Municipal Regional Permit (MRP) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Order No. R2-2015-0049). This report fulfills the requirements of MRP Provisions C.11.b.iii.(3), C.11.c.iii.(1), C.12.b.iii.(3), and C.12.c.iii.(1) for submitting the quantitative relationship between green infrastructure (GI) implementation and PCBs load reductions that will be used for the Reasonable Assurance Analysis (RAA) required by MRP Provisions C.11.c.ii.(2), C.11.d.ii, C.12.c.ii.(2), and C.12.d.ii.

This report was prepared in cooperation with the Contra Costa Clean Water Program. The RAA modeling described herein will be conducted for both countywide programs and will use data inputs from both Alameda County and Contra Costa County.

1.2 Background

1.1.1 PCBs and Mercury Total Maximum Daily Loads

Fish tissue monitoring in San Francisco Bay has revealed bioaccumulation of PCBs, mercury, and other pollutants. The levels found are thought to pose a health risk to people consuming fish caught in the Bay. As a result of these findings, California has issued an interim advisory on the consumption of fish from the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act "Section 303(d) list" due to PCBs and mercury. In response, the SFBRWQCB has developed Total Maximum Daily Load (TMDL) water quality restoration programs targeting PCBs and mercury in the Bay. The general goals of the TMDLs are to identify sources of PCBs and mercury to the Bay and implement actions to control the sources and restore water quality.

Municipal separate storm sewer systems (MS4s) are one of the PCBs and mercury source/pathways identified in the TMDL plans. Local public agencies (i.e., Permittees) subject to requirements via National Pollutant Discharge Elimination System (NPDES) permits are required to implement control measures in an attempt to reduce PCBs and mercury from entering stormwater runoff and the Bay. These control measures, also referred to as Best Management Practices (BMPs), are the tools that Permittees can use to assist in restoring water quality in the Bay.

1.1.2 Municipal Regional Permit

NPDES permit requirements associated with Phase I municipal stormwater programs and Permittees in the Bay area are included in the MRP, which was issued to 76 cities, counties and flood control districts in 2009 and revised in 2015. The MRP includes provisions to reduce loads of mercury and PCBs consistent with the TMDL implementation timeframe (Provisions C.11 and C.12, respectively) through implementation of GI projects (Provisions C.3.j, C.11.c, and C.12.c) and source controls (Provisions C.11.d and C.12.d).

The Permittees are reporting load reductions achieved before and during the current MRP term (2014 – 2020) using the approved Interim Accounting Methodology (BASMAA, 2017). MRP Provisions C.11.b.iii.(3) and C.12.b.iii.(3) requires the Permittees to report in the 2018 and subsequent Annual Reports any refinements to the Interim Accounting Methodology to be used in subsequent Permit terms. As part of this reporting requirement, Provision C.11.c.iii.(3) and C.12.c.iii.(1) requires the Permittees to report on the quantitative relationship between GI implementation and PCBs and mercury load reductions, including all data used and a full description of models and model inputs relied on to establish this relationship.

Green Infrastructure Planning and RAA

MRP Provision C.3.j requires the Permittees to develop a Green Infrastructure Plan for inclusion in the 2019 Annual Report. The Green Infrastructure Plan must be developed using a mechanism to prioritize and map areas for potential and planned GI projects, both public and private, on a drainage-area-specific basis, for implementation by 2020, 2030, and 2040.

MRP Provisions C.11.c and C.12.c require the Permittees to prepare an RAA for inclusion in the 2020 Annual Report that quantitatively demonstrates that specified mercury and PCBs load reductions will be achieved by 2040 through implementation of GI.

This RAA should do the following:

1. Quantify the relationship between the areal extent of GI implementation (e.g., acres treated) and mercury and PCBs load reductions. This quantification should take into consideration the scale of contamination of the treated area as well as the pollutant removal effectiveness of GI strategies likely to be implemented.
2. Estimate the amount and characteristics of land area that will be treated by GI by 2020, 2030, and 2040.
3. Estimate the amount of mercury and PCBs load reductions that will result from GI implementation by 2020, 2030, and 2040.

4. Ensure that the calculation methods, models, model inputs, and modeling assumptions used have been validated through a peer review process.

Additionally, MRP Provisions C.11.d. and C.12.d. require the Permittees to prepare plans and implementation schedules for mercury and PCBs control measures and an RAA demonstrating that sufficient control measures will be implemented to attain the mercury TMDL wasteload allocations by 2028 and the PCBs TMDL wasteload allocations by 2030. The implementation plans, which will also be included in the 2020 Annual Report, along with the GI-based RAA outlined above, must:

1. Identify all technically and economically feasible mercury or PCBs control measures (including GI projects, but also other control measures such as source property identification and abatement, managing PCBs in building materials during demolition, enhanced operations and maintenance, and other source controls) to be implemented;
2. Include a schedule according to which technically and economically feasible control measures will be fully implemented; and
3. Provide an evaluation and quantification of the mercury and PCBs load reduction of such measures as well as an evaluation of costs, control measure efficiency, and significant environmental impacts resulting from their implementation.

This report presents the quantitative relationship between GI implementation and PCBs and mercury load reductions, including the data used and a full description of models and model inputs relied on to establish this relationship. This relationship will be used to predict loads reduced through GI implementation for the RAAs described above and to report loads reduced through GI implementation in the subsequent Permit term.

2. DESCRIPTION OF RAA MODEL

This section provides an overview of the RAA modeling framework and describes the output of each component.

2.1 RAA Model Overview

The approach used to estimate the load reductions resulting from implementation of GI includes the model components listed below, which are described in further detail in the following sections:

- Baseline Pollutant Loading Model – the baseline pollutant loading model is a continuous simulation[1] hydrology model combined with pollutant loading inputs to obtain the average annual loading of mercury and PCBs across the county during the TMDL baseline period (i.e., 2003 – 2005).
  - Hydrology – this model component produces average annual runoff across each county for the period of record using a hydrologic response unit (HRU) approach. The HRU approach involves modeling various combinations of land surface features (i.e., imperviousness, underlying soil characteristics, slope, etc.) present within each county for a unit area drainage catchment. See Section 2.2.1.
  - Water Quality – the hydrology output is combined with average annual concentrations estimated by the Regional Monitoring Program's Regional Watershed Spreadsheet Model (RWSM; Wu et al, 2017) developed by the San Francisco Estuary Institute (SFEI) to produce average annual PCBs and mercury loading for the period of record. See Section 2.2.2.
- GI Performance Models – the GI performance models are developed to represent load reductions resulting from implementation of GI. See Section 2.3.
- Future Condition (RAA Scenario) Models – the RAA scenario models are conducted to represent future land use changes and control measure implementation that could result in pollutant load reduction. Both GI and source controls are considered, depending on the time frame of interest. See Section 2.4 for a description of load reduction calculations.

2.2 Baseline Loading Model

2.2.1 Hydrologic Model

As introduced above, the proposed approach for modeling hydrology is to use a hydrologic response unit (HRU) approach. An HRU is a unique combination of land surface features (imperviousness, underlying soil characteristics, slope, etc.) which is expected to give a consistent runoff response to rainfall, no matter where that unique combination is found. The HRU approach involves modeling all possible combinations of land surface features present within each county for a unit area drainage catchment and then storing these results in a database. These HRU results can been be scaled geospatially across the entire county without developing

[1] Continuous simulation models calculate outputs (e.g., runoff) "continuously", i.e., for many time steps over a long-term period of record (e.g., every 10 minutes for 10 years). Long-term "continuous" input data (e.g., hourly rainfall) is required. This is contrasted with design-event simulations which model a single rainfall event, e.g., a 24-hour storm with a 10-year recurrence frequency.

a detailed hydrologic model. This method is consistent with the *Bay Area RAA Guidance Document* (BASMAA, 2017b).

The generic HRUs are modeled using USEPA's Stormwater Management Model (SWMM) to obtain an average annual runoff volume per acre for the identified baseline period of record (water year [WY] 2000 – 2009) for each HRU. Certain HRU inputs (imperviousness, soil parameters) are adjusted as needed to calibrate the HRUs on an average annual basis to identified flow gauges in the counties.

The average annual runoff volume per acre associated with a specific HRU can then be multiplied by the area represented by that HRU across each county (or a selected smaller planning area, such as a watershed or jurisdictional boundary). The resulting volumes associated with each represented HRU within the specified geospatial area can then be summed for the identified area to obtain the estimated total average annual runoff volume.

2.2.2 Water Quality Model

Identified HRUs across each county are combined with the RWSM land use classifications layer to determine pollutant loading rates. The RWSM provides average annual concentrations of PCBs and mercury that wash off from various land use categories. On an average annual basis, this approach approximates the total load.

Average annual runoff volume associated with the geospatial HRUs is multiplied by the PCBs and mercury average annual concentration (based on the RWSM land use categories for the identified area) to obtain average annual pollutant load using the following equation:

$$Load_{Baseline} = \sum\left(\sum Unit\ Runoff_{HRU} \times Area_{LU,HRU}\right) \times Concentration_{LU} \times 0.00123 \qquad \text{Eqn. 1}$$

Where:

$Load_{Baseline}$ = The total average annual baseline pollutant load for the identified area for calculation [grams/year]

$Unit\ Runoff_{HRU}$ = The average annual runoff per acre for a given HRU within the identified area for calculation [ac-ft/acre/yr]

$Area_{LU,HRU}$ = The total area of the HRU within the RWSM land use category within the identified area for calculation [acres]

$Concentration_{LU}$ = The average annual pollutant concentration associated with the RWSM land use category [ng/L]

0.00123 = Conversion factor [(L/ac-ft)*(g/ng)]

2.3 Green Infrastructure Performance Model

Volume reduction (via retention in the green infrastructure facility) and pollutant load reduction (via filtration through media and discharge through an underdrain) are modeled utilizing a combination of hydraulic modeling in SWMM and currently available empirical GI performance data.

2.3.1 Hydraulic GI Models

GI control measure hydraulic performance is modeled in SWMM with a 100% impervious tributary area for three GI facility types: (1) bioretention[2] with a raised underdrain, (2) bioretention with no underdrain, and (3) lined bioretention. The model is run with varying footprint sizes and varying underlying infiltration rates (i.e., the rate at which treated runoff infiltrates into native soils underlying the BMP facility). Average annual volume retained, volume treated, and volume bypassed by the GI measure are recorded for each GI model run.

Volume-based performance[3] corresponding to the generic 100% impervious tributary area can be applied to the effective area in GI drainage areas made up of identified HRUs. The effective area is also known as the "runoff generating area" and is calculated as the tributary area multiplied by the long-term or average annual runoff coefficient.

2.3.2 Green Infrastructure Pollutant Reduction Calculations

To calculate pollutant load reduction associated with GI implementation, the hydraulic model results are combined with water quality performance data. The annual estimate of pollutant load reduction from the modeled drainage area is equivalent to the difference between the influent load and the sum of the pollutant load that bypasses the GI measure and the effluent load (Eqn. 2). Equations corresponding to the pollutant reduction calculation are provided below and the water balance is illustrated in Figure 1. In summary, influent load is calculated as the pollutant load produced by the 100% impervious tributary area for each RWSM land use category using Eqn. 3. The pollutant load that bypasses the facility is calculated as the proportion of runoff that bypasses the facility per the hydraulic GI model output, multiplied by the influent concentration

[2] The bioretention is assumed to include: 6-inch or 12-inch ponding depth, 1.5 ft of filter media with a 5 in/hr flow through rate, and 1 ft of gravel beneath the media.

[3] Volume-based performance refers to how much runoff volume the GI facility captures and retains or treats and discharges through the underdrain, typically represented as a percentage of the average annual runoff volume.

(Eqn. 4). The effluent load is calculated as the proportion of runoff that is captured by the facility per the hydraulic GI model output, combined with an effluent concentration (Eqn. 5 and Eqn. 6).

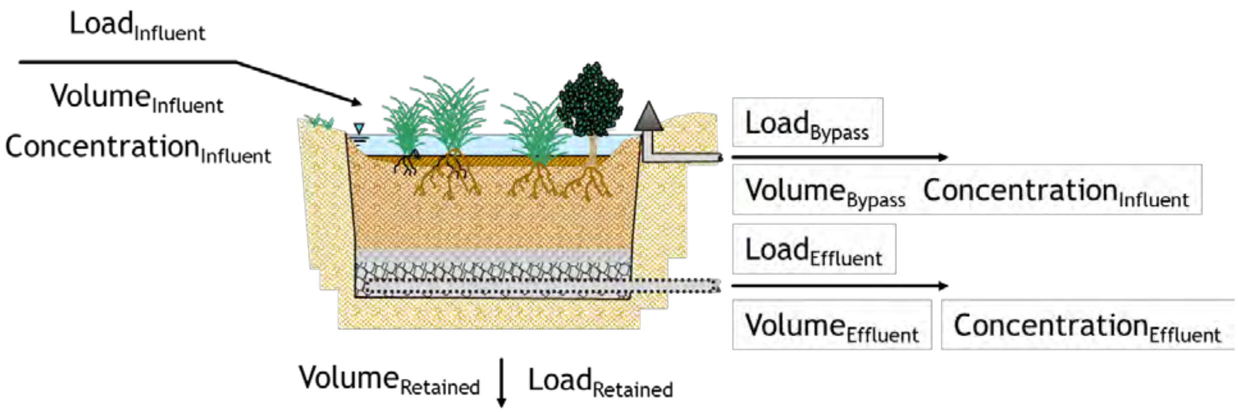

Figure 1: Illustration of GI Facility Pollutant Load Reduction Calculations

$$Load_{Reduced} = Load_{Influent} - Load_{Bypass} - Load_{Effluent} \quad \text{Eqn. 2}$$

$$Load_{Influent} = Volume_{Influent} \times Concentration_{Influent} \times C \quad \text{Eqn. 3}$$

$$Load_{Bypass} = Volume_{Bypass} \times Concentration_{Influent} \times C \quad \text{Eqn. 4}$$

$$Load_{Effluent} = (Volume_{Captured} - Volume_{Retained}) \times Concentration_{Effluent} \times C \quad \text{Eqn. 5}$$

$$Volume_{Captured} = Volume_{Influent} - Volume_{Bypass} \quad \text{Eqn. 6}$$

Where:

$Load_{Reduced}$ = The total average annual pollutant load reduced by the GI facility [g/year]

$Load_{Influent}$ = The total average annual pollutant load produced by the facility drainage area [g/year]

$Load_{Bypass}$ = The pollutant load that bypasses the facility [g/year]

$Load_{Effluent}$ = The pollutant load discharged from the facility after treatment [g/year]

$Volume_{Influent}$ = The runoff produced by the drainage area to the GI facility [ac-ft/year]

$Volume_{Bypass}$ = The proportion of influent runoff that bypasses the facility [ac-ft/year]

$Volume_{Captured}$	=	The proportion of influent runoff that is captured by the facility [ac-ft/year]
$Volume_{Retained}$	=	The proportion of captured runoff that is retained by the facility through infiltration and/or evapotranspiration [ac-ft/year]
$Concentration_{Influent}$	=	The pollutant concentration associated with the GI drainage area [ng/L]
$Concentration_{Effluent}$	=	The concentration discharged from the facility after treatment [ng/L]
C	=	Conversion factor constant = 0.00123 [(L/ac-ft)*(g/ng)]

2.4 RAA Scenario Loading Model

The loading corresponding with RAA future condition scenarios (2020, 2030, 2040) will be developed using the same volume and concentration combination approach used for the baseline condition. HRU outputs developed for the baseline model will scaled across the county corresponding to anticipated land use and development changes for each of the future conditions. Similarly, the RWSM land use classifications layer will be updated corresponding to each future condition scenario.

The outputs of the future hydrology scaling combined with the concentrations corresponding with future RWSM land use classification provides the land use-based loading estimated for each of the future conditions. To obtain the discharged load corresponding to each future GI scenario, load reductions associated with anticipated GI (developed as described above) will be subtracted from the land use-based load.

3. MODEL INPUTS AND DATA USED

This section describes the inputs to each component of the model and the data used.

3.1 Baseline Loading Model

3.1.1 Hydrologic Model

Generic HRU models are developed in SWMM to estimate average annual runoff volume per acre values that can be applied to all land surfaces within each county. The land surface feature inputs that will be varied to model the generic HRUs are described in the sections below and summarized in Table 3.

Climate Inputs

HRU climate inputs provide the total amount of precipitation that falls on the land surface and the amount of precipitation that is lost to the atmosphere via evapotranspiration before running off the land surface. Multiple gauges from across Alameda and Contra Costa counties that had continuous hourly precipitation data were chosen to represent distinct rainfall regions within both counties. For precipitation, these regions are based on 30-year annual rainfall regimes as identified by PRISM[4]. For evapotranspiration rates, the California Irrigation Management Information System (CIMIS) evapotranspiration zones were used within each county. The combination of the identified precipitation regions and evapotranspiration regions were combined to yield "climate zones" used for generic HRU models. Precipitation zones, evapotranspiration zones, and climate zones are shown in Exhibit 1 through Exhibit 3 (see Appendix A). Table 1 provides a summary of precipitation gauges used and average annual rainfall corresponding to the entire period of record and WY 2000 - 2009. Table 2 provides a summary of the CIMIS data used for the daily reference evapotranspiration rate for each evapotranspiration zone.

Table 1: HRU Precipitation Gauges WY2000-2009

Gauge ID	Gauge Name	Average Annual Precipitation (inches) WY 2000 - 2009	Gauge Source
KHWD	Hayward Air Terminal (ASOS)	16.3	ASOS[1]
KLVK	Livermore Municipal Airport (ASOS)	14.6	ASOS
KOAK	Oakland Airport (ASOS)	19.0	ASOS
DBF	Dublin Fire Station, San Ramon	17.3	CCCFCD[2]
FCD	Flood Control District, Martinez	16.2	CCCFCD
LSM	Los Medanos, Pittsburg	11.8	CCCFCD
SMC	Saint Mary's College, Moraga	28.9	CCCFCD

1. Automated Surface Observation System (ASOS) data were used for Alameda County gauge sites for the period of WY2000-2009 since NCDC gauge data was not available for the baseline period. ASOS sites sometimes co-occur with NCDC gauge sites (e.g., airports), but are maintained and delivered by separate government entities.
2. Contra Costa County gauge data is collected by the Flood Control District but was provided to Geosyntec by Dubin Engineering.

[4] Parameter-elevation Relationships on Independent Slopes Model (PRISM), developed and managed by the PRISM Climate Group, Oregon State University http://prism.oregonstate.edu/.

Table 2: CIMIS Reference Evapotranspiration

ET Zone	Monthly Evapotranspiration (in/day)[1]											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.03	0.05	0.08	0.11	0.13	0.15	0.15	0.13	0.11	0.08	0.04	0.02
2	0.04	0.06	0.1	0.13	0.15	0.17	0.16	0.15	0.13	0.09	0.06	0.04
3	0.06	0.08	0.12	0.16	0.17	0.19	0.18	0.17	0.14	0.11	0.08	0.06
6	0.06	0.08	0.11	0.16	0.18	0.21	0.21	0.2	0.16	0.12	0.08	0.06
8	0.04	0.06	0.11	0.16	0.2	0.23	0.24	0.21	0.17	0.11	0.06	0.03
14	0.05	0.08	0.12	0.17	0.22	0.26	0.28	0.25	0.19	0.13	0.07	0.05

1. CIMIS reference evapotranspiration, which is based on irrigated turf grass, was scaled by 0.6 to represent the local mix of vegetated cover including urban vegetation, native xeric adapted plants, and unirrigated vegetated open space areas.

Slope

Slope affects how quickly rainfall will run off a modeled land surface and therefore how much is able to be infiltrated into the subsurface. The available digital elevation model (DEM)[5] for the counties was analyzed to obtain percent slope values for each ~30m by ~30m square of land surface. These percent slope values were classified into three distinct slope zones as summarized in Table 3 and shown in Exhibit 4 (see Appendix A).

Underlying Soil Inputs

Physical characteristics of the soil underlying the land surface affect the amount of rainfall that may be infiltrated into the subsurface. Infiltration was simulated in SWMM using the Green-Ampt infiltration model option. The physical soil input parameters for the Green-Ampt infiltration model were varied based on hydrologic soil group (HSG) as identified by the National Resource Conservation Service (NRCS[6]) soil survey and were modified as described below for developed areas. Soil parameters used as model inputs include suction head, hydraulic conductivity, and initial moisture deficit. Developed areas that are assumed to have been compacted and therefore result in less infiltration to the subsurface are modeled using 75 percent of the HSG hydraulic conductivity value. Soil parameters are not reported here, as this input is adjusted as part of baseline model calibration. Details about soil inputs are provided in Table 3. A map of hydrologic soil group is provided as Exhibit 5 (see Appendix A).

[5] U.S. Geological Survey. National Elevation Dataset (NED) 1/3 arc-second. 2013

[6] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. link: https://websoilsurvey.sc.egov.usda.gov/

Areas of development were identified based on the land use of the surface. Soils within urban and agricultural use areas were considered to have been compacted by the site preparation and activities.

Imperviousness

Imperviousness (i.e., the percentage of impervious area) affects area on the land surface where rainfall may be infiltrated and therefore the quantity of runoff produced. The runoff from a range of land use imperviousness values is modeled by area-weighting the results of a pervious surface runoff result (i.e., pervious HRU output) with a corresponding impervious surface runoff result (i.e., impervious HRU output) (see Table 3 and Exhibit 6 (see Appendix A)).

The baseline model HRU imperviousness is developed by geospatially combining the land uses identified by the Association of Bay Area Governments (ABAG, 2005) with the National Land Cover Dataset (NLCD, 2006) data. Each feature of the ABAG dataset is assigned a single imperviousness value that is used to determine the average hydrologic response of that land surface. A lookup-table containing NLCD-based imperviousness for each ABAG land use code was used as a starting value for HRU calibration. Imperviousness may be adjusted within an appropriate range as part of baseline model calibration.

3.1.2 Developing HRUs across each County

Each identified combination of land surface features is modeled for a generic unit-acre drainage area in SWMM for the baseline period of record (i.e., WY 2000 – 2009), utilizing a batch-processing method (which allows for inputs to be altered, model files run, and results extracted for many models automatically). The average annual runoff volume per acre is then extracted for each generic HRU modeled.

Table 3: Land Surface Feature Inputs for Generic HRU Hydrologic Models

Variables	Description	Number of Varying Features	Feature Representations	Source
Hourly Annual Precipitation	Rainfall Gauge and Rainfall Zone	7	Contra Costa County Gauges: DBF, FCD, LSM, SMC Alameda County ASOS Gauges: KHWD, KLVK, KOAK	PRISM[1], NCDC/ County-maintained rainfall gauges
Daily Evapotranspiration Rate	Evapotranspiration Zone	5	Zones 1, 2, 3, 6, 8, 14	CIMIS[2]
Slope Zone	Representation of Slope	3	<5%, 5-15%, 15%+	USGS[3]
Developed/ Undeveloped Areas	Representation of Compaction of Underlying Soils (Pervious Areas Only)	2	Undeveloped (Ksat * 1) Developed (Ksat * 0.75)	ABAG Land Use 2005[4]
Hydrologic Soil Group	Representation of Underlying Soil Type (pervious areas only)	6	HSG A, B, C, D[5], Rock, Water	NRCS[6]
Imperviousness	Representation of Imperviousness	2	0% and 100%	NLCD and ABAG 2005

1. PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, 30-year normal mean annual precipitation
2. California Irrigation Management Information System (CIMIS) Reference Evapotranspiration; digitized from http://www.cimis.water.ca.gov/App_Themes/images/etozonemap.jpg
3. U.S. Geological Survey. National Elevation Dataset (NED) 1/3 arc-second. 2013
4. ABAG land use features are proposed to be used for identifying developed and undeveloped condition and will have an imperviousness value assigned based on a geospatial analysis of the NLCD Imperviousness layer. The impervious value for each ABAG land use feature will then be carried into the HRU model calibration and adjusted accordingly.
5. “Urban” representation will be re-classified based on the dominant adjacent HSG.
6. U.S. Department of Agriculture, Natural Resources Conservation Service. Soil Survey Geographic (SSURGO) database. 2016

HRUs are determined geospatially based on the climate zone, slope zone, developed/undeveloped areas, and HSG, along with land use-based imperviousness. Exhibits 1 through 5 (see Appendix A) display the data used to develop climate zones, county slope zones, and the HSG distribution across each county. Imperviousness designations will occur based on land use at the parcel, by combining the geospatial ABAG land use layer[7] with the other hydrologic input regions. This results in a “patchwork” of HRUs across the counties[8].

The resulting patchwork of HRUs can be combined at the scale of choice to provide total runoff volumes for a specific area, such as a watershed or jurisdictional boundary. To estimate the total runoff for the identified area, the total acreage of each designated HRU present within a watershed or jurisdiction will be multiplied by the average annual runoff per acre associated with each HRU and then summed (i.e., area-weighting the average annual runoff volume per acre for all HRUs present).

3.1.3 HRU Input Calibration

Calibration of hydrologic models is required by the *Bay Area RAA Guidance Document*. Calibration of the generic HRU models will be conducted utilizing available stream flow records and based solely upon the annual discharge volume between WY 2000-2009. This annual calibration means that the HRU runoff estimates are representative of the approximate annual runoff volume but will not be used to estimate or compare discharge rates at smaller timesteps, such as the hourly or daily runoff hydrograph.

The list of candidate gauge sites within the counties was developed based on an assessment of the representativeness of the gauged watersheds and the mitigation of confounding factors that interfere with calibration such as missing data and upstream impoundments. For the purposes of calibration, the candidate gauge sites that were selected included stream depth rating curves and at least daily mean records for the historical period of interest. The USGS flow gauges considered for calibration are provided in Table 4 and shown in Exhibit 8 (see Appendix A).

Table 4: Flow Gauge Considered for RAA Model Calibration

Gauge ID	Gauge Name	Location	County	Data Frequency
11337600	Marsh Creek	Brentwood	Contra Costa	Daily
11182500	San Ramon Creek	San Ramon	Contra Costa	Daily
11181390	Wildcat Creek	Richmond / San Pablo	Contra Costa	Daily
11181040	Lan Lorenzo Creek	San Lorenzo	Alameda	Daily
11181008	Castro Valley Creek	Hayward	Alameda	Daily

[7] ABAG land use features will be used to aggregate the imperviousness for the land surface. The relationship between ABAG feature and its imperviousness will be developed based upon other local sources (SMCWPPP, 2017) and analysis of national public data sets such as the National Land Cover Dataset (NLCD).

[8] This will be done once all the HRU input files are finalized, including the imperviousness layers.

Gauge ID	Gauge Name	Location	County	Data Frequency
11181000	San Lorenzo Creek	Hayward	Alameda	Daily
11180700	Alameda Creek Flood Channel	Union City	Alameda	Daily
11179000	Alameda Creek	Fremont	Alameda	Daily
11176900	Arroyo de la Laguna	Verona	Alameda	Daily
11173575	Alameda Creek Below Welch Creek	Sunol	Alameda	Daily
11173510	Alameda Creek Below Calaveras Creek	Sunol	Alameda	Daily

The effective area tributary to each flow gauge is used to calibrate the HRUs to the stream gauge records. Annual flow predicted by area-weighting HRU runoff output for the watersheds draining to the stream gauges was compared to annual flow in the stream records for the identified period of record.

Calibration of land surface runoff hydrology to stream gauge records requires that baseflow be computed and accounted for throughout the period of record. A variety of methods exist for separating baseflow from runoff, including the fixed-interval method and the local-minimum method (Sloto and Crouse, 1996). The most appropriate method for separating baseflow is determined on a gauge by gauge basis depending on the variability in the flow record, and the occurrence of confounding factors that affect baseflow such as dam releases and other dry weather inflows.

The average percent difference between the area-weighted HRU total average annual runoff volume for the watershed and the average annual flow (converted to volume) measured for the WY 2000 – 2009 period will be calculated. The acceptable ranges included in the RAA Guidance document are provided in Table 5 below.

Table 5: Allowable Difference between Simulated and Observed Annual Volumes

Model parameters	Average % difference between simulated annual results and observed data		
	Very Good	Good	Fair (lower bound, upper bound)
Hydrology/Flow	<10	10-15	15-25

If the average percent difference between simulated and measured annual storm flow volumes is greater than 25%, HRU model parameters are adjusted until the percent difference is within the acceptable range. The primary model parameters adjusted include underlying soil hydraulic conductivity and land use imperviousness, but other hydrologic model parameters, such as depression storage, may be adjusted as appropriate.

Once average percent differences in all identified watersheds are within the acceptable range, the HRU model parameters are finalized and the HRU results database will be regenerated. HRUs and resulting average annual baseline volume will be applied across each county to obtain the baseline volume discharged by each county.

3.1.4 Water Quality Model

RWSM values used to develop pollutant loading estimates across each county are:

Table 6: Regional Watershed Spreadsheet Model PCBs and Mercury Concentrations in Runoff

Land Use Category	Total PCBs (ng/L)	Total mercury (ng/L)
Ag, Open	0.2	80
New Urban	0.2	3
Old Residential	4	63
Old Commercial/ Transportation	40	63
Old Industrial and Source Areas	204	40

Water quality calculations are also used to perform baseline pollutant loading validation. The calculated pollutant load draining to Regional Monitoring Program stations will be validated by calculating the volume-weighted watershed pollutant concentration using the modeling results and comparing it to the observed concentrations in the Regional Monitoring Program data. The equation used to calculate concentration (in ng/L) at an end-of-watershed location is as follows:

$$Concentration_{Baseline} = \frac{\sum Runoff_{HRU} \times Area_{HRU} \times Concentration_{LU,HRU}}{\sum Runoff_{HRU} \times Area_{HRU}} \qquad \text{Eqn. 7}$$

Pollutant concentration and loading data from the Regional Monitoring Program will be compared to the result of Equation 7 for several watersheds for validation purposes.

3.2 Green Infrastructure Performance Model

3.2.1 Long-Term Green Infrastructure Simulations

Long term performance was assessed for each BMP configuration using continuous historical rainfall records. In Contra Costa County historical data was available at the same gauges that were used for the HRU runoff modeling between WY2000-2009, but for Alameda County other gauge sites with longer histories were used for long term BMP performance modeling. The rainfall gauges used to model BMP performance are shown in Table 7.

Table 7: Long Term GI Performance Precipitation Gauges

Gauge ID	Gauge Name	Period of Record	Average Annual Precipitation (inches)	Gauge Source[1]
040693	Berkeley (NCDC)	1948-1990	19.8	NCDC
041060	Brentwood (NCDC)	1950-1985	14.9	NCDC
043863	Hayward (NCDC)	1948-1988	24.3	NCDC
046335	Oakland Airport (NCDC)	1948-1985	16.4	NCDC
047821	San Jose Airport (NCDC)	1948-2010	13.6	NCDC
DBF	Dublin Fire Station, San Ramon	1973-2016	15.0	CCCFCD
FCD	Flood Control District, Martinez	1971-2016	16.5	CCCFCD
LSM	Los Medanos, Pittsburg	1974-2016	10.6	CCCFCD
SMC	Saint Mary's College, Moraga	1972-2016	26.8	CCCFCD

1. NCDC data was used for Alameda County and San Jose gauge sites. Contra Costa County gauge data is collected by the Flood Control District and was provided to Geosyntec by Dubin Engineering.

3.2.2 Hydraulic Green Infrastructure Model

Hydraulic GI models were developed in SWMM to estimate hydraulic performance for a 100% impervious tributary area. Hydraulic model inputs that were varied to model the GI facility performance for the counties are described below and summarized in Table 8.

1. BMP Configuration – three GI facility types were assumed: (1) bioretention with a raised underdrain, (2) bioretention with no underdrain, and (3) lined bioretention with an underdrain.
2. BMP Footprint Size – the BMP footprint size was varied as a percent of impervious area to model different levels of hydraulic capture performance depending on facility sizing.
3. BMP Underlying Infiltration Rate – the infiltration rate of the soils underneath the bioretention facility was varied for the bioretention with a raised underdrain and bioretention with no underdrain configurations (I.e., the unlined facility types).

Table 8: Land Surface Feature Inputs for Generic GI Performance Hydraulic Models

Variables	Description	Number of Varying Features	Feature Representations
Hourly Precipitation	Rainfall Gauge	9	NCDC: 040693 (Berkeley) 046335 (Oakland Airport) 043863 (Hayward) 047821 (San Jose) 041060 (Brentwood) Contra Costa County: DBF, FCD, LSM, SMC
Daily Evapotranspiration Rate	Evapotranspiration Zone	4	CIMIS Zones: 1, 6, 8, 14
BMP Configurations	BMP profiles and underdrain	3	Lined Bioretention with underdrain Unlined Bioretention with elevated underdrain Infiltration Basin without underdrain
BMP Surface Ponding Depth	Depth (feet)	2	0.5, 1
BMP Footprint Sizes	% of Impervious Area	12	0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6
BMP Infiltration Rates	Ksat of underlying soil (in/hr)	7 3	Unlined Bioretention: 0.024, 0.05, 0.1, 0.2, 0.24, 0.3, 0.4, 0.5 Infiltration Basin: 0.5, 1, 2

The BMP cross-sections that were modeled each include:

- 6-inches or 12-inches ponding depth (both were modeled),
- 1.5 ft of filter media with 25% porosity with a 5 in/hr flow through rate, and
- 1 ft of gravel beneath the media with 40% porosity.

Two of the modeled BMP configurations include underdrains. In the lined bioretention facility, the underdrain is located at the bottom of the gravel layer. In the unlined bioretention facility, the underdrain was modeled at the top of the gravel layer. BMP configurations are shown in Exhibits 9 through 11 (see Appendix A).

3.2.3 Green Infrastructure Pollutant Reduction Calculations

As described in Section 2.3.2, pollutant load reduction associated with GI is calculated by combining the hydraulic model results with water quality performance data. The annual estimate of pollutant load reduction from the modeled drainage area is equivalent to the difference between the influent load and the sum of the pollutant load that bypasses the GI measure and the effluent load. The effluent load is calculated as the proportion of runoff that is treated by the GI measure multiplied by an effluent concentration.

Water quality performance data from selected, representative studies were used to determine a method to predict effluent concentrations in stormwater following treatment through a biofiltration (bioretention or tree well filters) GI measure. The data used to develop the relationship came from three studies: a) 2011 monitoring study of the El Cerrito Rain Gardens (Gilbreath, Pearce, and McKee, 2012), b) Clean Watersheds for a Clean Bay (CW4CB)[9] (Geosyntec and EOA, 2017), and c) a study at Echo Lake in King County, WA (King County, 2017). A summary of the paired influent-effluent data associated with each study is provided in table:

Table 9: Data used to Develop Effluent Concentrations

Project Name	Project Sponsor	Facility ID	Influent-Effluent Data Pairs (n pairs)	
			PCBs	**Mercury**
El Cerrito Green Streets – CW4CB	El Cerrito	ELC-B1	3	3
El Cerrito Green Streets – SFEI	SFEI	ELC-B1	4	4
PG&E Substation 1st and Cutting Bioretention Cells – CW4CB	Richmond	LAU-3	8	8
Monitoring Stormwater Retrofits in the Echo Lake Drainage Basin Bioretention Planter Boxes – SAM Effectiveness Study	King County, Dept. of Natural Resources and Parks	BPB-1 BPB-2 BPB-3 BPB-4	4 4 4 2	0 0 0 0
West Oakland Industrial Area Tree Wells – CW4CB	Oakland	ETT-TW2 ETT-TW6	4 4	4 4
Monitoring Stormwater Retrofits in the Echo Lake Drainage Basin Tree Well – SAM Effectiveness Study	King County, Dept. of Natural Resources and Parks	FLT-1	4	0
		Total Data Pairs	41	23

[9] The CW4CB study included additional monitoring of the El Cerrito rain gardens.

These data were statistically evaluated to identify an appropriate method for predicting effluent concentrations of PCBs and total mercury. The data analysis first evaluated whether available influent and effluent concentration data were significantly different and, if so, whether a monotonic relationship existed (i.e., effluent generally increased when influent increased).

A Wilcoxon non-parametric hypothesis test was run on the PCBs and total mercury paired influent-effluent data to determine if influent and effluent concentrations were statistically different at a 5% significance level. This difference was found to be significant for PCBs, and significant for total mercury when corresponding influent suspended solids concentration was greater than 20 mg/L.

Spearman's rho and Kendall's tau, which are non-parametric rank correlation coefficients, were used to identify the direction and strength of correlation between influent and effluent concentrations. As shown in Table 10, both correlation coefficients suggest that effluent concentrations are positively correlated with influent concentrations for both PCBs and mercury.

Table 10: Influent/Effluent Correlation Coefficients

Correlation Coefficient	Total PCBs	Total Mercury
Spearman's rho	0.725	0.547
Kendall's tau	0.527	0.396

The Kendall-Theil Robust Line (KTRL) method (Granato, 2006) was used to determine the best fit line between influent and effluent data. This non-parametric method uses the median of all possible pairwise slopes between points, which is more robust to outliers than a simple linear regression. Because stormwater data tend to be lognormal, the analysis was focused on linear and log-linear relationships. After the KTRL was generated, the lower portion of the curve was adjusted to assume that neither PCBs nor total mercury can be exported from biofilters under normal circumstances, i.e., that the maximum effluent concentration of PCBs or total mercury is equal to the influent concentration. The resulting KTRL for PCBs is shown Figure 2. The resulting KTRL for total mercury is shown in Figure 3. Each figure also includes a constant average effluent concentration line with data fit statistics: root mean square error (RMSE) and median absolute deviation (MAD). As indicated, the KTRL provide a better fit of the data. However, the resulting effluent concentrations are not much different between the two lines except when influent PCBs are low (<10 ng/L) and total mercury concentration are high (>50 ng/L). For total mercury, concentration reductions are only predicted to occur when influent concentrations are greater than about 30 ng/L. Due to observed export of total mercury for several events, particularly for the 1st and Cutting bioretention cell (LAU-3), the moderate concentration reductions assumed by the KTRL at higher influent concentrations is reasonably conservative.

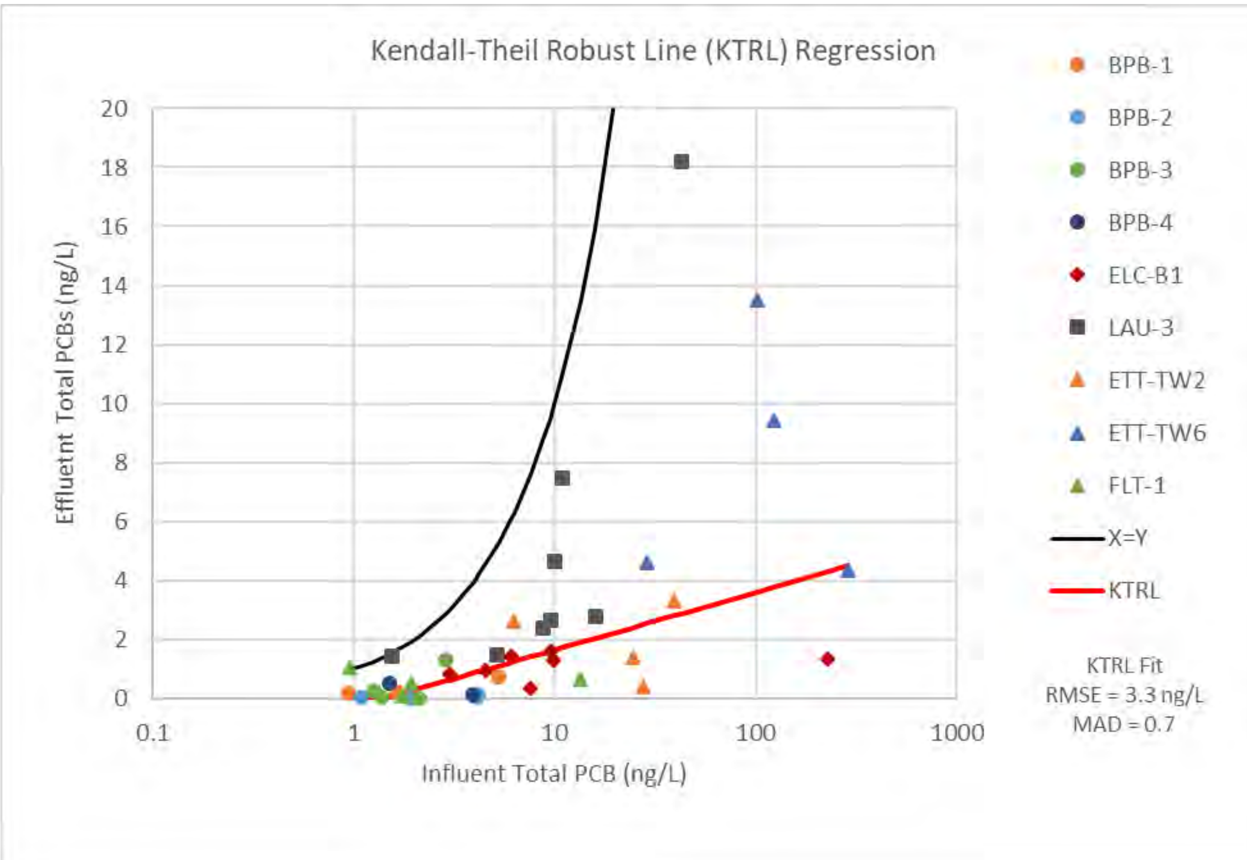

Figure 2: PCBs Influent vs Effluent Concentration Relationship Determined by KTRL Regression

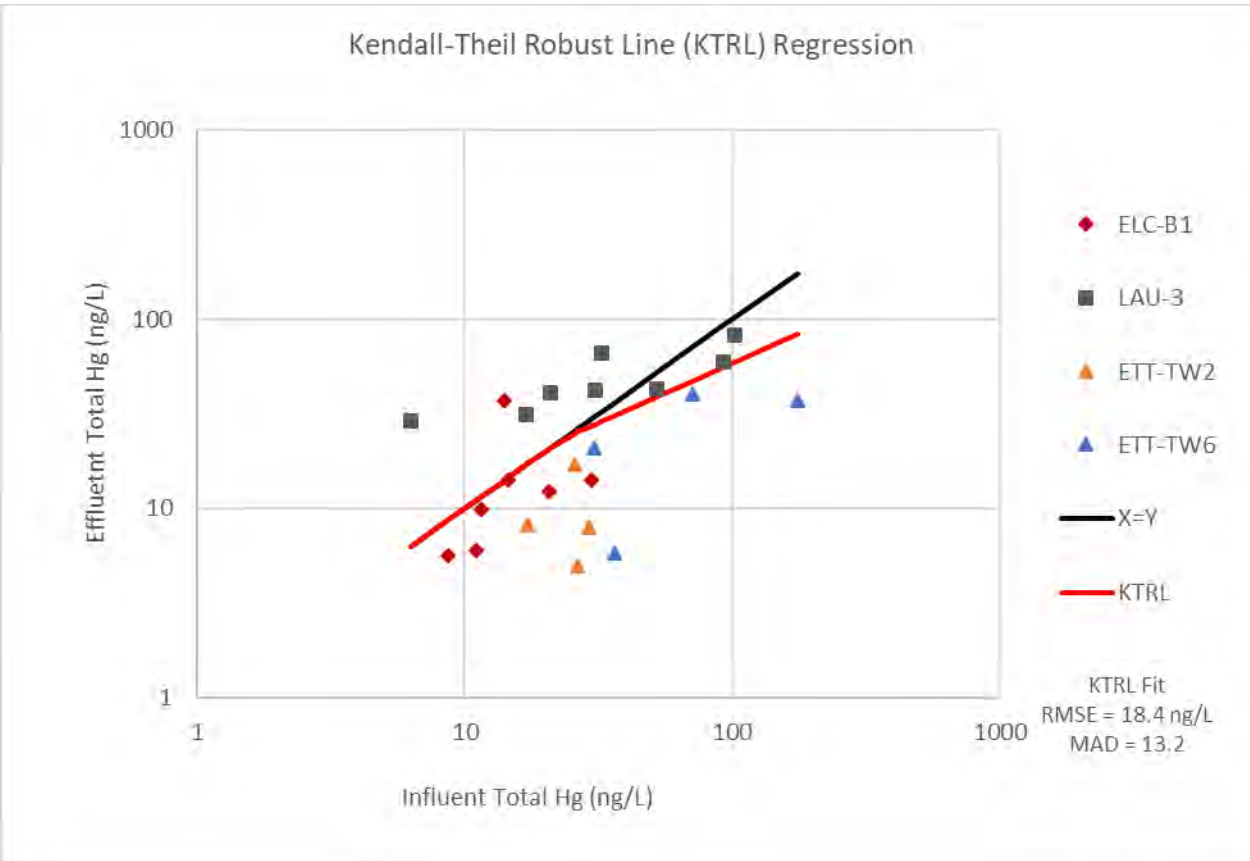

Figure 3: Mercury Influent vs Effluent Concentration Relationship Determined by KTRL Regression

3.3 RAA Scenario Loading Model

To model RAA future scenarios, future condition land use is needed. Future condition land use will be estimated using predictions of private parcel new development and redevelopment in combination with GI implementation on public parcels and rights-of-way.

Load reductions estimated for implementation of GI will be applied to future condition RAA scenario models based on estimated locations of GI and the tributary drainage areas to those GI. Effective area will be used to relate the HRUs, which can have a variety of imperviousness values, to the GI performance which will be based on a unit of effective area with 100% imperviousness. The GI performance curves can thus be applied to many different HRU types and/or combinations of HRUs that make up the tributary drainage areas for future GI measures.

4. QUANTITATIVE RELATIONSHIP BETWEEN GI IMPLEMENTATION AND PCBS LOADS REDUCED

The results of the hydraulic and pollutant reduction modeling of GI measures were used to develop a quantitative relationship between GI implementation and PCBs that can be applied to RAA future scenario models. An example quantitative relationship is provided for GI models run for the Berkeley gauge (040693). Utilizing output from hydraulic modeling, GI measure volumetric percent capture was calculated on an average annual basis. Volumetric model results for runs with GI measures sized to achieve 80%, 85%, 90%, and 95% capture were combined with water quality inputs to obtain pollutant load reduction for varying PCBs influent concentration.

The results of this analysis are shown in nomographs[10] provided in Figure 4, Figure 5, and Figure 6, which correspond to infiltrating bioretention (i.e., with no underdrain), bioretention with a raised underdrain, and lined bioretention, respectively. All facilities shown in the figures below have a 6-inch ponding depth. For bioretention with a raised underdrain, the facility configuration with an underlying infiltration rate of 0.24 in/hr only is shown (see Table 8 for all modeled infiltration rates). Facilities sized to achieve 80%, 85%, 90%, and 95% capture from the 100% impervious tributary catchment are shown in series, with pollutant load reduction in grams per effective acre[11] displayed as a function of influent concentration. Constant influent lines corresponding with RWSM land use-based influent concentrations are shown.

[10] A nomograph is a graphical relationship between two variables that can be used to quickly estimate one value from another.

[11] Effective area is calculated as the area multiplied by the runoff coefficient.

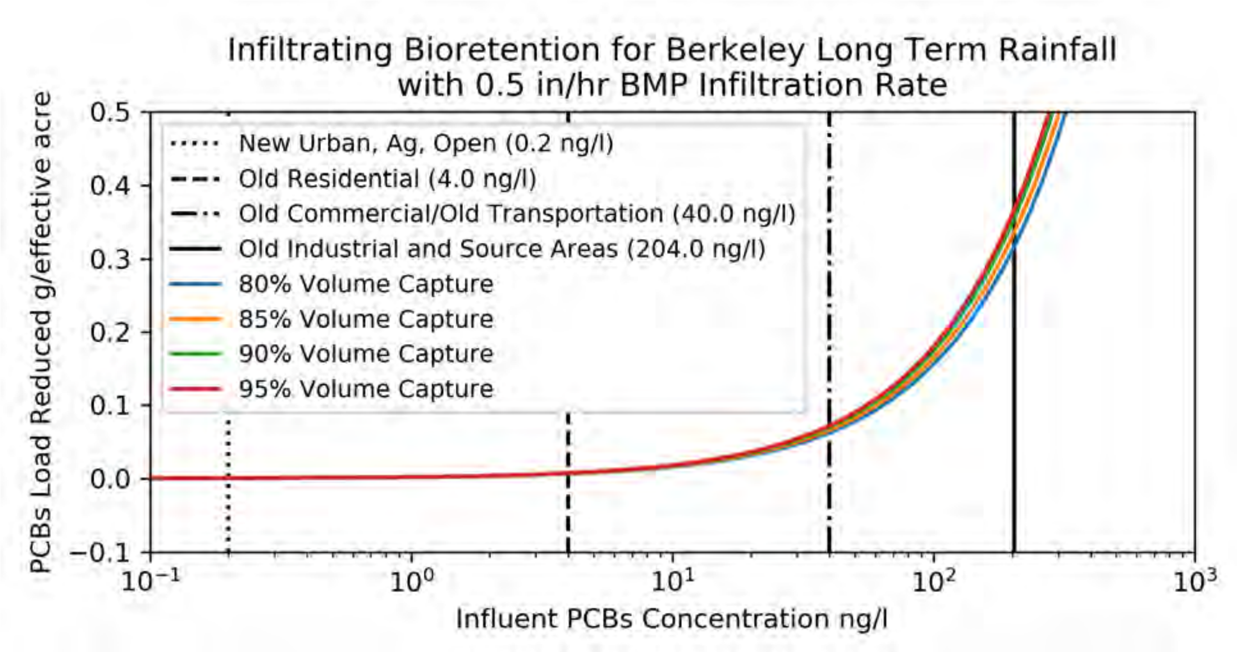

Figure 4: Modeled PCBs Load Removal Performance for Infiltrating Bioretention Basin

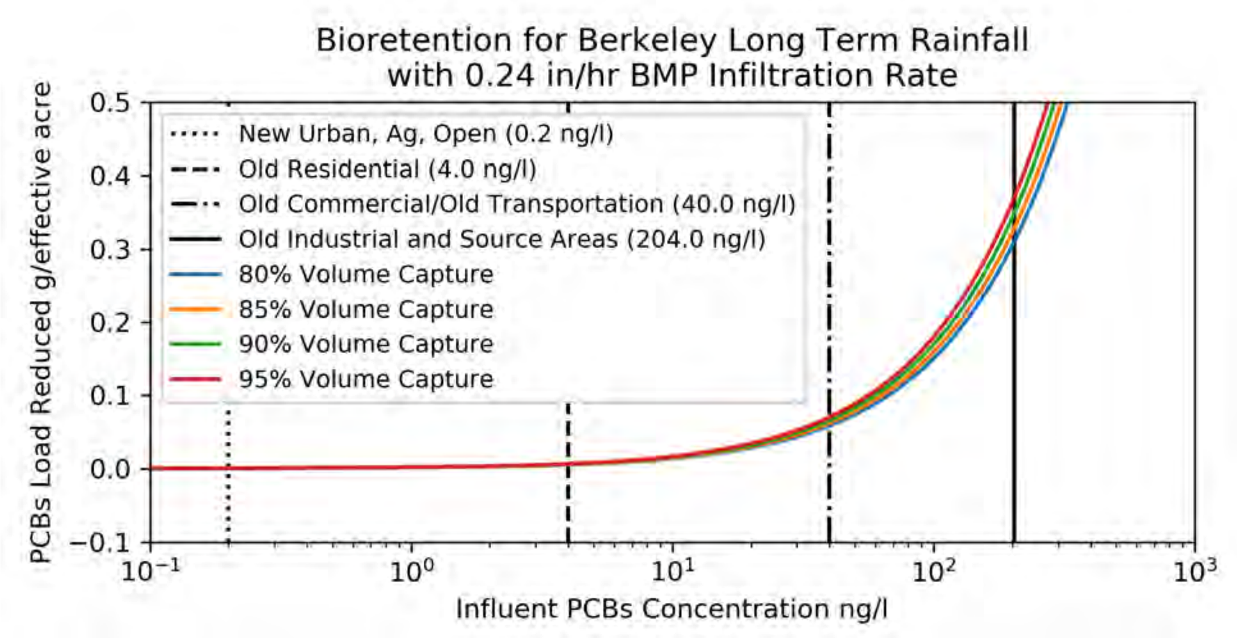

Figure 5: Modeled PCBs Load Removal Performance for Bioretention Basin with Elevated Underdrain

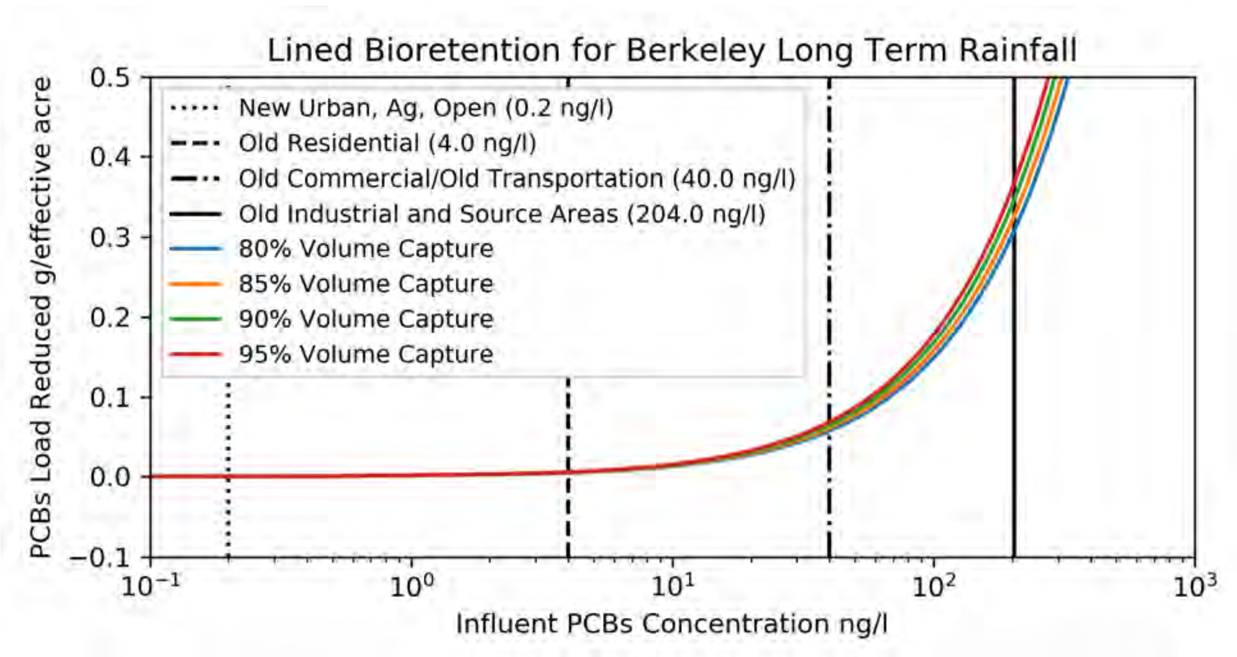

Figure 6: Modeled PCBs Load Removal Performance for Lined Bioretention Basin with Underdrain

The intersection points between the load reduction series and the constant influent lines represent the load reduced in grams per acre for each specific RWSM land use category. These intersection points are listed in Table 11.

Table 11: PCBs Load Reduction for RWSM Land Use Categories for Berkeley Gauge for Different BMP Percent Capture Values

Facility Configuration	Land Use Category	PCBs Load Reduced (g/effective ac)			
		80% Capture[1]	85% Capture[1]	90% Capture[1]	95% Capture[1]
Infiltrating Bioretention (0.5 underlying infiltration rate)	New Urban, Ag, Open	3.12E-04	3.30E-04	3.49E-04	3.61E-04
	Old Residential	0.00623	0.0066	0.00698	0.00722
	Old Commercial / Old Transportation	0.0623	0.066	0.0698	0.0722
	Old Industrial and Source Areas	0.318	0.337	0.356	0.368
Bioretention with Raised Underdrain (0.24 underlying infiltration rate)	New Urban, Ag, Open	3.08E-04	3.26E-04	3.47E-04	3.67E-04
	Old Residential	0.00518	0.0055	0.00589	0.00633
	Old Commercial / Old Transportation	0.0586	0.0621	0.0661	0.0703
	Old Industrial and Source Areas	0.311	0.329	0.350	0.371
Lined Bioretention	New Urban, Ag, Open	3.08E-04	3.26E-04	3.46E-04	3.67E-04
	Old Residential	0.00484	0.00513	0.00545	0.00577
	Old Commercial / Old Transportation	0.0574	0.0608	0.0647	0.0685
	Old Industrial and Source Areas	0.309	0.327	0.348	0.368

1. Average Annual Facility Volumetric Runoff Capture

5. QUANTITATIVE RELATIONSHIP BETWEEN GI IMPLEMENTATION AND MERCURY LOADS REDUCED

Mercury load reduction results for the Berkeley Gauge are shown in nomographs[12] in Figure 7, Figure 8, and Figure 9, which correspond to infiltrating bioretention (i.e., with no underdrain), bioretention with a raised underdrain, and lined bioretention, respectively. All facilities shown in the figures below have a 6-inch ponding depth. For bioretention with a raised underdrain, the facility configuration with an underlying infiltration rate of 0.24 in/hr only is shown (see Table 9 for all modeled infiltration rates). Facilities sized to achieve 80%, 85%, 90%, and 95% capture from the 100% impervious tributary catchment are shown in series, with pollutant load reduction in grams per acre displayed as a function of influent concentration. Constant influent lines corresponding with RWSM land use-based influent concentrations are shown.

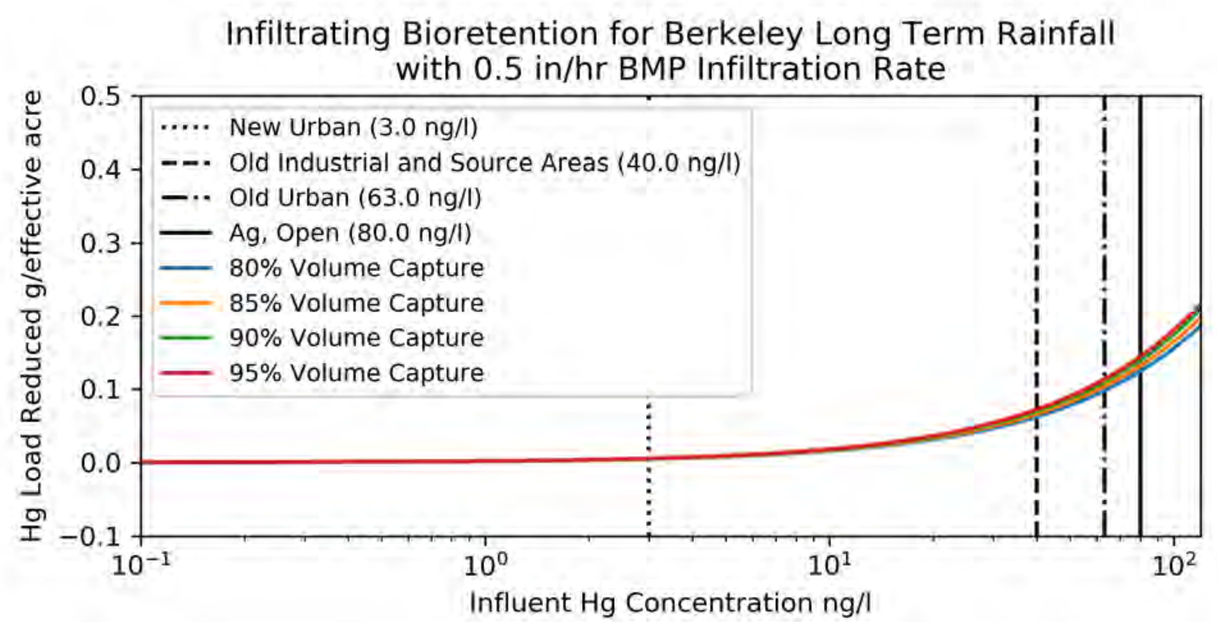

Figure 7: Modeled Mercury Load Removal Performance for Infiltrating Bioretention Basin

[12] A nomograph is a graphical relationship between two variables that can be used to quickly estimate one value from another.

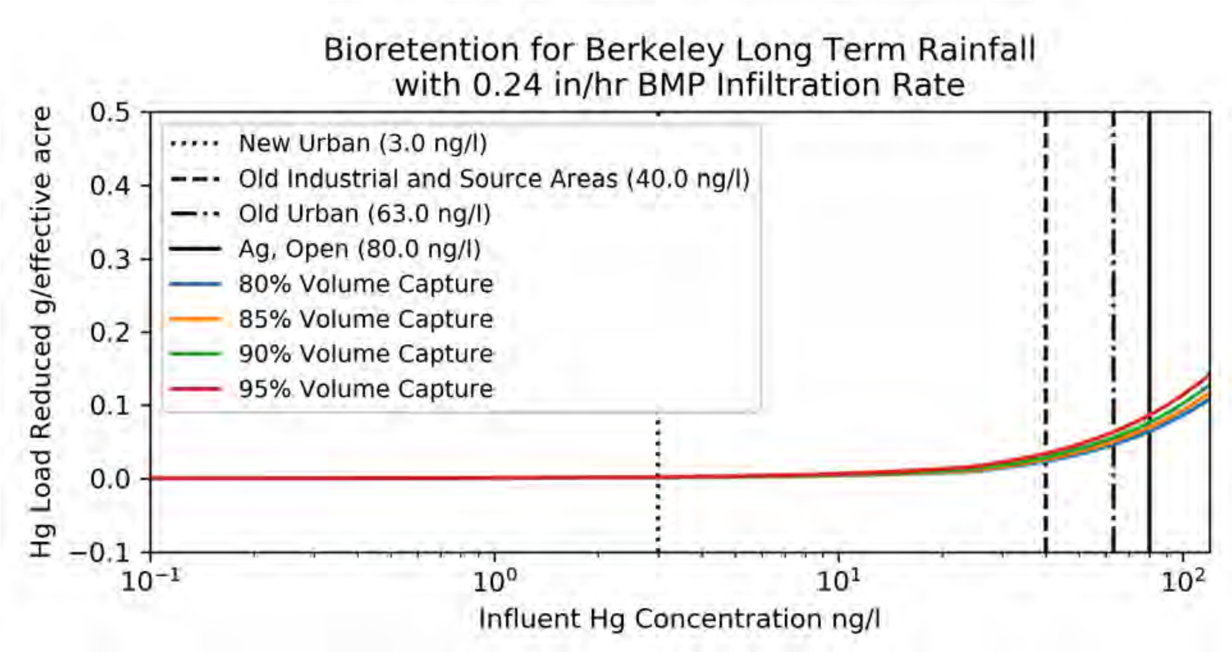

Figure 8: Modeled Mercury Load Removal Performance for Bioretention Basin with Elevated Underdrain

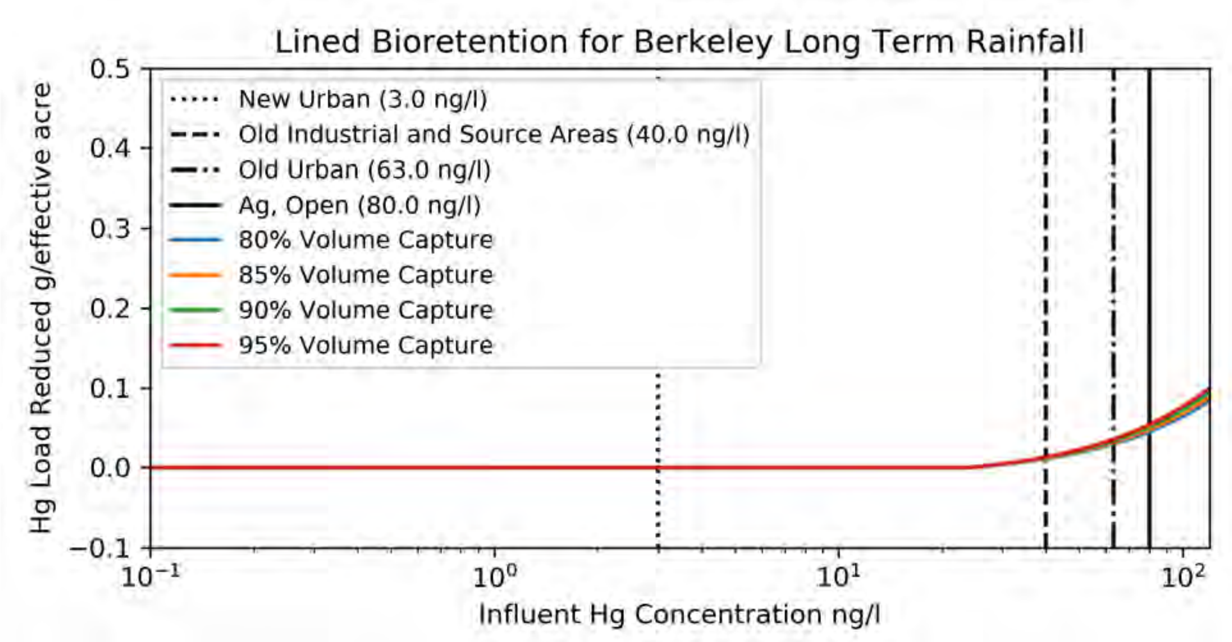

Figure 9: Modeled Mercury Load Removal Performance for Lined Bioretention Basin with Underdrain

The intersection points between the load reduction series and the constant influent lines represent the load reduced in grams per acre for each specific RWSM land use category. These intersection points are summarized in Table 12.

Table 12: Mercury Load Reduction for RWSM Land Use Categories for Berkeley Gauge for Different BMP Percent Capture Values

Facility Configuration	Land Use Category	Mercury Load Reduced (g/effective acre)			
		80% Capture[1]	85% Capture[1]	90% Capture[1]	95% Capture[1]
Infiltrating Bioretention (0.5 underlying infiltration rate)	New Urban	0.00467	0.00495	0.00524	0.00541
	Old Industrial and Source Areas	0.0623	0.066	0.0698	0.0722
	Old Urban	0.0981	0.104	0.110	0.114
	Ag, Open	0.125	0.132	0.140	0.144
Bioretention with Raised Underdrain (0.24 underlying infiltration rate)	New Urban	0.00113	0.0013	0.00153	0.00192
	Old Industrial and Source Areas	0.0234	0.0258	0.029	0.0341
	Old Urban	0.0462	0.0503	0.0556	0.0634
	Ag, Open	0.0643	0.0696	0.0765	0.0862
Lined Bioretention	New Urban	0	0	0	0
	Old Industrial and Source Areas	0.0108	0.0115	0.0123	0.0130
	Old Urban	0.0296	0.0314	0.0335	0.0353
	Ag, Open	0.0449	0.0476	0.0507	0.0536

[1] Average Annual Facility Volumetric Runoff Capture

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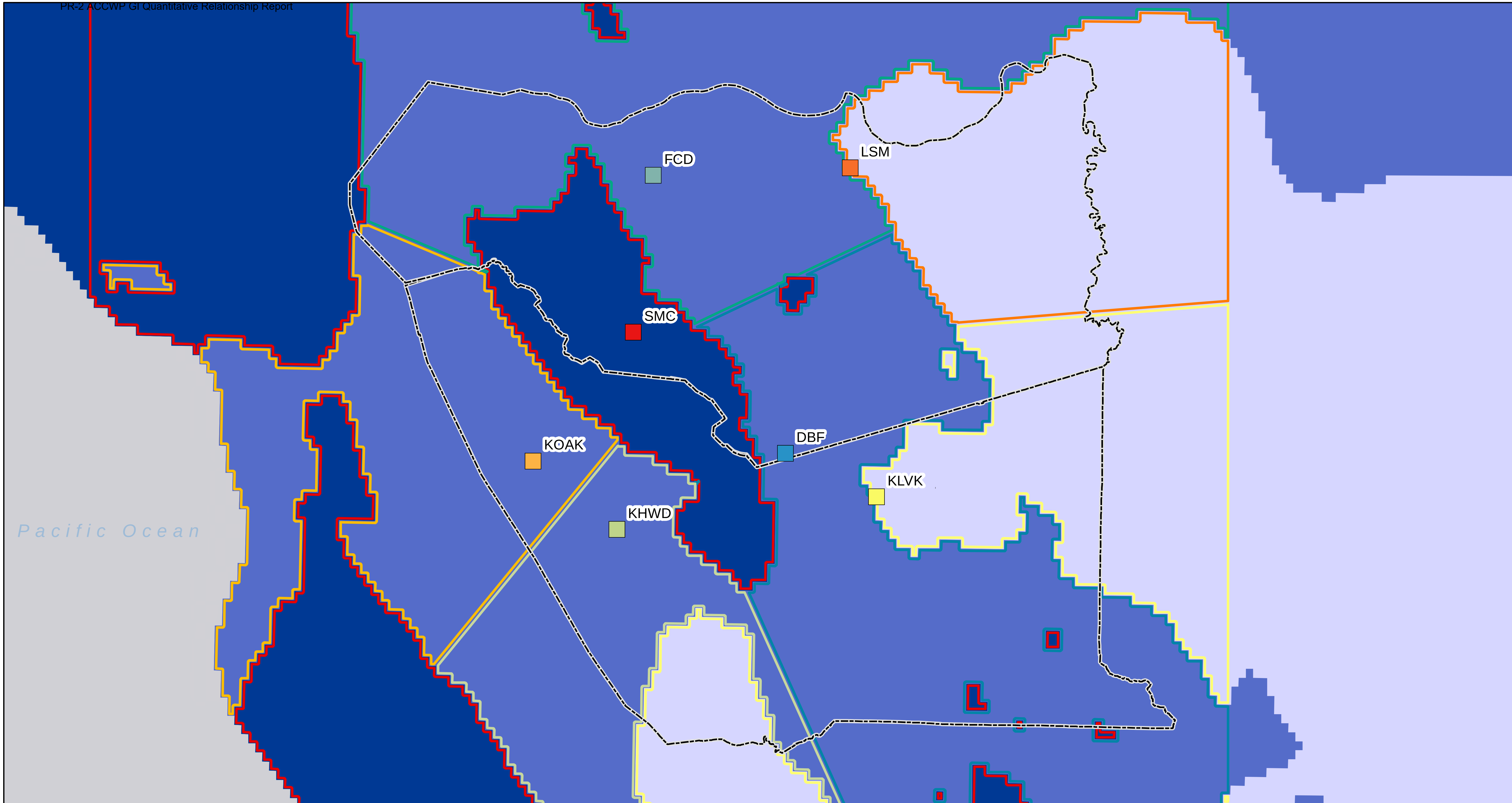
APPENDIX A

Modeling Inputs and Data Exhibits



Rain Gauge ID
- Rain Gauge ID
- County Boundary

Mean Annual Precipitation (in)
- < 16
- 16 - 25
- > 25

Rain Gauge Zones
- DBF
- FCD
- KHWD
- KLVK
- KOAK
- LSM
- SMC

N

0 6 12 Miles

Precipitation Zones for Baseline Runoff Period (WY 2000-2009)

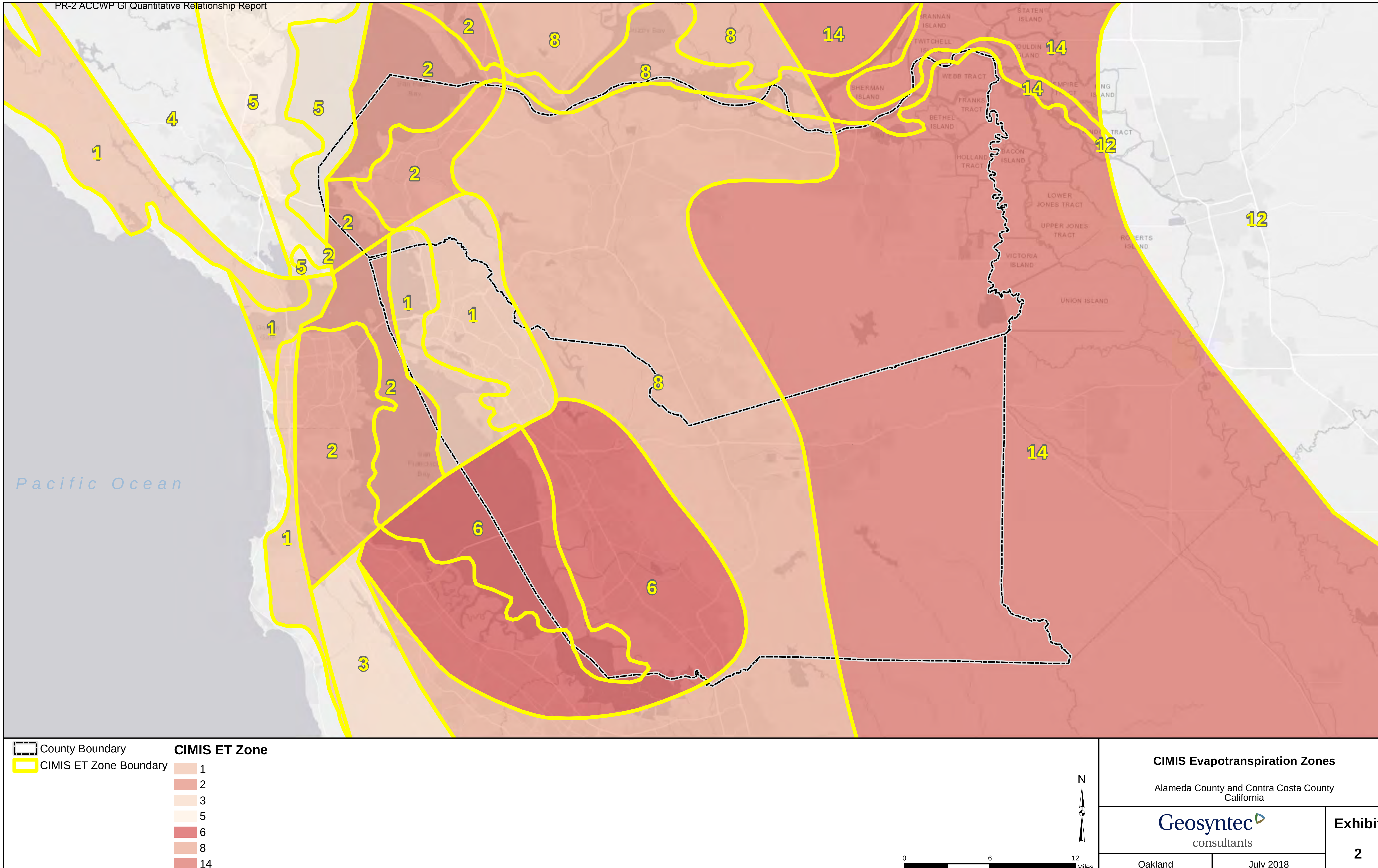
Alameda County and Contra Costa County
California

Geosyntec consultants

Exhibit

1

Oakland | July 2018



CIMIS Evapotranspiration Zones

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 2

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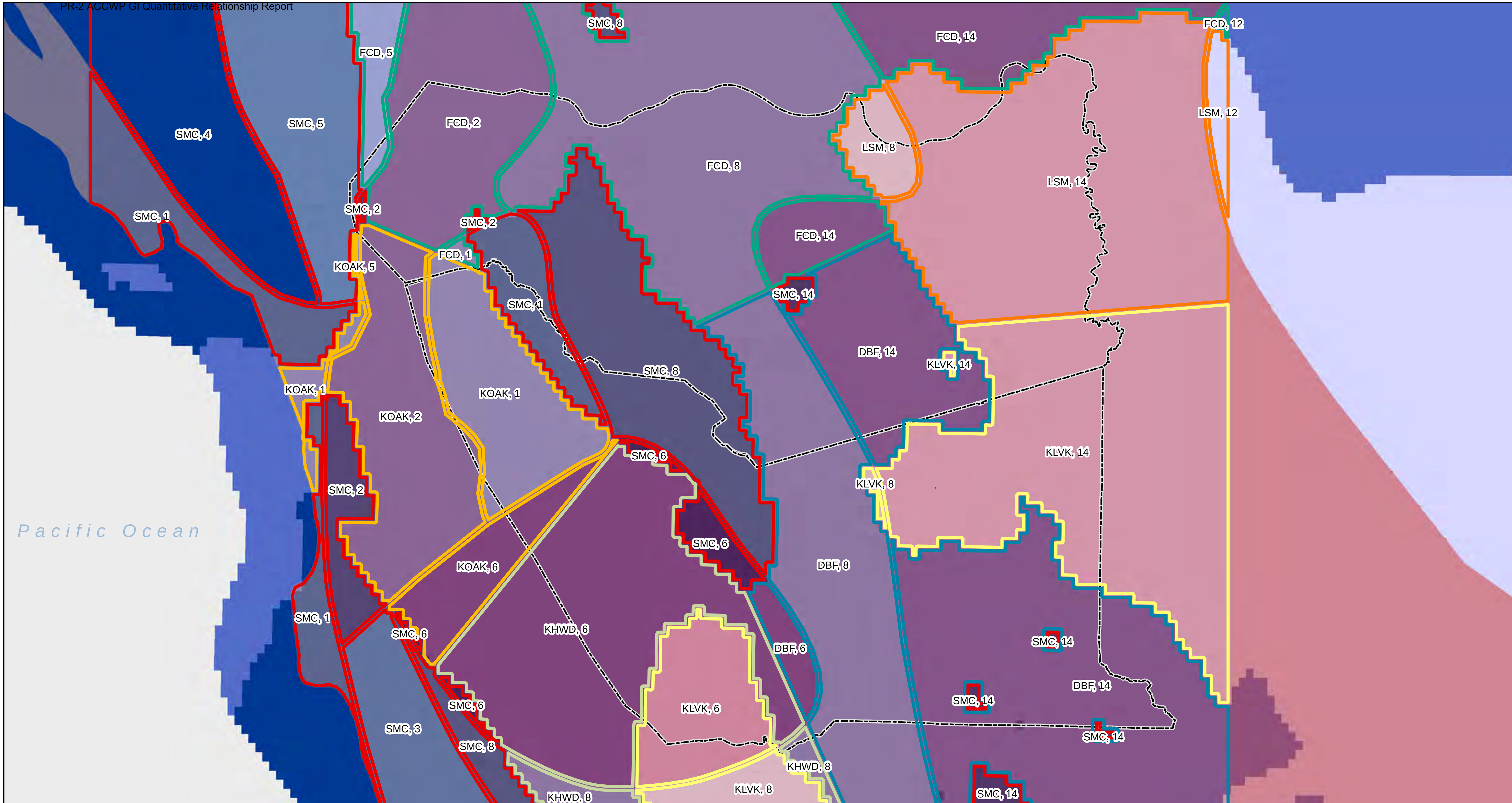

County Boundary

Mean Annual Precipitation (in)

- < 16
- 16 - 25
- > 25

CIMIS ET Zone

- 1
- 2
- 3
- 5
- 6
- 8
- 14

Climate Zones are created by overlapping precipitation zones and ET zones.The unique climate zones that occur in Contra Costa and Alameda County are labeled as "Gauge ID, ET Zone".

N

0 6 12 Miles

Climate Zones for Baseline Runoff Period (WY 2000-2009)

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 3

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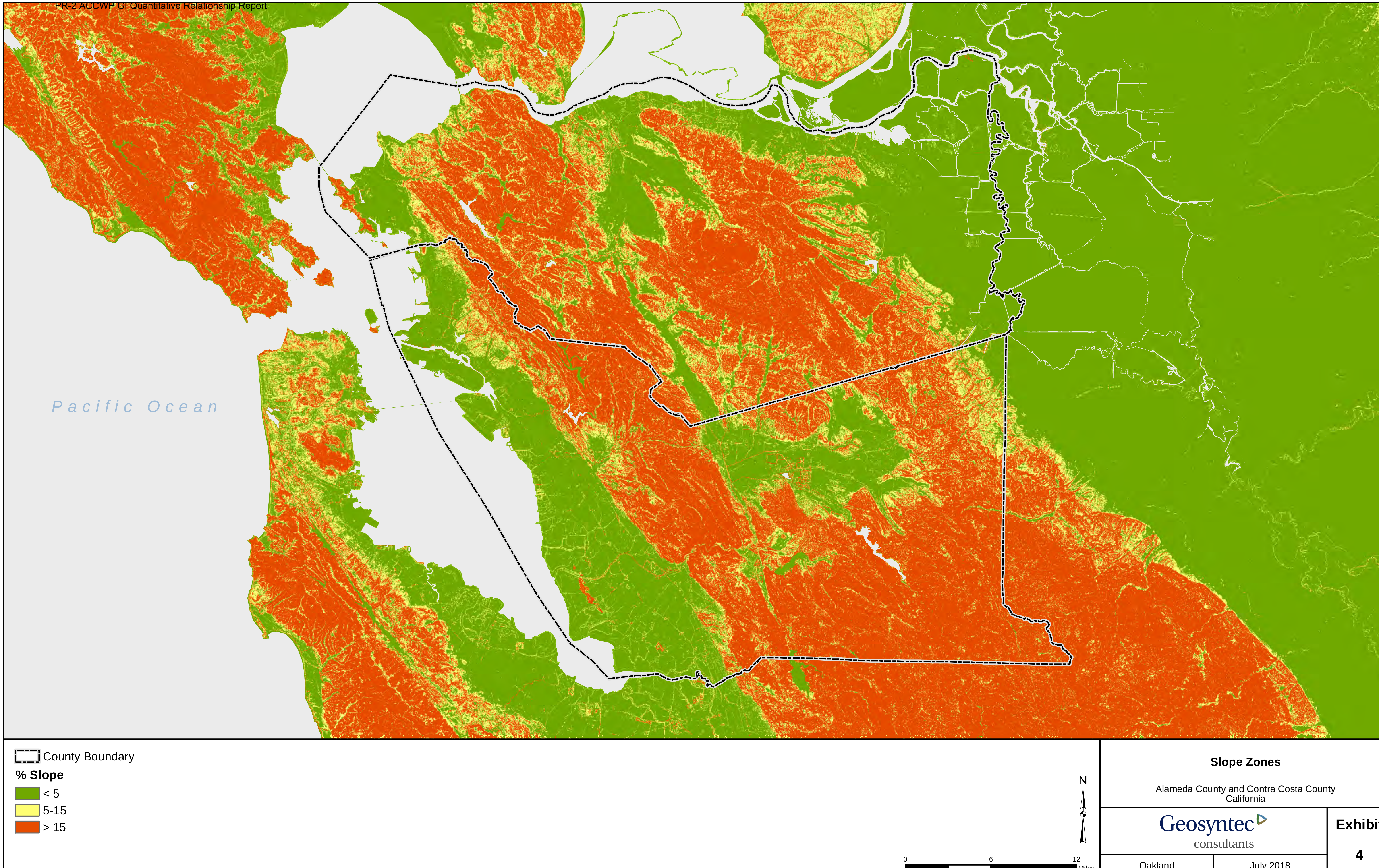

Slope Zones

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 4

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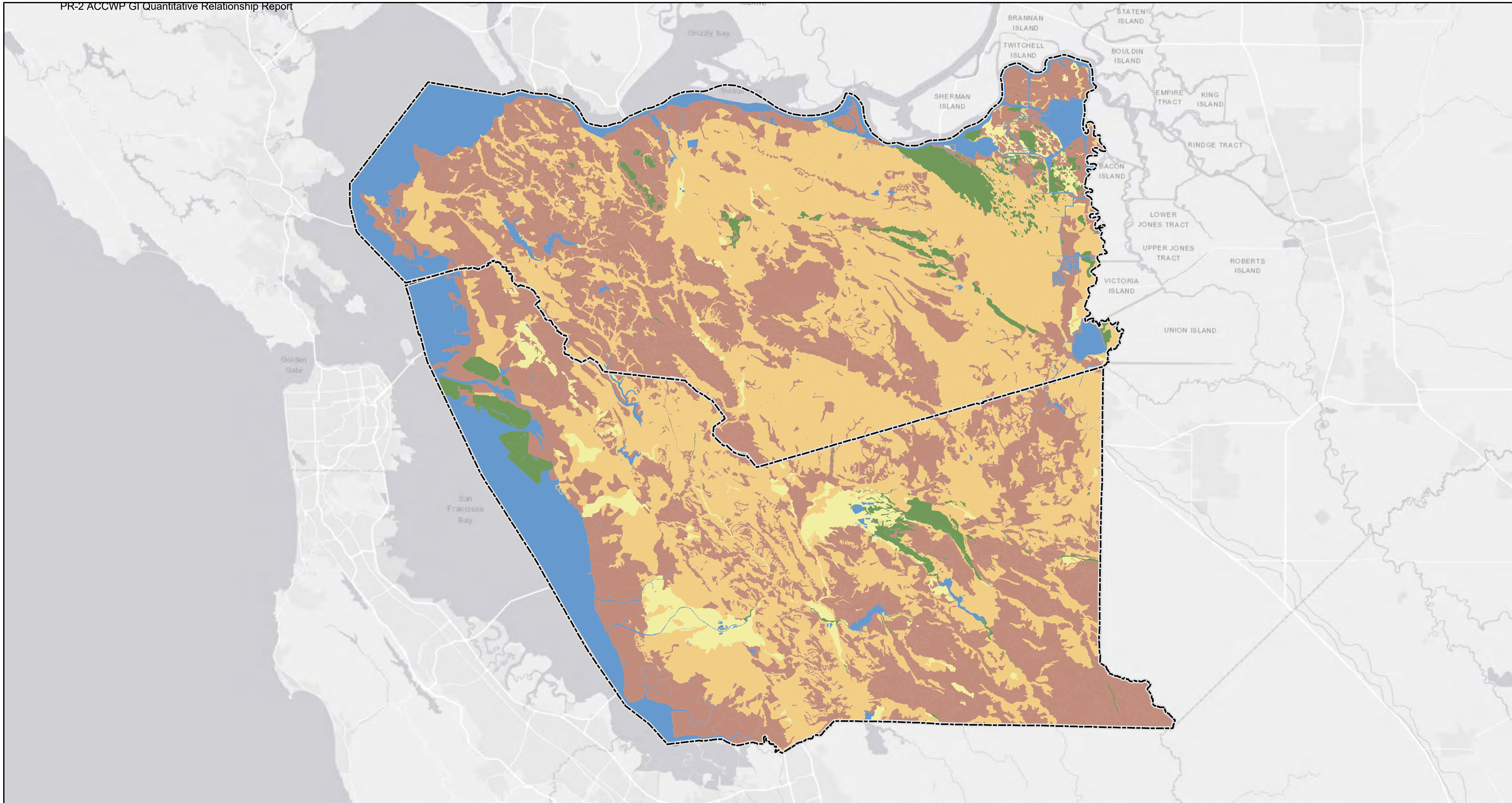

Note: Area within the county with no HSG assignment was assigned the HSG of the most prominant adjacent soil group.

Hydrologic Soil Group

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 5

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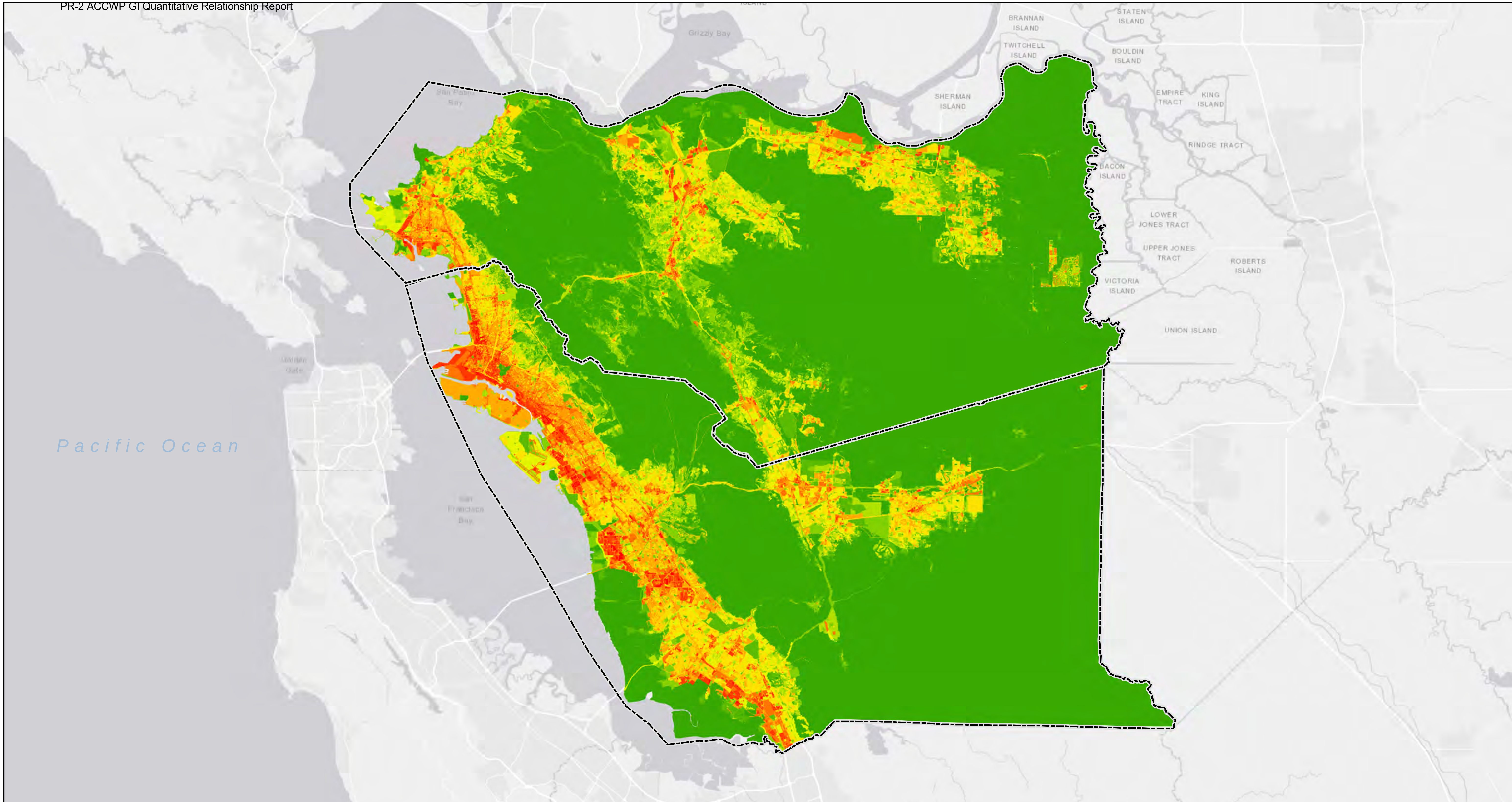

County Boundary

ABAG 2005 Imperviousness

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

Note:
Imperviousness is assigned to ABAG 2005 landuse based on the NLCD 2006 Impervious Cover layer. These values may be adjusted during calibration for certain categories of ABAG landuse.

For purposes of calculating runoff from areas with compacted soil, developed areas and agricultural uses were assumed to be compacted to 0.75 times the underlying saturated soil conductivity (ksat). These areas generally have percent imperviousness > 20%.

N

0 6 12 Miles

Regional Imperviousness

Alameda County and Contra Costa County
California

Geosyntec consultants

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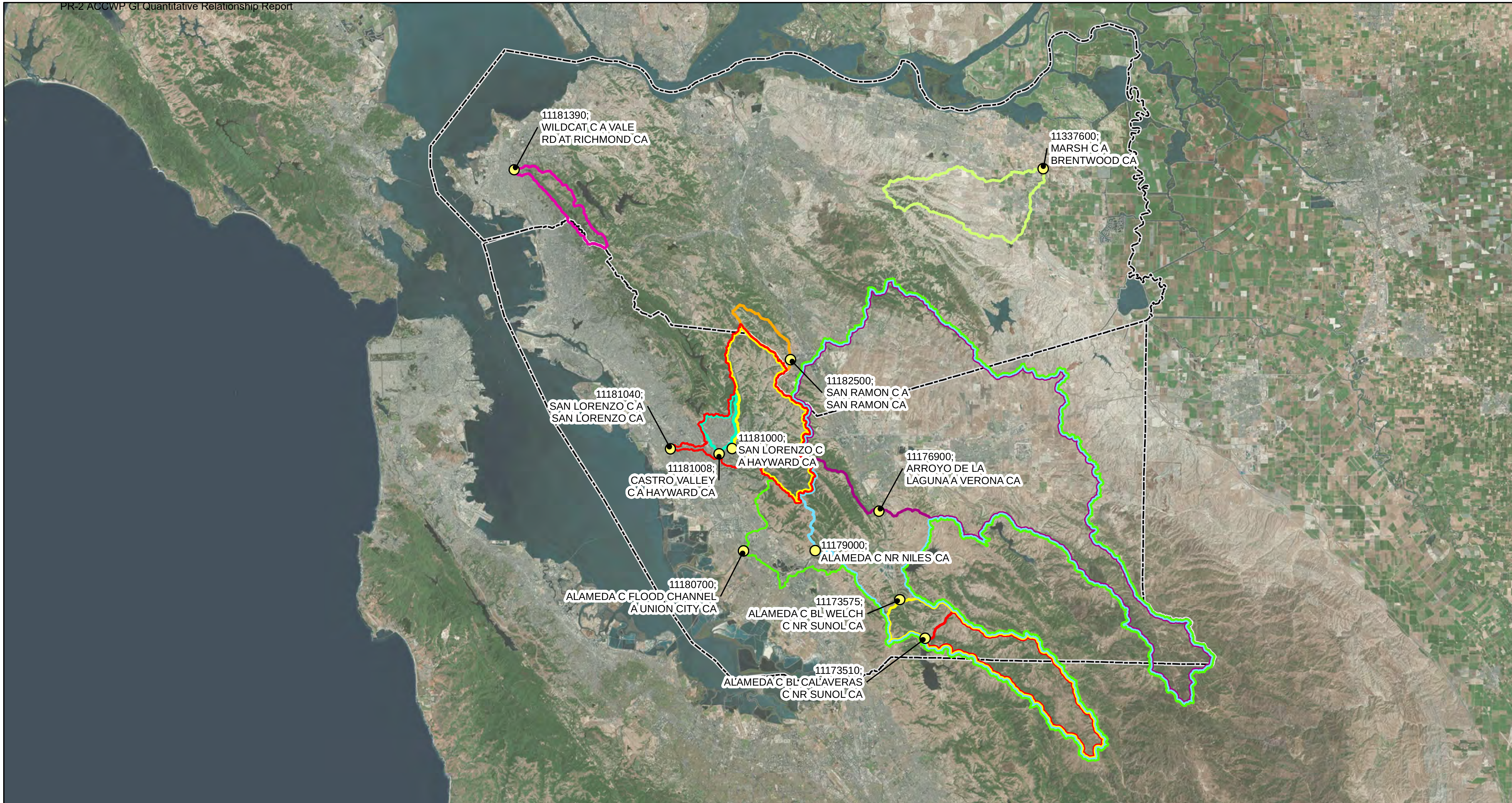
Exhibit

6

P:\GIS\Bay_Area_RAA\Project\GI_Load_Reduced_Report_Exhibits\Exhibit_6_Imperv_dev_undev.mxd 8/1/2018 10:14:41 AM



	Group 1	Group 2	Group 3	Group 4	Group 4
County Boundary	11181040	11180700	11182500	11337600	11181390
Gauge Location	11181000	11179000			
	11181008	11173575			
		11176900			
		11173510			

N

0 6 12 Miles

Candidate Calibration Watersheds

Alameda County and Contra Costa County
California

Geosyntec consultants

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Exhibit 7

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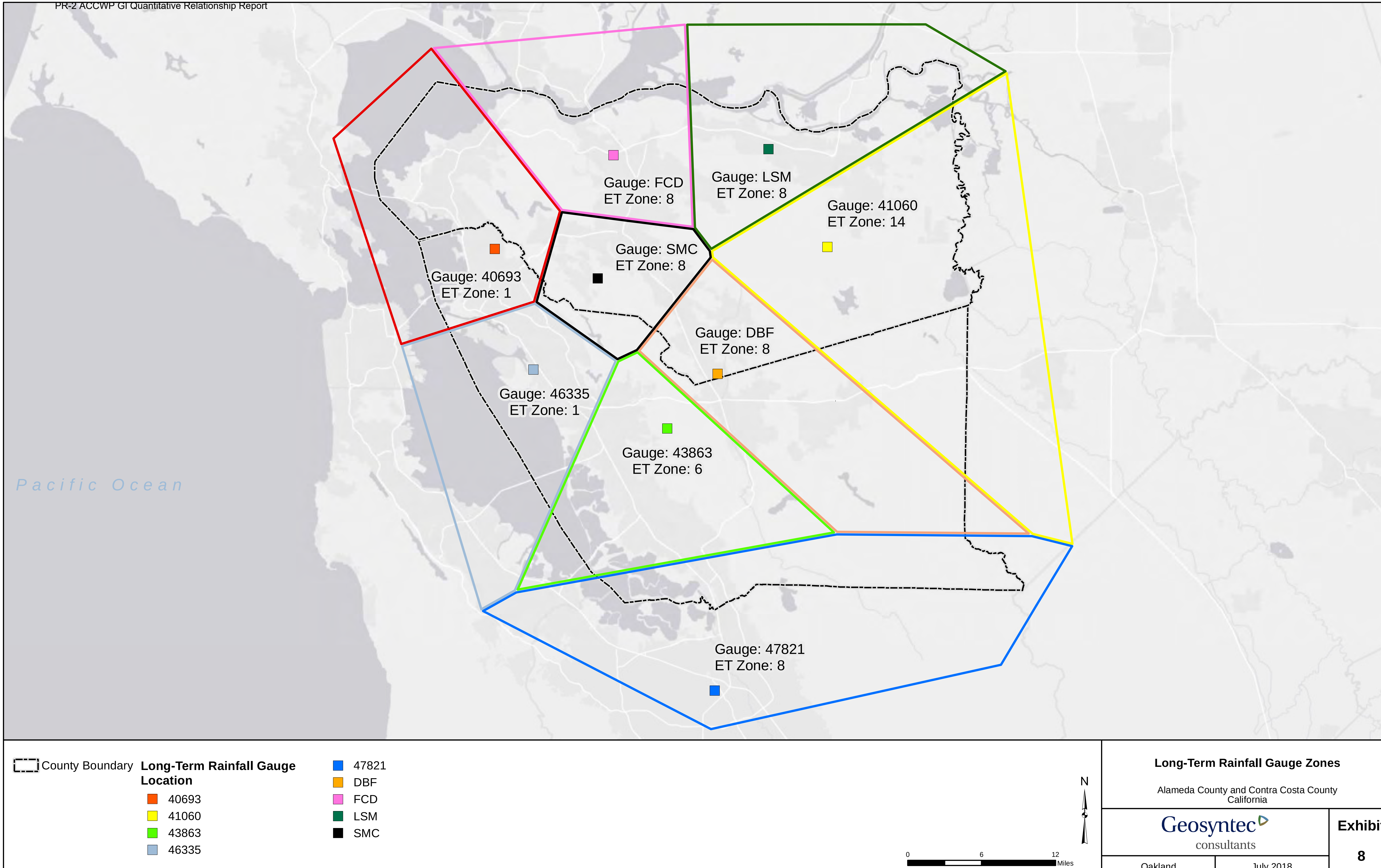


Long-Term Rainfall Gauge Zones

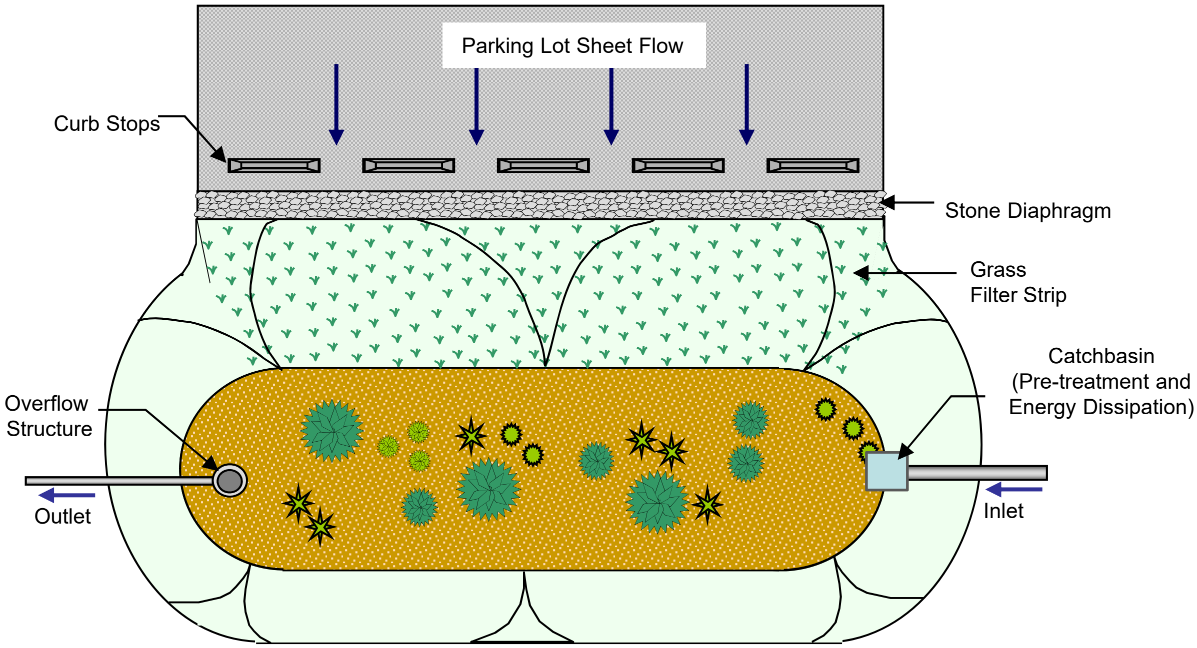
Alameda County and Contra Costa County
California

Geosyntec consultants

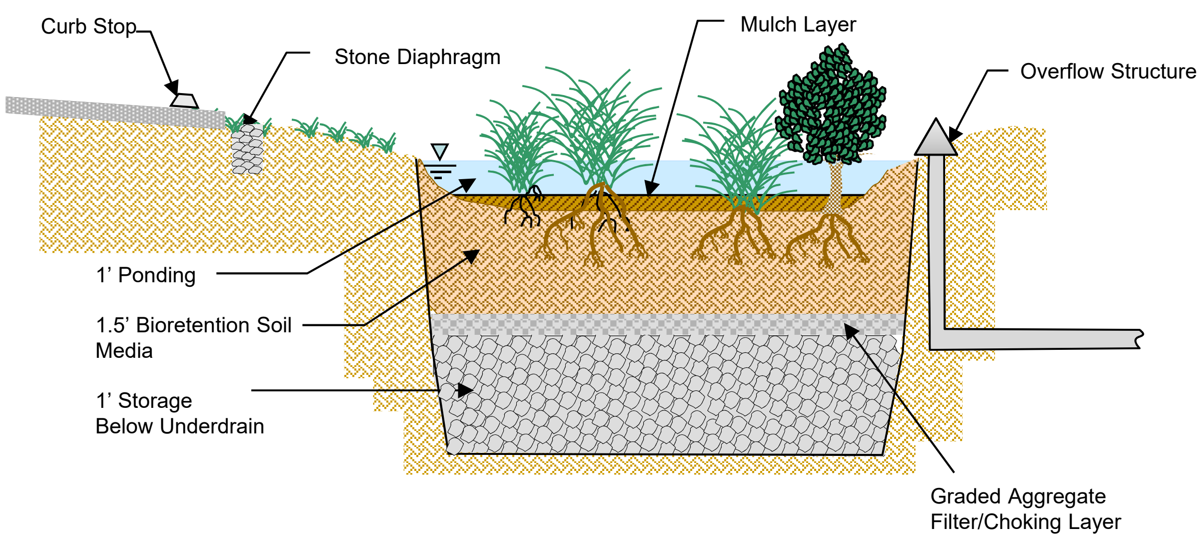
Oakland | July 2018

Exhibit 8

Plan View



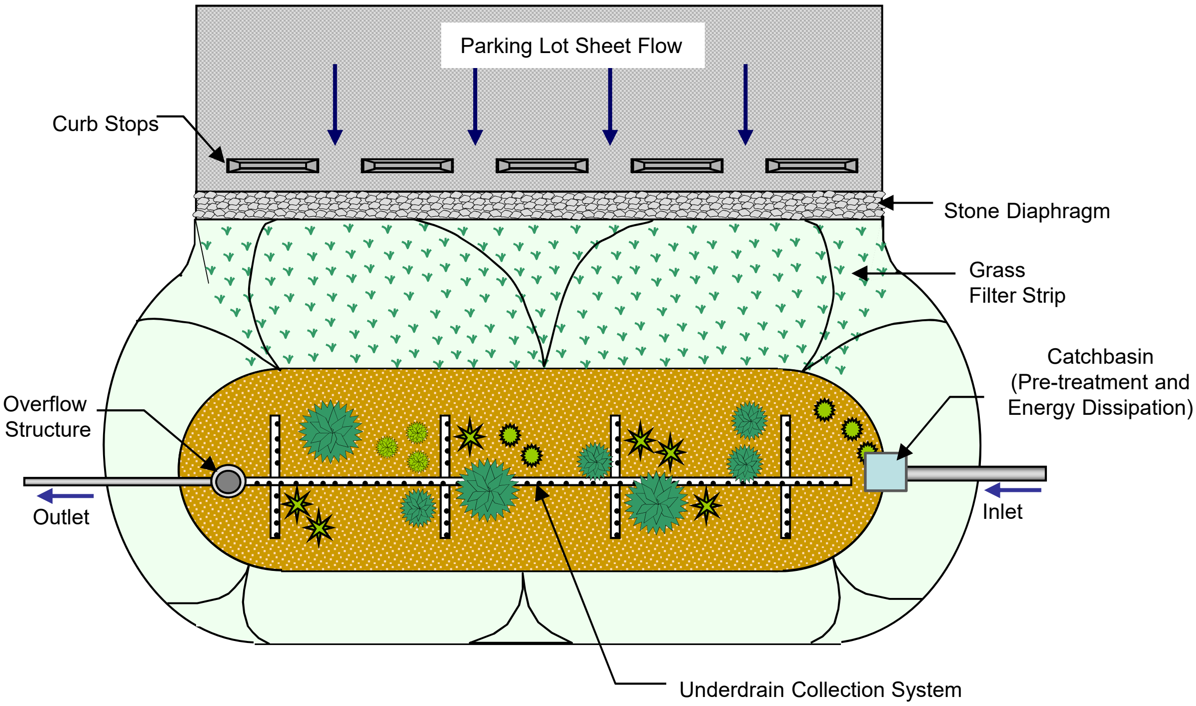
Profile



Note: Plan and Profile views are not to scale

Conceptual Illustration of an Infiltration Facility		
Geosyntec consultants		Exhibit 9
Oakland	July 2018	

Plan View



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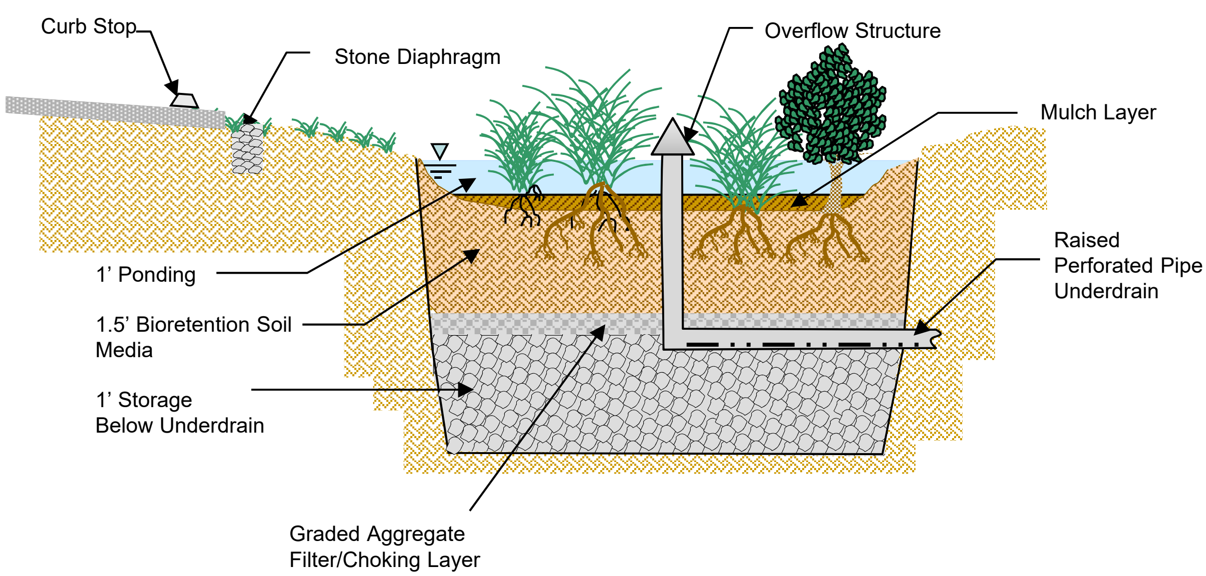
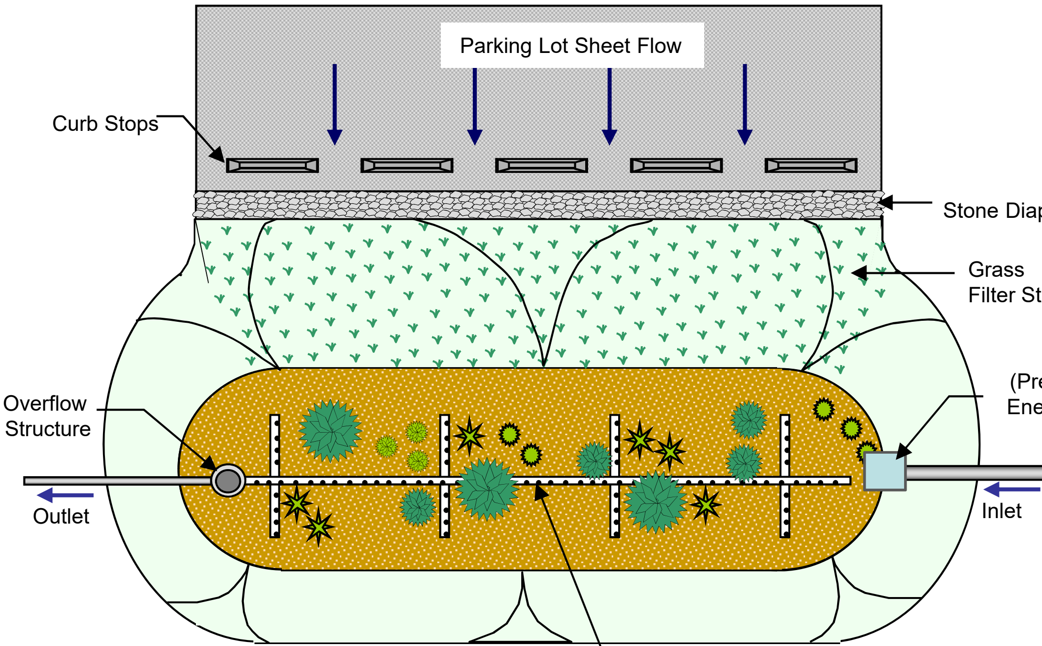


Note: Plan and Profile views are not to scale

Conceptual Illustration of a Bioretention/Bioinfiltration Facility		
Geosyntec consultants		Exhibit 10
Oakland	July 2018	

Plan View



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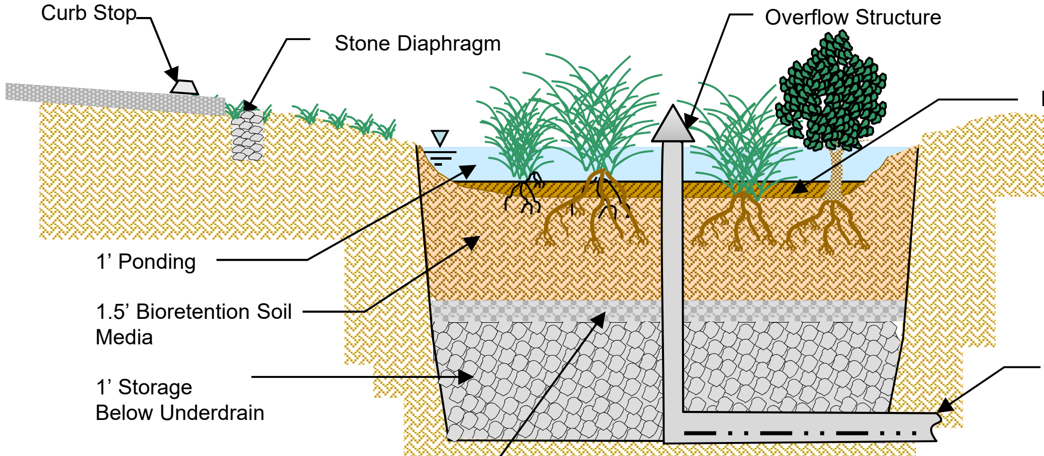

Note: Plan and Profile views are not to scale

Conceptual Illustration of a Biofiltration Facility		
Geosyntec consultants		Exhibit 11
Oakland	July 2018	

PR-3 Contra Costa Clean Water Program GI Quantitative Relationship Report

QUANTITATIVE RELATIONSHIP BETWEEN GREEN INFRASTRUCTURE IMPLEMENTATION AND PCBs/MERCURY LOAD REDUCTIONS

Submitted in Compliance with Provisions C.11.b.iii.(3), C.11.c.iii.(3), C.12.b.iii.(3), and C.12.c.iii.(1)

Municipal Regional Stormwater Permit
NPDES Permit No. CAS612008
Order No. R2-2015-0049

August 22, 2018

The Contra Costa Clean Water Program – A Municipal Stormwater Program consisting of Contra Costa County, its 19 Incorporated Cities/Towns, and the Contra Costa County Flood Control & Water Conservation District

This report is submitted by the agencies of the

Program Participants:

- Cities of: Antioch, Brentwood, Clayton, Concord, Danville (Town), El Cerrito, Hercules, Lafayette, Martinez, Moraga (Town), Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon and Walnut Creek
- Contra Costa County
- Contra Costa County Flood Control & Water Conservation District

Contra Costa Clean Water Program
255 Glacier Drive
Martinez, CA 94553-482

Tel (925) 313-2360
Fax (925) 313-2301

Website: www.cccleanwater.org

Report Prepared By:

Geosyntec Consultants

on behalf of the
Contra Costa Clean Water Program

LIST OF ACRONYMS

ASOS	Automated Surface Observation System
BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practices
CCCWP	Contra Costa Clean Water Program
CIMIS	California Irrigation Management Information System
GI	Green Infrastructure
GIS	Geographic Information System
HRU	Hydrologic Response Unit
KTRL	Kendall-Theil Robust Line
MAD	Median Absolute Deviation
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
ng/kg	nanogram per kilogram
NPDES	National Pollutant Discharge Elimination System
PCBs	Polychlorinated Biphenyls
RAA	Reasonable Assurance Analysis
RMSE	Root Mean Square Error
ROW	Right-of-Way
RWSM	Regional Watershed Spreadsheet Model
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SWMM	Stormwater Management Model
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
WY	Water Year

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1. INTRODUCTION

1.1 Purpose

This *Quantitative Relationship between Green Infrastructure Implementation and PCBs/Mercury Load Reductions* report was prepared by the Contra Costa Clean Water Program (CCCWP) per the Municipal Regional Permit (MRP) for urban stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB; Order No. R2-2015-0049). This report fulfills the requirements of MRP Provisions C.11.b.iii.(3), C.11.c.iii.(3), C.12.b.iii.(3), and C.12.c.iii.(1) for submitting the quantitative relationship between green infrastructure (GI) implementation and PCBs load reductions that will be used for the Reasonable Assurance Analysis (RAA) required by MRP Provisions C.11.c.ii.(2), C.11.d.ii, C.12.c.ii.(2), and C.12.d.ii.

This report was prepared in cooperation with the Alameda Countywide Clean Water Program. The RAA modeling described herein will be conducted for both countywide programs and will use data inputs from both Contra Costa County and Alameda County.

1.2 Background

1.1.1 <u>PCBs and Mercury Total Maximum Daily Loads</u>

Fish tissue monitoring in San Francisco Bay has revealed bioaccumulation of PCBs, mercury, and other pollutants. The levels found are thought to pose a health risk to people consuming fish caught in the Bay. As a result of these findings, California has issued an interim advisory on the consumption of fish from the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act "Section 303(d) list" due to PCBs and mercury. In response, the SFBRWQCB has developed Total Maximum Daily Load (TMDL) water quality restoration programs targeting PCBs and mercury in the Bay. The general goals of the TMDLs are to identify sources of PCBs and mercury to the Bay and implement actions to control the sources and restore water quality.

Municipal separate storm sewer systems (MS4s) are one of the PCBs and mercury source/pathways identified in the TMDL plans. Local public agencies (i.e., Permittees) subject to requirements via National Pollutant Discharge Elimination System (NPDES) permits are required to implement control measures in an attempt to reduce PCBs and mercury from entering stormwater runoff and the Bay. These control measures, also referred to as Best Management Practices (BMPs), are the tools that Permittees can use to assist in restoring water quality in the Bay.

1.1.2 Municipal Regional Permit

NPDES permit requirements associated with Phase I municipal stormwater programs and Permittees in the Bay area are included in the MRP, which was issued to 76 cities, counties and flood control districts in 2009 and revised in 2015[1]. The MRP includes provisions to reduce loads of mercury and PCBs consistent with the TMDL implementation timeframe (Provisions C.11 and C.12, respectively) through implementation of GI projects (Provisions C.3.j, C.11.c, and C.12.c) and source controls (Provisions C.11.d and C.12.d).

The Permittees are reporting load reductions achieved before and during the current MRP term (2014 – 2020) using the approved Interim Accounting Methodology (BASMAA, 2017). MRP Provisions C.11.b.iii.(3) and C.12.b.iii.(3) requires the Permittees to report in the 2018 and subsequent Annual Reports any refinements to the Interim Accounting Methodology to be used in subsequent Permit terms. As part of this reporting requirement, Provision C.11.c.iii.(3) and C.12.c.iii.(1) requires the Permittees to report on the quantitative relationship between GI implementation and PCBs and mercury load reductions, including all data used and a full description of models and model inputs relied on to establish this relationship.

Green Infrastructure Planning and RAA

MRP Provision C.3.j requires the Permittees to develop a Green Infrastructure Plan for inclusion in the 2019 Annual Report. The Green Infrastructure Plan must be developed using a mechanism

[1] The cities of Antioch, Brentwood, and Oakley, and the eastern portions of unincorporated Contra Costa County and the Contra Costa County Flood Control & Water Conservation District (the East County Permittees) are located within the jurisdiction of the Central Valley Water Board and are covered under a separate Joint Municipal NPDES Permit titled “East Contra Costa County Municipal NPDES Permit” (East County Permit), which was last reissued in September 2010 (NPDES Permit No. CAS083313, Order No. R5-2010-0102). The East County Permit expired on September 1, 2015; however, it remains in force and effect until a new permit is reissued. In October 2016, the East County Permittees requested that the Central Valley Water Board designate the San Francisco Bay Water Board as the permitting authority for MS4 discharges in eastern Contra Costa County. In response to this request, the Central Valley Water Board provided a letter, dated January 6, 2017, that documents written agreement by both Water Boards to designate the San Francisco Bay Water Board to regulate MS4 discharges from the East County Permittees under MRP 2.0 and any successor orders. This East County Permittees are implementing PCBs and mercury control measures and this document reports those implementation efforts and the associated load reductions.

to prioritize and map areas for potential and planned GI projects, both public and private, on a drainage-area-specific basis, for implementation by 2020, 2030, and 2040.

MRP Provisions C.11.c and C.12.c require the Permittees to prepare an RAA for inclusion in the 2020 Annual Report that quantitatively demonstrates that specified mercury and PCBs load reductions will be achieved by 2040 through implementation of GI.

This RAA should do the following:

1. Quantify the relationship between the areal extent of GI implementation (e.g., acres treated) and mercury and PCBs load reductions. This quantification should take into consideration the scale of contamination of the treated area as well as the pollutant removal effectiveness of GI strategies likely to be implemented.
2. Estimate the amount and characteristics of land area that will be treated by GI by 2020, 2030, and 2040.
3. Estimate the amount of mercury and PCBs load reductions that will result from GI implementation by 2020, 2030, and 2040.
4. Ensure that the calculation methods, models, model inputs, and modeling assumptions used have been validated through a peer review process.

Additionally, MRP Provisions C.11.d. and C.12.d. require the Permittees to prepare plans and implementation schedules for mercury and PCBs control measures and an RAA demonstrating that sufficient control measures will be implemented to attain the mercury TMDL wasteload allocations by 2028 and the PCBs TMDL wasteload allocations by 2030. The implementation plans, which will also be included in the 2020 Annual Report, along with the GI-based RAA outlined above, must:

1. Identify all technically and economically feasible mercury or PCBs control measures (including GI projects, but also other control measures such as source property identification and abatement, managing PCBs in building materials during demolition, enhanced operations and maintenance, and other source controls) to be implemented;
2. Include a schedule according to which technically and economically feasible control measures will be fully implemented; and
3. Provide an evaluation and quantification of the mercury and PCBs load reduction of such measures as well as an evaluation of costs, control measure efficiency, and significant environmental impacts resulting from their implementation.

This report presents the quantitative relationship between GI implementation and PCBs and mercury load reductions, including the data used and a full description of models and model inputs relied on to establish this relationship. This relationship will be used to predict loads reduced through GI implementation for the RAAs described above and to report loads reduced through GI implementation in the subsequent Permit term.

2. DESCRIPTION OF RAA MODEL

This section provides an overview of the RAA modeling framework and describes the output of each component.

2.1 RAA Model Overview

The approach used to estimate the load reductions resulting from implementation of GI includes the model components listed below, which are described in further detail in the following sections:

- Baseline Pollutant Loading Model – the baseline pollutant loading model is a continuous simulation[2] hydrology model combined with pollutant loading inputs to obtain the average annual loading of mercury and PCBs across the county during the TMDL baseline period (i.e., 2003 – 2005).
    - Hydrology – this model component produces average annual runoff across each county for the period of record using a hydrologic response unit (HRU) approach. The HRU approach involves modeling various combinations of land surface features (i.e., imperviousness, underlying soil characteristics, slope, etc.) present within each county for a unit area drainage catchment. See Section 2.2.1.
    - Water Quality – the hydrology output is combined with average annual concentrations estimated by the Regional Monitoring Program's Regional Watershed Spreadsheet Model (RWSM; Wu et al, 2017) developed by the San Francisco Estuary Institute (SFEI) to produce average annual PCBs and mercury loading for the period of record. See Section 2.2.2.

[2] Continuous simulation models calculate outputs (e.g., runoff) "continuously", i.e., for many time steps over a long-term period of record (e.g., every 10 minutes for 10 years). Long-term "continuous" input data (e.g., hourly rainfall) is required. This is contrasted with design-event simulations which model a single rainfall event, e.g., a 24-hour storm with a 10-year recurrence frequency.

- GI Performance Models – the GI performance models are developed to represent load reductions resulting from implementation of GI. See Section 2.3.
- Future Condition (RAA Scenario) Models – the RAA scenario models are conducted to represent future land use changes and control measure implementation that could result in pollutant load reduction. Both GI and source controls are considered, depending on the time frame of interest. See Section 2.4 for a description of load reduction calculations.

2.2 Baseline Loading Model

2.2.1 Hydrologic Model

As introduced above, the proposed approach for modeling hydrology is to use a hydrologic response unit (HRU) approach. An HRU is a unique combination of land surface features (imperviousness, underlying soil characteristics, slope, etc.) which is expected to give a consistent runoff response to rainfall, no matter where that unique combination is found. The HRU approach involves modeling all possible combinations of land surface features present within each county for a unit area drainage catchment and then storing these results in a database. These HRU results can been be scaled geospatially across the entire county without developing a detailed hydrologic model. This method is consistent with the *Bay Area RAA Guidance Document* (BASMAA, 2017b).

The generic HRUs are modeled using USEPA's Stormwater Management Model (SWMM) to obtain an average annual runoff volume per acre for the identified baseline period of record (water year [WY] 2000 – 2009) for each HRU. Certain HRU inputs (imperviousness, soil parameters) are adjusted as needed to calibrate the HRUs on an average annual basis to identified flow gauges in the counties.

The average annual runoff volume per acre associated with a specific HRU can then be multiplied by the area represented by that HRU across each county (or a selected smaller planning area, such as a watershed or jurisdictional boundary). The resulting volumes associated with each represented HRU within the specified geospatial area can then be summed for the identified area to obtain the estimated total average annual runoff volume.

2.2.2 Water Quality Model

Identified HRUs across each county are combined with the RWSM land use classifications layer to determine pollutant loading rates. The RWSM provides average annual concentrations of PCBs and mercury that wash off from various land use categories. On an average annual basis, this approach approximates the total load.

Average annual runoff volume associated with the geospatial HRUs is multiplied by the PCBs and mercury average annual concentration (based on the RWSM land use categories for the identified area) to obtain average annual pollutant load using the following equation:

$$Load_{Baseline} = \sum\left(\sum Unit\ Runoff_{HRU} \times Area_{LU,HRU}\right) \times Concentration_{LU} \times 0.00123 \qquad \text{Eqn. 1}$$

Where:

$Load_{Baseline}$	=	The total average annual baseline pollutant load for the identified area for calculation [grams/year]
$Unit\ Runoff_{HRU}$	=	The average annual runoff per acre for a given HRU within the identified area for calculation [ac-ft/acre/yr]
$Area_{LU,HRU}$	=	The total area of the HRU within the RWSM land use category within the identified area for calculation [acres]
$Concentration_{LU}$	=	The average annual pollutant concentration associated with the RWSM land use category [ng/L]
0.00123	=	Conversion factor [(L/ac-ft)*(g/ng)]

2.3 Green Infrastructure Performance Model

Volume reduction (via retention in the green infrastructure facility) and pollutant load reduction (via filtration through media and discharge through an underdrain) are modeled utilizing a combination of hydraulic modeling in SWMM and currently available empirical GI performance data.

2.3.1 Hydraulic GI Models

GI control measure hydraulic performance is modeled in SWMM with a 100% impervious tributary area for three GI facility types: (1) bioretention[3] with a raised underdrain, (2) bioretention with no underdrain, and (3) lined bioretention. The model is run with varying footprint sizes and varying underlying infiltration rates (i.e., the rate at which treated runoff infiltrates into native soils underlying the BMP facility). Average annual volume retained, volume treated, and volume bypassed by the GI measure are recorded for each GI model run.

Volume-based performance[4] corresponding to the generic 100% impervious tributary area can be applied to the effective area in GI drainage areas made up of identified HRUs. The effective area is also known as the "runoff generating area" and is calculated as the tributary area multiplied by the long-term or average annual runoff coefficient.

2.3.2 Green Infrastructure Pollutant Reduction Calculations

To calculate pollutant load reduction associated with GI implementation, the hydraulic model results are combined with water quality performance data. The annual estimate of pollutant load reduction from the modeled drainage area is equivalent to the difference between the influent load and the sum of the pollutant load that bypasses the GI measure and the effluent load (Eqn. 2). Equations corresponding to the pollutant reduction calculation are provided below and the water balance is illustrated in Figure 1. In summary, influent load is calculated as the pollutant load produced by the 100% impervious tributary area for each RWSM land use category using Eqn. 3. The pollutant load that bypasses the facility is calculated as the proportion of runoff that bypasses the facility per the hydraulic GI model output, multiplied by the influent concentration (Eqn. 4). The effluent load is calculated as the proportion of runoff that is captured by the facility per the hydraulic GI model output, combined with an effluent concentration (Eqn. 5 and Eqn. 6).

[3] The bioretention is assumed to include: 6-inch or 12-inch ponding depth, 1.5 ft of filter media with a 5 in/hr flow through rate, and 1 ft of gravel beneath the media.

[4] Volume-based performance refers to how much runoff volume the GI facility captures and retains or treats and discharges through the underdrain, typically represented as a percentage of the average annual runoff volume.

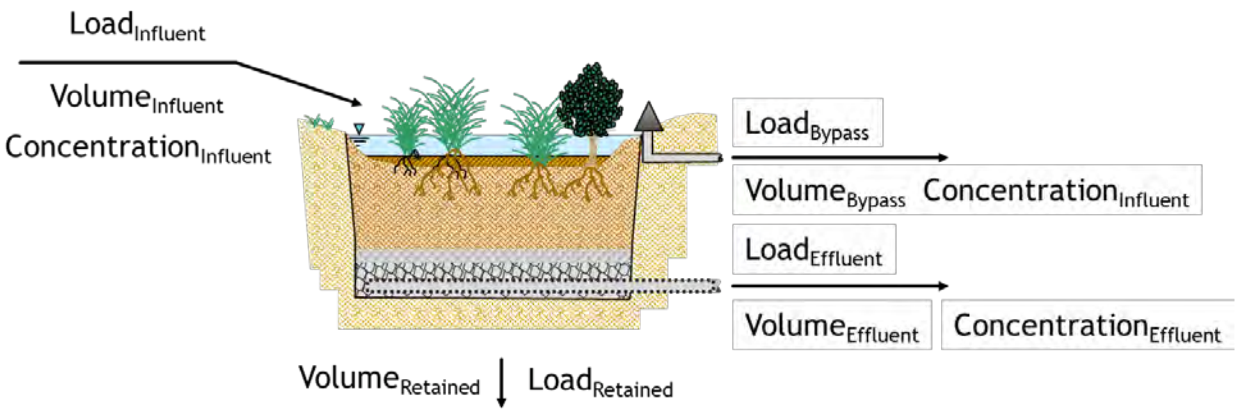

Figure 1: Illustration of GI Facility Pollutant Load Reduction Calculations

$$Load_{Reduced} = Load_{Influent} - Load_{Bypass} - Load_{Effluent} \quad \text{Eqn. 2}$$

$$Load_{Influent} = Volume_{Influent} \times Concentration_{Influent} \times C \quad \text{Eqn. 3}$$

$$Load_{Bypass} = Volume_{Bypass} \times Concentration_{Influent} \times C \quad \text{Eqn. 4}$$

$$Load_{Effluent} = (Volume_{Captured} - Volume_{Retained}) \times Concentration_{Effluent} \times C \quad \text{Eqn. 5}$$

$$Volume_{Captured} = Volume_{Influent} - Volume_{Bypass} \quad \text{Eqn. 6}$$

Where:

$Load_{Reduced}$ = The total average annual pollutant load reduced by the GI facility [g/year]

$Load_{Influent}$ = The total average annual pollutant load produced by the facility drainage area [g/year]

$Load_{Bypass}$ = The pollutant load that bypasses the facility [g/year]

$Load_{Effluent}$ = The pollutant load discharged from the facility after treatment [g/year]

$Volume_{Influent}$ = The runoff produced by the drainage area to the GI facility [ac-ft/year]

$Volume_{Bypass}$ = The proportion of influent runoff that bypasses the facility [ac-ft/year]

$Volume_{Captured}$	=	The proportion of influent runoff that is captured by the facility [ac-ft/year]
$Volume_{Retained}$	=	The proportion of captured runoff that is retained by the facility through infiltration and/or evapotranspiration [ac-ft/year]
$Concentration_{Influent}$	=	The pollutant concentration associated with the GI drainage area [ng/L]
$Concentration_{Effluent}$	=	The concentration discharged from the facility after treatment [ng/L]
C	=	Conversion factor constant = 0.00123 [(L/ac-ft)*(g/ng)]

2.4 RAA Scenario Loading Model

The loading corresponding with RAA future condition scenarios (2020, 2030, 2040) will be developed using the same volume and concentration combination approach used for the baseline condition. HRU outputs developed for the baseline model will scaled across the county corresponding to anticipated land use and development changes for each of the future conditions. Similarly, the RWSM land use classifications layer will be updated corresponding to each future condition scenario.

The outputs of the future hydrology scaling combined with the concentrations corresponding with future RWSM land use classification provides the land use-based loading estimated for each of the future conditions. To obtain the discharged load corresponding to each future GI scenario, load reductions associated with anticipated GI (developed as described above) will be subtracted from the land use-based load.

3. MODEL INPUTS AND DATA USED

This section describes the inputs to each component of the model and the data used.

3.1 Baseline Loading Model

3.1.1 Hydrologic Model

Generic HRU models are developed in SWMM to estimate average annual runoff volume per acre values that can be applied to all land surfaces within each county. The land surface feature inputs that will be varied to model the generic HRUs are described in the sections below and summarized in Table 3.

Climate Inputs

HRU climate inputs provide the total amount of precipitation that falls on the land surface and the amount of precipitation that is lost to the atmosphere via evapotranspiration before running off the land surface. Multiple gauges from across Alameda and Contra Costa counties that had continuous hourly precipitation data were chosen to represent distinct rainfall regions within both counties. For precipitation, these regions are based on 30-year annual rainfall regimes as identified by PRISM[5]. For evapotranspiration rates, the California Irrigation Management Information System (CIMIS) evapotranspiration zones were used within each county. The combination of the identified precipitation regions and evapotranspiration regions were combined to yield "climate zones" used for generic HRU models. Precipitation zones, evapotranspiration zones, and climate zones are shown in Exhibit 1 through Exhibit 3 (see Appendix A). Table 1 provides a summary of precipitation gauges used and average annual rainfall corresponding to the entire period of record and WY 2000 - 2009. Table 2 provides a summary of the CIMIS data used for the daily reference evapotranspiration rate for each evapotranspiration zone.

Table 1: HRU Precipitation Gauges WY2000-2009

Gauge ID	Gauge Name	Average Annual Precipitation (inches) WY 2000 - 2009	Gauge Source
KHWD	Hayward Air Terminal (ASOS)	16.3	ASOS[1]
KLVK	Livermore Municipal Airport (ASOS)	14.6	ASOS
KOAK	Oakland Airport (ASOS)	19.0	ASOS
DBF	Dublin Fire Station, San Ramon	17.3	CCCFCD[2]
FCD	Flood Control District, Martinez	16.2	CCCFCD
LSM	Los Medanos, Pittsburg	11.8	CCCFCD
SMC	Saint Mary's College, Moraga	28.9	CCCFCD

1. Automated Surface Observation System (ASOS) data were used for Alameda County gauge sites for the period of WY2000-2009 since NCDC gauge data was not available for the baseline period. ASOS sites sometimes co-occur with NCDC gauge sites (e.g., airports), but are maintained and delivered by separate government entities.
2. Contra Costa County gauge data is collected by the Flood Control District but was provided to Geosyntec by Dubin Engineering.

[5] Parameter-elevation Relationships on Independent Slopes Model (PRISM), developed and managed by the PRISM Climate Group, Oregon State University http://prism.oregonstate.edu/.

Table 2: CIMIS Reference Evapotranspiration

ET Zone	Monthly Evapotranspiration (in/day)[1]											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.03	0.05	0.08	0.11	0.13	0.15	0.15	0.13	0.11	0.08	0.04	0.02
2	0.04	0.06	0.1	0.13	0.15	0.17	0.16	0.15	0.13	0.09	0.06	0.04
3	0.06	0.08	0.12	0.16	0.17	0.19	0.18	0.17	0.14	0.11	0.08	0.06
6	0.06	0.08	0.11	0.16	0.18	0.21	0.21	0.2	0.16	0.12	0.08	0.06
8	0.04	0.06	0.11	0.16	0.2	0.23	0.24	0.21	0.17	0.11	0.06	0.03
14	0.05	0.08	0.12	0.17	0.22	0.26	0.28	0.25	0.19	0.13	0.07	0.05

1. CIMIS reference evapotranspiration, which is based on irrigated turf grass, was scaled by 0.6 to represent the local mix of vegetated cover including urban vegetation, native xeric adapted plants, and unirrigated vegetated open space areas.

Slope

Slope affects how quickly rainfall will run off a modeled land surface and therefore how much is able to be infiltrated into the subsurface. The available digital elevation model (DEM)[6] for the counties was analyzed to obtain percent slope values for each ~30m by ~30m square of land surface. These percent slope values were classified into three distinct slope zones as summarized in Table 3 and shown in Exhibit 4 (see Appendix A).

Underlying Soil Inputs

Physical characteristics of the soil underlying the land surface affect the amount of rainfall that may be infiltrated into the subsurface. Infiltration was simulated in SWMM using the Green-Ampt infiltration model option. The physical soil input parameters for the Green-Ampt infiltration model were varied based on hydrologic soil group (HSG) as identified by the National Resource Conservation Service (NRCS[7]) soil survey and were modified as described below for developed areas. Soil parameters used as model inputs include suction head, hydraulic conductivity, and initial moisture deficit. Developed areas that are assumed to have been compacted and therefore result in less infiltration to the subsurface are modeled using 75 percent of the HSG hydraulic conductivity value. Soil parameters are not reported here, as this input is adjusted as part of

[6] U.S. Geological Survey. National Elevation Dataset (NED) 1/3 arc-second. 2013

[7] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. link: https://websoilsurvey.sc.egov.usda.gov/

baseline model calibration. Details about soil inputs are provided in Table 3. A map of hydrologic soil group is provided as Exhibit 5 (see Appendix A).

Areas of development were identified based on the land use of the surface. Soils within urban and agricultural use areas were considered to have been compacted by the site preparation and activities.

Imperviousness

Imperviousness (i.e., the percentage of impervious area) affects area on the land surface where rainfall may be infiltrated and therefore the quantity of runoff produced. The runoff from a range of land use imperviousness values is modeled by area-weighting the results of a pervious surface runoff result (i.e., pervious HRU output) with a corresponding impervious surface runoff result (i.e., impervious HRU output) (see Table 3 and Exhibit 6 (see Appendix A)).

The baseline model HRU imperviousness is developed by geospatially combining the land uses identified by Association of Bay Area Governments (ABAG, 2005) with the National Land Cover Dataset (NLCD, 2006) data. Each feature of the ABAG dataset is assigned a single imperviousness value that is used to determine the average hydrologic response of that land surface. A lookup-table containing NLCD based imperviousness for each ABAG land use code was used as a starting value for HRU calibration. These initial values may be adjusted within an appropriate range as part of baseline model calibration.

3.1.2 Developing HRUs across each County

Each identified combination of land surface features is modeled for a generic unit-acre drainage area in SWMM for the baseline period of record (i.e., WY 2000 – 2009), utilizing a batch-processing method (which allows for inputs to be altered, model files run, and results extracted for many models automatically). The average annual runoff volume per acre is then extracted for each generic HRU modeled.

Table 3: Land Surface Feature Inputs for Generic HRU Hydrologic Models

Variables	Description	Number of Varying Features	Feature Representations	Source
Hourly Annual Precipitation	Rainfall Gauge and Rainfall Zone	7	Contra Costa County Gauges: DBF, FCD, LSM, SMC Alameda County ASOS Gauges: KHWD, KLVK, KOAK	PRISM[1], NCDC/ County-maintained rainfall gauges
Daily Evapotranspiration Rate	Evapotranspiration Zone	5	Zones 1, 2, 3, 6, 8, 14	CIMIS[2]
Slope Zone	Representation of Slope	3	<5%, 5-15%, 15%+	USGS[3]
Developed/ Undeveloped Areas	Representation of Compaction of Underlying Soils (Pervious Areas Only)	2	Undeveloped (Ksat * 1) Developed (Ksat * 0.75)	ABAG Land Use 2005[4]
Hydrologic Soil Group	Representation of Underlying Soil Type (pervious areas only)	6	HSG A, B, C, D[5], Rock, Water	NRCS[6]
Imperviousness	Representation of Imperviousness	2	0% and 100%	NLCD and ABAG 2005

1. PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, 30-year normal mean annual precipitation
2. California Irrigation Management Information System (CIMIS) Reference Evapotranspiration; digitized from http://www.cimis.water.ca.gov/App_Themes/images/etozonemap.jpg
3. U.S. Geological Survey. National Elevation Dataset (NED) 1/3 arc-second. 2013
4. ABAG land uses are proposed to be used for identifying developed and undeveloped condition and will have an imperviousness value assigned based on a geospatial analysis of the NLCD Imperviousness layer. The impervious value for each ABAG land use feature will then be carried into the HRU model calibration and adjusted accordingly.
5. "Urban" representation will be re-classified based on the dominant adjacent HSG.
6. U.S. Department of Agriculture, Natural Resources Conservation Service. Soil Survey Geographic (SSURGO) database. 2016

HRUs are determined geospatially based on the climate zone, slope zone, developed/undeveloped areas, and HSG, along with land use-based imperviousness. Exhibits 1 through 5 (see Appendix A) display the data used to develop climate zones, county slope zones, and the HSG distribution across each county. Imperviousness designations will occur based on land use at the parcel level, by combining the geospatial ABAG land use layer[8] with the other hydrologic input regions. This results in a “patchwork” of HRUs across the counties[9].

The resulting patchwork of HRUs can be combined at the scale of choice to provide total runoff volumes for a specific area, such as a watershed or jurisdictional boundary. To estimate the total runoff for the identified area, the total acreage of each designated HRU present within a watershed or jurisdiction will be multiplied by the average annual runoff per acre associated with each HRU and then summed (i.e., area-weighting the average annual runoff volume per acre for all HRUs present).

3.1.3 HRU Input Calibration

Calibration of hydrologic models is required by the *Bay Area RAA Guidance Document*. Calibration of the generic HRU models will be conducted utilizing available stream flow records and based solely upon the annual discharge volume between WY 2000-2009. This annual calibration means that the HRU runoff estimates are representative of the approximate annual runoff volume but will not be used to estimate or compare discharge rates at smaller timesteps, such as the hourly or daily runoff hydrograph.

The list of candidate gauge sites within the counties was developed based on an assessment of the representativeness of the gauged watersheds and the mitigation of confounding factors that interfere with calibration such as missing data and upstream impoundments. For the purposes of calibration, the candidate gauge sites that were selected included stream depth rating curves and at least daily mean records for the historical period of interest. The USGS flow gauges considered for calibration are provided in Table 4 and shown in Exhibit 8 (see Appendix A).

[8] ABAG land use features will used to aggregate the imperviousness for the land surface. The relationship between AGAB feature and its imperviousness will be developed based upon other local sources (SMCWPPP, 2017) and analysis of national public data sets such as the National Land Cover Dataset (NLCD)

[9] This will be done once all the HRU input files are finalized, including the imperviousness layers.

Table 4: Flow Gauge Considered for RAA Model Calibration

Gauge ID	Gauge Name	Location	County	Data Frequency
11337600	Marsh Creek	Brentwood	Contra Costa	Daily
11182500	San Ramon Creek	San Ramon	Contra Costa	Daily
11181390	Wildcat Creek	Richmond / San Pablo	Contra Costa	Daily
11181040	Lan Lorenzo Creek	San Lorenzo	Alameda	Daily
11181008	Castro Valley Creek	Hayward	Alameda	Daily
11181000	San Lorenzo Creek	Hayward	Alameda	Daily
11180700	Alameda Creek Flood Channel	Union City	Alameda	Daily
11179000	Alameda Creek	Fremont	Alameda	Daily
11176900	Arroyo de la Laguna	Verona	Alameda	Daily
11173575	Alameda Creek Below Welch Creek	Sunol	Alameda	Daily
11173510	Alameda Creek Below Calaveras Creek	Sunol	Alameda	Daily

The effective area tributary to each flow gauge is used to calibrate the HRUs to the stream gauge records. Annual flow predicted by area-weighting HRU runoff output for the watersheds draining to the stream gauges was compared to annual flow in the stream records for the identified period of record.

Calibration of land surface runoff hydrology to stream gauge records requires that baseflow be computed and accounted for throughout the period of record. A variety of methods exist for separating baseflow from runoff, including the fixed-interval method and the local-minimum method (Sloto and Crouse, 1996). The most appropriate method for separating baseflow is determined on a gauge by gauge basis depending on the variability in the flow record, and the occurrence of confounding factors that affect baseflow such as dam releases and other dry weather inflows.

The average percent difference between the area-weighted HRU total average annual runoff volume for the watershed and the average annual flow (converted to volume) measured for the WY 2000 – 2009 period will be calculated. The acceptable ranges included in the RAA Guidance document are provided in Table 5 below.

Table 5: Allowable Difference between Simulated and Observed Annual Volumes

Model parameters	Average % difference between simulated annual results and observed data		
	Very Good	Good	Fair (lower bound, upper bound)
Hydrology/Flow	<10	10-15	15-25

If the average percent difference between simulated and measured annual storm flow volumes is greater than 25%, HRU model parameters are adjusted until the percent difference is within the acceptable range. The primary model parameters adjusted include underlying soil hydraulic conductivity and land use imperviousness, but other hydrologic model parameters, such as depression storage, may be adjusted as appropriate.

Once average percent differences in all identified watersheds are within the acceptable range, the HRU model parameters are finalized and the HRU results database will be regenerated. HRUs and resulting average annual baseline volume will be applied across each county to obtain the baseline volume discharged by each county.

3.1.4 Water Quality Model

RWSM values used to develop pollutant loading estimates across each county are:

Table 6: Regional Watershed Spreadsheet Model PCBs and Mercury Concentrations in Runoff

Land Use Category	Total PCBs (ng/L)	Total mercury (ng/L)
Ag, Open	0.2	80
New Urban	0.2	3
Old Residential	4	63
Old Commercial/ Transportation	40	63
Old Industrial and Source Areas	204	40

Water quality calculations are also used to perform baseline pollutant loading validation. The calculated pollutant load draining to Regional Monitoring Program stations will be validated by calculating the volume-weighted watershed pollutant concentration using the modeling results and comparing it to the observed concentrations in the Regional Monitoring Program data. The equation used to calculate concentration (in ng/L) at an end-of-watershed location is as follows:

$$Concentration_{Baseline} = \frac{\sum Runoff_{HRU} \times Area_{HRU} \times Concentration_{LU,HRU}}{\sum Runoff_{HRU} \times Area_{HRU}} \qquad \text{Eqn. 7}$$

Pollutant concentration and loading data from the Regional Monitoring Program will be compared to the result of Equation 7 for several watersheds for validation purposes.

3.2 Green Infrastructure Performance Model

3.2.1 Long-Term Green Infrastructure Simulations

Long term performance was assessed for each BMP configuration using continuous historical rainfall records. In Contra Costa County historical data was available at the same gauges that were used for the HRU runoff modeling between WY2000-2009, but for Alameda County other gauge sites with longer histories were used for long term BMP performance modeling. The rainfall gauges used to model BMP performance are shown in Table 7.

Table 7: Long Term GI Performance Precipitation Gauges

Gauge ID	Gauge Name	Period of Record	Average Annual Precipitation (inches)	Gauge Source[1]
040693	Berkeley (NCDC)	1948-1990	19.8	NCDC
041060	Brentwood (NCDC)	1950-1985	14.9	NCDC
043863	Hayward (NCDC)	1948-1988	24.3	NCDC
046335	Oakland Airport (NCDC)	1948-1985	16.4	NCDC
047821	San Jose Airport (NCDC)	1948-2010	13.6	NCDC
DBF	Dublin Fire Station, San Ramon	1973-2016	15.0	CCCFCD
FCD	Flood Control District, Martinez	1971-2016	16.5	CCCFCD
LSM	Los Medanos, Pittsburg	1974-2016	10.6	CCCFCD
SMC	Saint Mary's College, Moraga	1972-2016	26.8	CCCFCD

1. NCDC data was used for Alameda County and San Jose gauge sites. Contra Costa County gauge data is collected by the Flood Control District and was provided to Geosyntec by Dubin Engineering.

3.2.2 Hydraulic Green Infrastructure Model

Hydraulic GI models were developed in SWMM to estimate hydraulic performance for a 100% impervious tributary area. Hydraulic model inputs that were varied to model the GI facility performance for the counties are described below and summarized in Table 8.

1. BMP Configuration – three GI facility types were assumed: (1) bioretention with a raised underdrain, (2) bioretention with no underdrain, and (3) lined bioretention with an underdrain.

2. BMP Footprint Size – the BMP footprint size was varied as a percent of impervious area to model different levels of hydraulic capture performance depending on facility sizing.
3. BMP Underlying Infiltration Rate – the infiltration rate of the soils underneath the bioretention facility was varied for the bioretention with a raised underdrain and bioretention with no underdrain configurations (I.e., the unlined facility types).

Table 8: Land Surface Feature Inputs for Generic GI Performance Hydraulic Models

Variables	Description	Number of Varying Features	Feature Representations
Hourly Precipitation	Rainfall Gauge	9	NCDC: 040693 (Berkeley) 046335 (Oakland Airport) 043863 (Hayward) 047821 (San Jose) 041060 (Brentwood) Contra Costa County: DBF, FCD, LSM, SMC
Daily Evapotranspiration Rate	Evapotranspiration Zone	4	CIMIS Zones: 1, 6, 8, 14
BMP Configurations	BMP profiles and underdrain	3	Lined Bioretention with underdrain Unlined Bioretention with elevated underdrain Infiltration Basin without underdrain
BMP Surface Ponding Depth	Depth (feet)	2	0.5, 1
BMP Footprint Sizes	% of Impervious Area	12	0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6
BMP Infiltration Rates	Ksat of underlying soil (in/hr)	7 3	Unlined Bioretention: 0.024, 0.05, 0.1, 0.2, 0.24, 0.3, 0.4, 0.5 Infiltration Basin: 0.5, 1, 2

The BMP cross-sections that were modeled each include:

- 6-inches or 12-inches ponding depth (both were modeled),
- 1.5 ft of filter media with 25% porosity with a 5 in/hr flow through rate, and

- 1 ft of gravel beneath the media with 40% porosity.

Two of the modeled BMP configurations include underdrains. In the lined bioretention facility, the underdrain is located at the bottom of the gravel layer. In the unlined bioretention facility, the underdrain was modeled at the top of the gravel layer. BMP configurations are shown in Exhibits 9 through 11 (see Appendix A).

3.2.3 Green Infrastructure Pollutant Reduction Calculations

As described in Section 2.3.2, pollutant load reduction associated with GI is calculated by combining the hydraulic model results with water quality performance data. The annual estimate of pollutant load reduction from the modeled drainage area is equivalent to the difference between the influent load and the sum of the pollutant load that bypasses the GI measure and the effluent load. The effluent load is calculated as the proportion of runoff that is treated by the GI measure multiplied by an effluent concentration.

Water quality performance data from selected, representative studies were used to determine a method to predict effluent concentrations in stormwater following treatment through a biofiltration (bioretention or tree well filters) GI measure. The data used to develop the relationship came from three studies: a) 2011 monitoring study of the El Cerrito Rain Gardens (Gilbreath, Pearce, and McKee, 2012), b) Clean Watersheds for a Clean Bay (CW4CB)[10] (Geosyntec and EOA, 2017), and c) a study at Echo Lake in King County, WA (King County, 2017). A summary of the paired influent-effluent data associated with each study is provided in table:

Table 9: Data used to Develop Effluent Concentrations

Project Name	Project Sponsor	Facility ID	Influent-Effluent Data Pairs (n pairs)	
			PCBs	Mercury
El Cerrito Green Streets – CW4CB	El Cerrito	ELC-B1	3	3
El Cerrito Green Streets – SFEI	SFEI	ELC-B1	4	4
PG&E Substation 1st and Cutting Bioretention Cells – CW4CB	Richmond	LAU-3	8	8

[10] The CW4CB study included additional monitoring of the El Cerrito rain gardens.

Project Name	Project Sponsor	Facility ID	Influent-Effluent Data Pairs (n pairs)	
			PCBs	Mercury
Monitoring Stormwater Retrofits in the Echo Lake Drainage Basin Bioretention Planter Boxes – SAM Effectiveness Study	King County, Dept. of Natural Resources and Parks	BPB-1	4	0
		BPB-2	4	0
		BPB-3	4	0
		BPB-4	2	0
West Oakland Industrial Area Tree Wells – CW4CB	Oakland	ETT-TW2	4	4
		ETT-TW6	4	4
Monitoring Stormwater Retrofits in the Echo Lake Drainage Basin Tree Well – SAM Effectiveness Study	King County, Dept. of Natural Resources and Parks	FLT-1	4	0
		Total Data Pairs	41	23

These data were statistically evaluated to identify an appropriate method for predicting effluent concentrations of PCBs and total mercury. The data analysis first evaluated whether available influent and effluent concentration data were significantly different and, if so, whether a monotonic relationship existed (i.e., effluent generally increased when influent increased).

A Wilcoxon non-parametric hypothesis test was run on the PCBs and total mercury paired influent-effluent data to determine if influent and effluent concentrations were statistically different at a 5% significance level. This difference was found to be significant for PCBs, and significant for total mercury when corresponding influent suspended solids concentration was greater than 20 mg/L.

Spearman’s rho and Kendall’s tau, which are non-parametric rank correlation coefficients, were used to identify the direction and strength of correlation between influent and effluent concentrations. As shown in Table 10, both correlation coefficients suggest that effluent concentrations are positively correlated with influent concentrations for both PCBs and mercury.

Table 10: Influent/Effluent Correlation Coefficients.

Correlation Coefficient	Total PCBs	Total Mercury
Spearman’s rho	0.725	0.547
Kendall’s tau	0.527	0.396

The Kendall-Theil Robust Line (KTRL) method (Granato, 2006) was used to determine the best fit line between influent and effluent data. This non-parametric method uses the median of all possible pairwise slopes between points, which is more robust to outliers than a simple linear regression. Because stormwater data tend to be lognormal, the analysis was focused on linear and log-linear relationships. After the KTRL was generated, the lower portion of the curve was adjusted to assume that neither PCBs nor total mercury can be exported from biofilters under normal circumstances, i.e., that the maximum effluent concentration of PCBs or total mercury is equal to the influent concentration. The resulting KTRL for PCBs is shown Figure 2. The resulting KTRL for total mercury is shown in Figure 3. Each figure also includes a constant average effluent concentration line with data fit statistics: root mean square error (RMSE) and median absolute deviation (MAD). As indicated, the KTRL provide a better fit of the data. However, the resulting effluent concentrations are not much different between the two lines except when influent PCBs are low (<10 ng/L) and total mercury concentration are high (>50 ng/L). For total mercury, concentration reductions are only predicted to occur when influent concentrations are greater than about 30 ng/L. Due to observed export of total mercury for several events, particularly for the 1st and Cutting bioretention cell (LAU-3), the moderate concentration reductions assumed by the KTRL at higher influent concentrations is reasonably conservative.

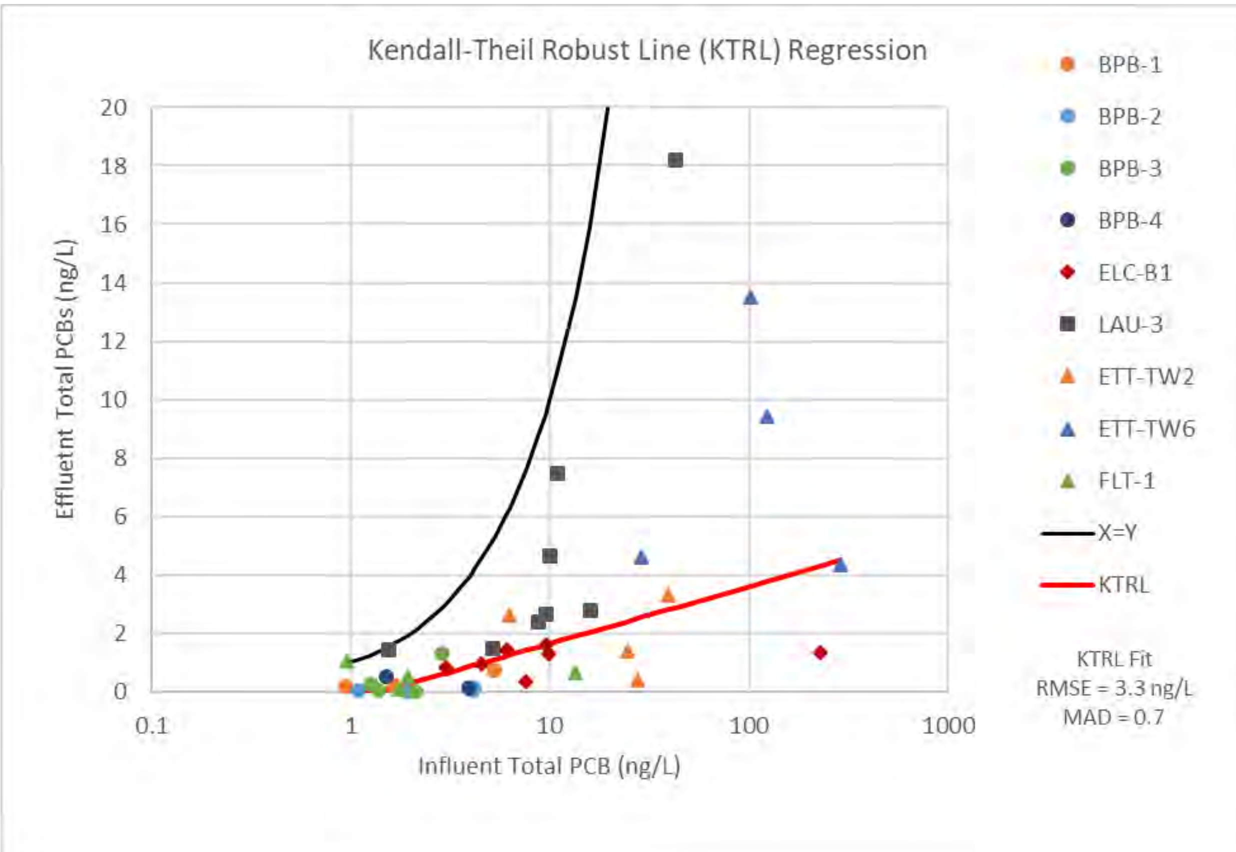

Figure 2: PCBs Influent vs Effluent Concentration Relationship Determined by KTRL Regression

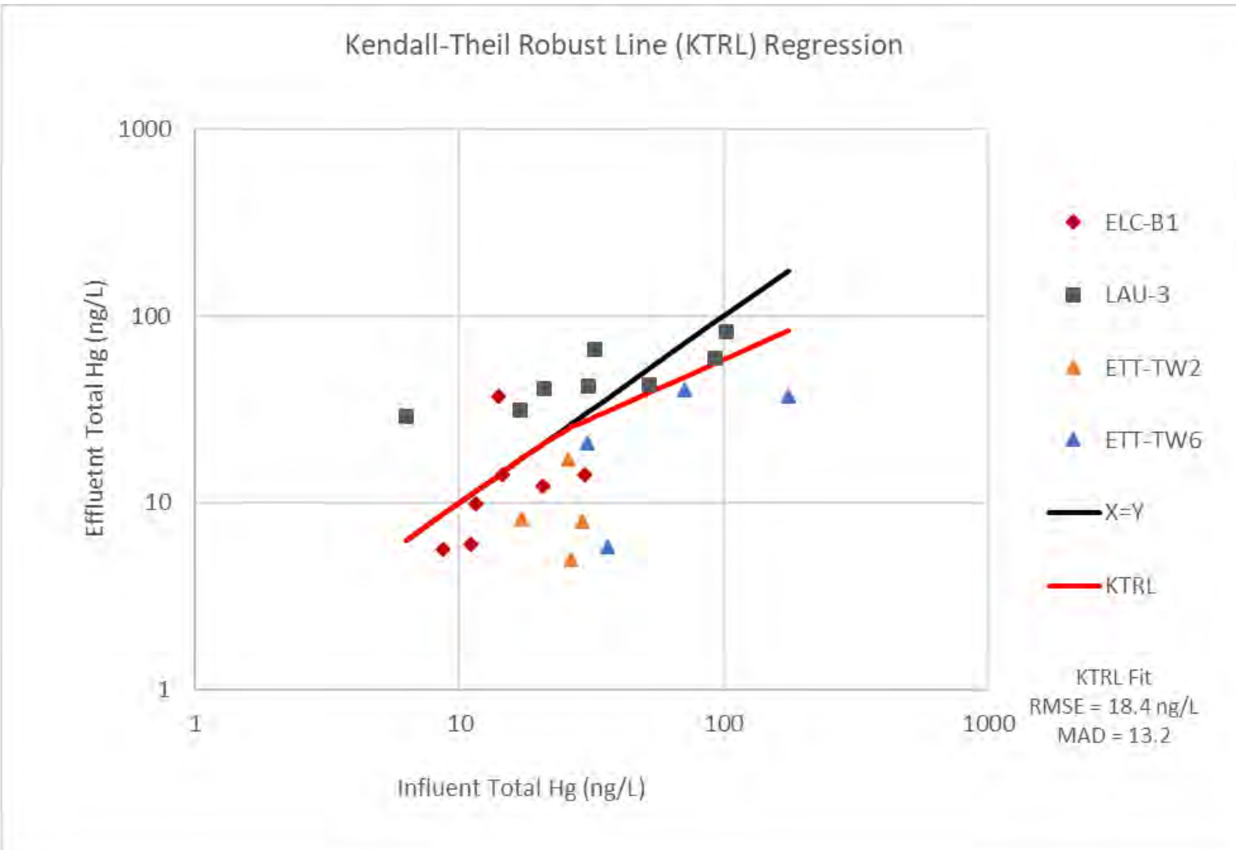

Figure 3: Mercury Influent vs Effluent Concentration Relationship Determined by KTRL Regression

3.3 RAA Scenario Loading Model

To model RAA future scenarios, future condition land use is needed. Future condition land use will be estimated using predictions of private parcel new development and redevelopment in combination with GI implementation on public parcels and rights-of-way.

Load reductions estimated for implementation of GI will be applied to future condition RAA scenario models based on estimated locations of GI and the tributary drainage areas to those GI. Effective area will be used to relate the HRUs, which can have a variety of imperviousness values, to the GI performance which will be based on a unit of effective area with 100% imperviousness. The GI performance curves can thus be applied to many different HRU types and/or combinations of HRUs that make up the tributary drainage areas for future GI measures.

4. QUANTITATIVE RELATIONSHIP BETWEEN GI IMPLEMENTATION AND PCBS LOADS REDUCED

The results of the hydraulic and pollutant reduction modeling of GI measures were used to develop a quantitative relationship between GI implementation and PCBs that can be applied to RAA future scenario models. An example quantitative relationship is provided for GI models run for the Berkeley gauge (040693). Utilizing output from hydraulic modeling, GI measure volumetric percent capture was calculated on an average annual basis. Volumetric model results for runs with GI measures sized to achieve 80%, 85%, 90%, and 95% capture were combined with water quality inputs to obtain pollutant load reduction for varying PCBs influent concentration.

The results of this analysis are shown in nomographs[11] provided in Figure 4, Figure 5, and Figure 6, which correspond to infiltrating bioretention (i.e., with no underdrain), bioretention with a raised underdrain, and lined bioretention, respectively. All facilities shown in the figures below have a 6-inch ponding depth. For bioretention with a raised underdrain, the facility configuration with an underlying infiltration rate of 0.24 in/hr only is shown (see Table 8 for all modeled infiltration rates). Facilities sized to achieve 80%, 85%, 90%, and 95% capture from the 100% impervious tributary catchment are shown in series, with pollutant load reduction in grams per effective acre[12] displayed as a function of influent concentration. Constant influent lines corresponding with RWSM land use-based influent concentrations are shown.

[11] A nomograph is a graphical relationship between two variables that can be used to quickly estimate one value from another.

[12] Effective area is calculated as the area multiplied by the runoff coefficient.

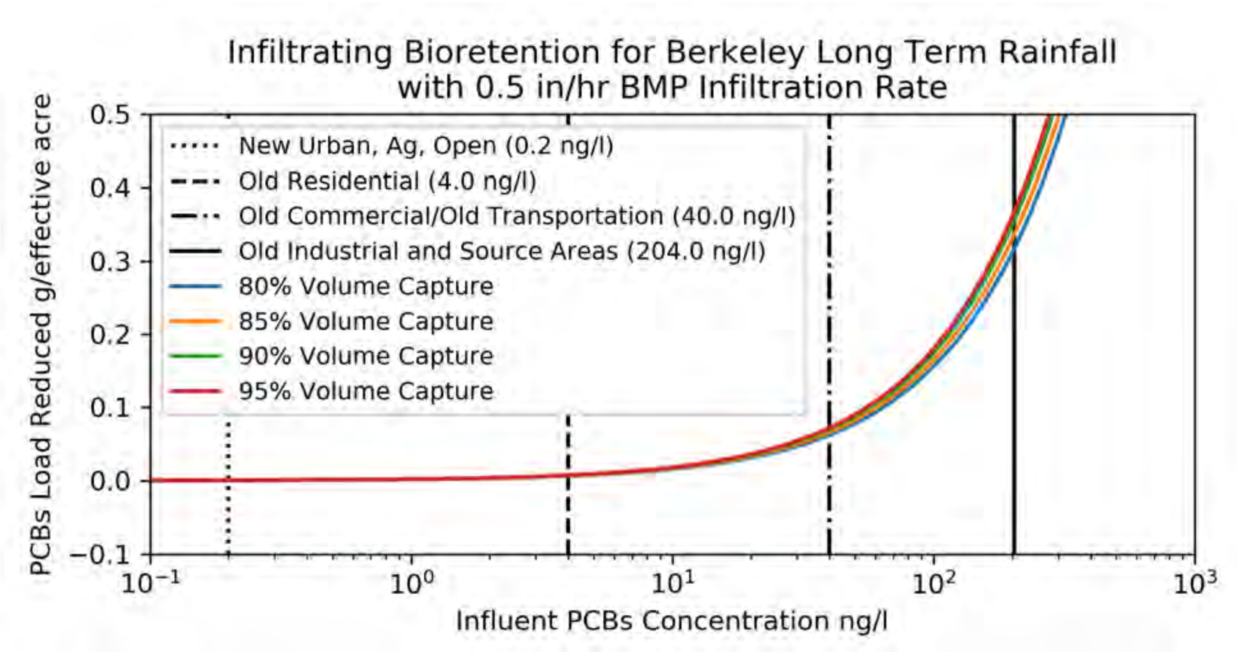

Figure 4: Modeled PCBs Load Removal Performance for Infiltrating Bioretention Basin

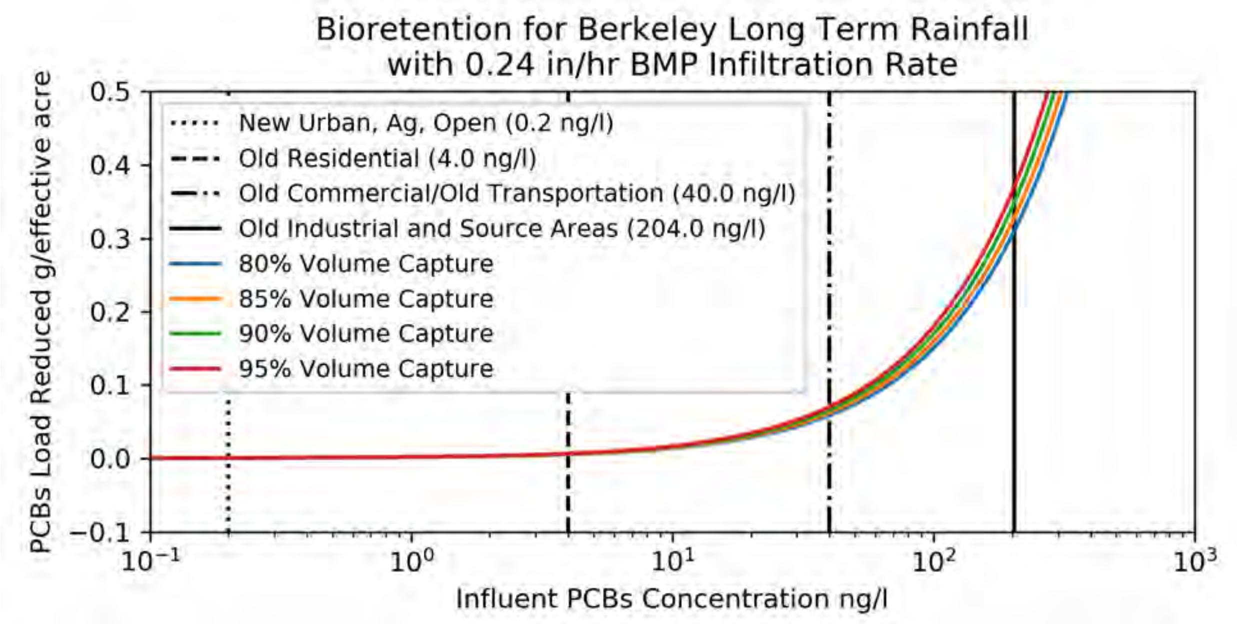

Figure 5: Modeled PCBs Load Removal Performance for Bioretention Basin with Elevated Underdrain

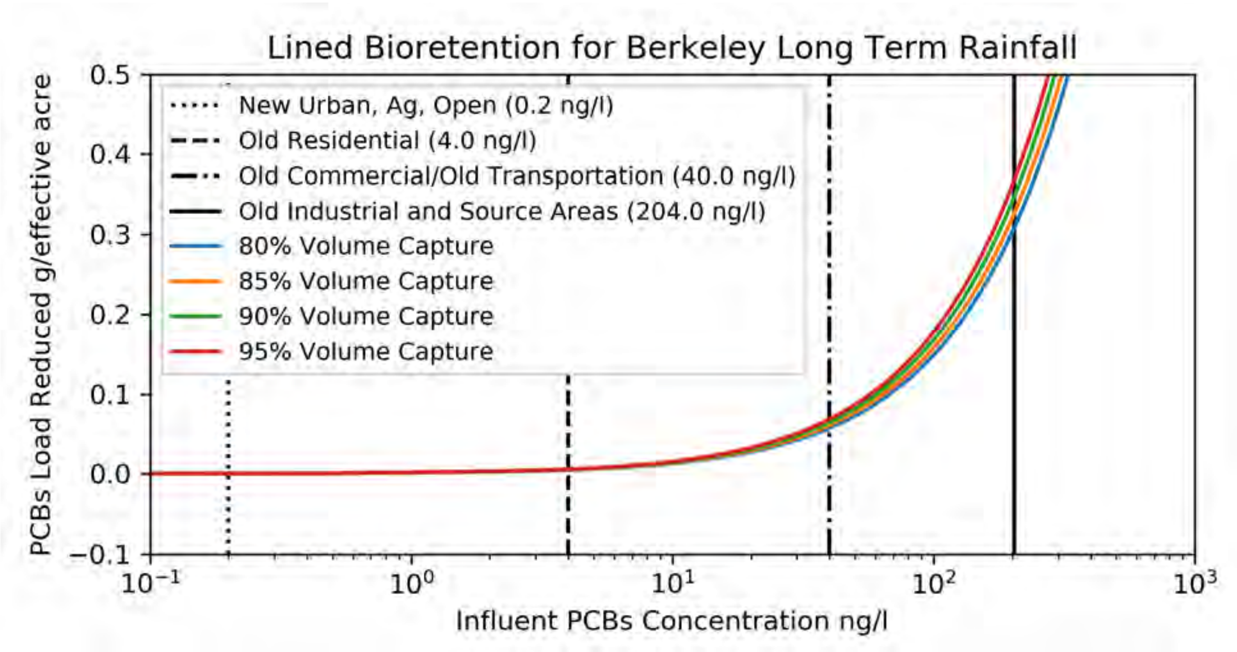

Figure 6: Modeled PCBs Load Removal Performance for Lined Bioretention Basin with Underdrain

The intersection points between the load reduction series and the constant influent lines represent the load reduced in grams per acre for each specific RWSM land use category. These intersection points are listed in Table 11.

Table 11: PCBs Load Reduction for RWSM Land Use Categories for Berkeley Gauge for Different BMP Percent Capture Values

Facility Configuration	Land Use Category	PCBs Load Reduced (g/effective ac)			
		80% Capture[1]	85% Capture[1]	90% Capture[1]	95% Capture[1]
Infiltrating Bioretention (0.5 underlying infiltration rate)	New Urban, Ag, Open	3.12E-04	3.30E-04	3.49E-04	3.61E-04
	Old Residential	0.00623	0.0066	0.00698	0.00722
	Old Commercial / Old Transportation	0.0623	0.066	0.0698	0.0722
	Old Industrial and Source Areas	0.318	0.337	0.356	0.368
Bioretention with Raised Underdrain (0.24 underlying infiltration rate)	New Urban, Ag, Open	3.08E-04	3.26E-04	3.47E-04	3.67E-04
	Old Residential	0.00518	0.0055	0.00589	0.00633
	Old Commercial / Old Transportation	0.0586	0.0621	0.0661	0.0703
	Old Industrial and Source Areas	0.311	0.329	0.350	0.371

Facility Configuration	Land Use Category	PCBs Load Reduced (g/effective ac)			
		80% Capture[1]	85% Capture[1]	90% Capture[1]	95% Capture[1]
Lined Bioretention	New Urban, Ag, Open	3.08E-04	3.26E-04	3.46E-04	3.67E-04
	Old Residential	0.00484	0.00513	0.00545	0.00577
	Old Commercial / Old Transportation	0.0574	0.0608	0.0647	0.0685
	Old Industrial and Source Areas	0.309	0.327	0.348	0.368

1. Average Annual Facility Volumetric Runoff Capture

5. QUANTITATIVE RELATIONSHIP BETWEEN GI IMPLEMENTATION AND MERCURY LOADS REDUCED

Mercury load reduction results for the Berkeley Gauge are shown in nomographs[13] in Figure 7, Figure 8, and Figure 9, which correspond to infiltrating bioretention (i.e., with no underdrain), bioretention with a raised underdrain, and lined bioretention, respectively. All facilities shown in the figures below have a 6-inch ponding depth. For bioretention with a raised underdrain, the facility configuration with an underlying infiltration rate of 0.24 in/hr only is shown (see Table 9 for all modeled infiltration rates). Facilities sized to achieve 80%, 85%, 90%, and 95% capture from the 100% impervious tributary catchment are shown in series, with pollutant load reduction in grams per acre displayed as a function of influent concentration. Constant influent lines corresponding with RWSM land use-based influent concentrations are shown.

[13] A nomograph is a graphical relationship between two variables that can be used to quickly estimate one value from another.

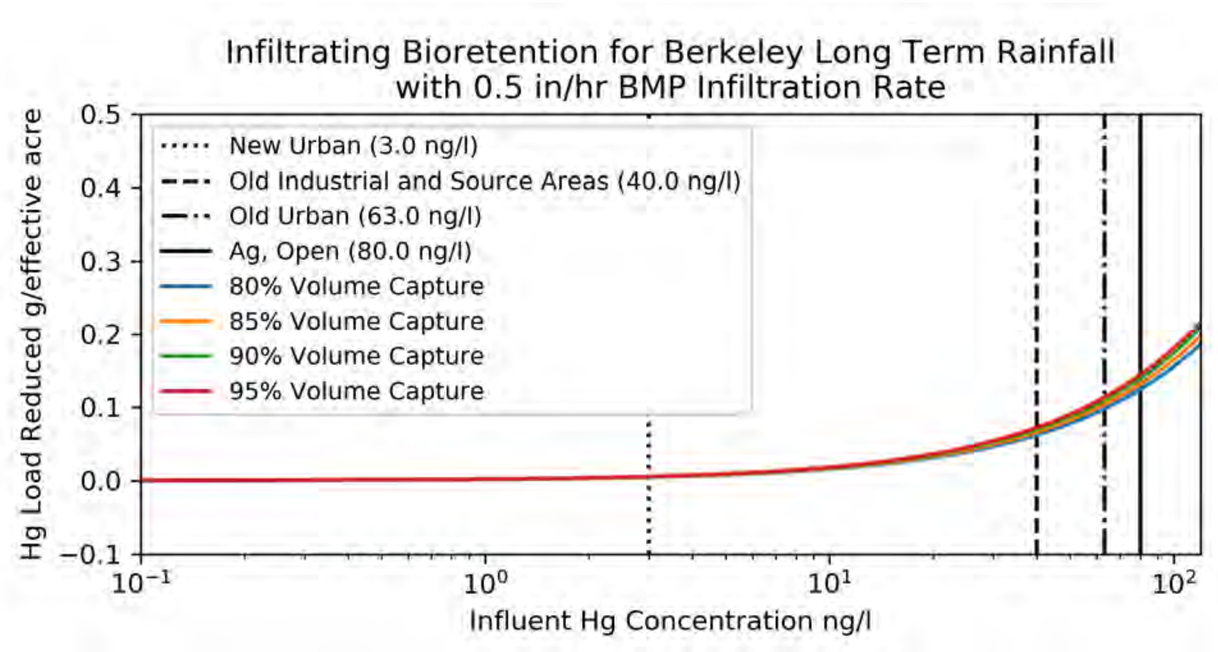

Figure 7: Modeled Mercury Load Removal Performance for Infiltrating Bioretention Basin

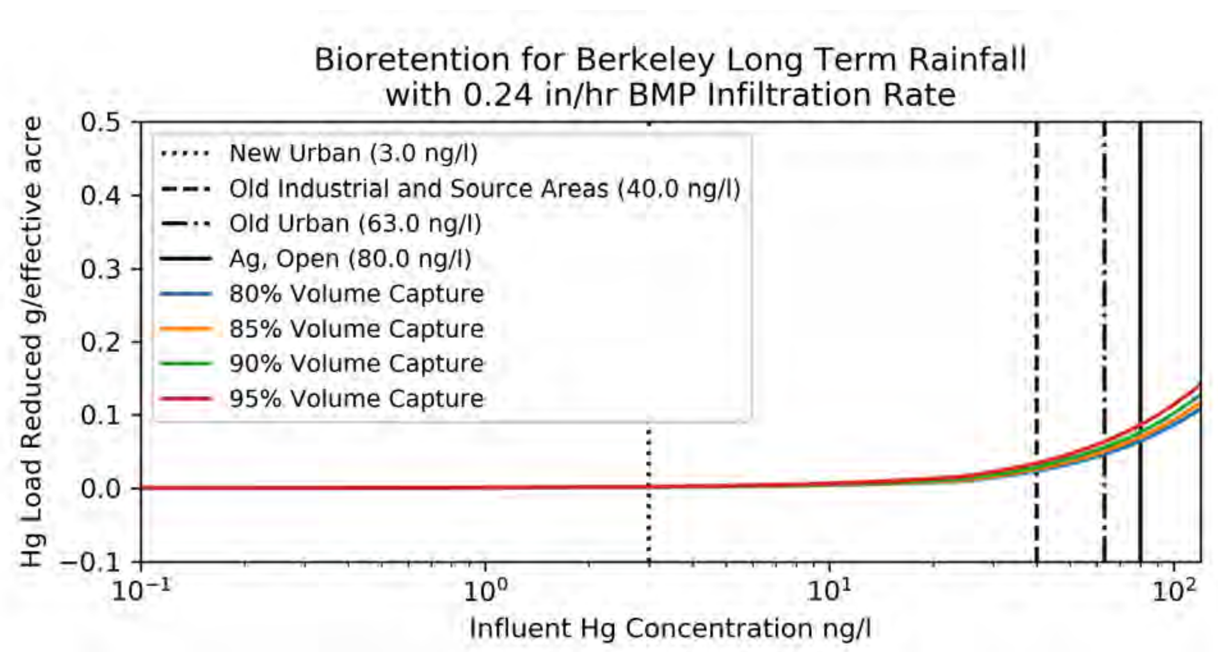

Figure 8: Modeled Mercury Load Removal Performance for Bioretention Basin with Elevated Underdrain

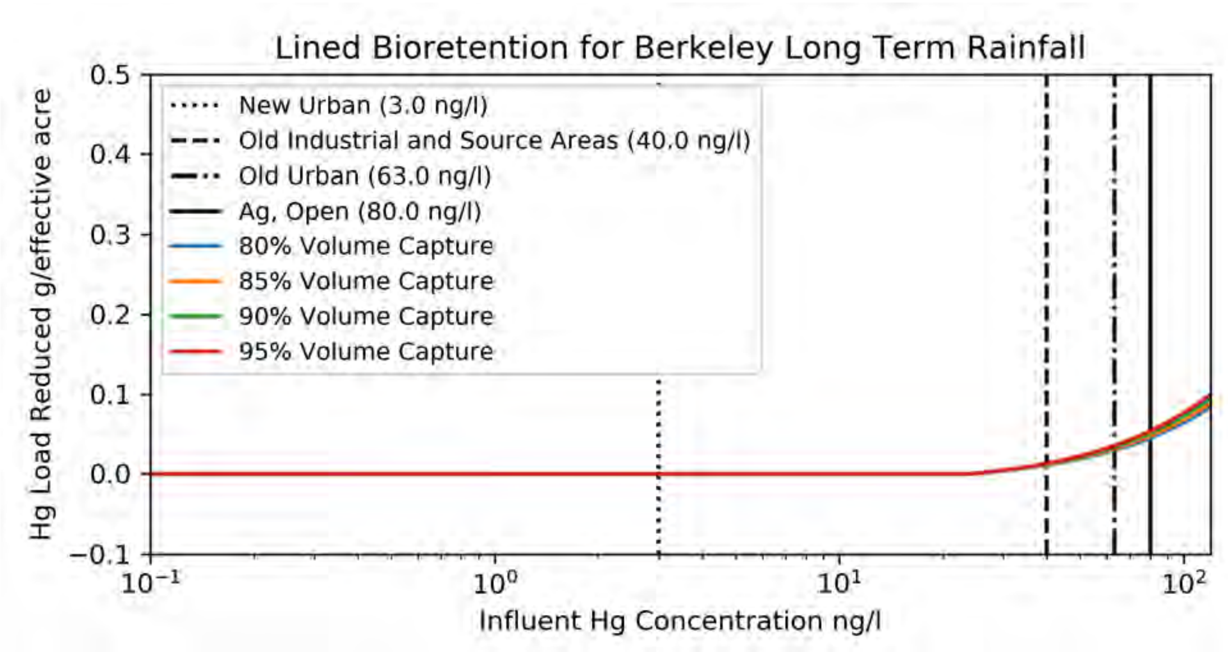

Figure 9: Modeled Mercury Load Removal Performance for Lined Bioretention Basin with Underdrain

The intersection points between the load reduction series and the constant influent lines represent the load reduced in grams per acre for each specific RWSM land use category. These intersection points are summarized in Table 12.

Table 12: Mercury Load Reduction for RWSM Land Use Categories for Berkeley Gauge for Different BMP Percent Capture Values

Facility Configuration	Land Use Category	Mercury Load Reduced (g/effective acre)			
		80% Capture[1]	85% Capture[1]	90% Capture[1]	95% Capture[1]
Infiltrating Bioretention (0.5 underlying infiltration rate)	New Urban	0.00467	0.00495	0.00524	0.00541
	Old Industrial and Source Areas	0.0623	0.066	0.0698	0.0722
	Old Urban	0.0981	0.104	0.110	0.114
	Ag, Open	0.125	0.132	0.140	0.144
Bioretention with Raised Underdrain (0.24 underlying infiltration rate)	New Urban	0.00113	0.0013	0.00153	0.00192
	Old Industrial and Source Areas	0.0234	0.0258	0.029	0.0341
	Old Urban	0.0462	0.0503	0.0556	0.0634
	Ag, Open	0.0643	0.0696	0.0765	0.0862

Facility Configuration	Land Use Category	Mercury Load Reduced (g/effective acre)			
		80% Capture[1]	85% Capture[1]	90% Capture[1]	95% Capture[1]
Lined Bioretention	New Urban	0	0	0	0
	Old Industrial and Source Areas	0.0108	0.0115	0.0123	0.0130
	Old Urban	0.0296	0.0314	0.0335	0.0353
	Ag, Open	0.0449	0.0476	0.0507	0.0536

[1] Average Annual Facility Volumetric Runoff Capture

6. REFERENCES

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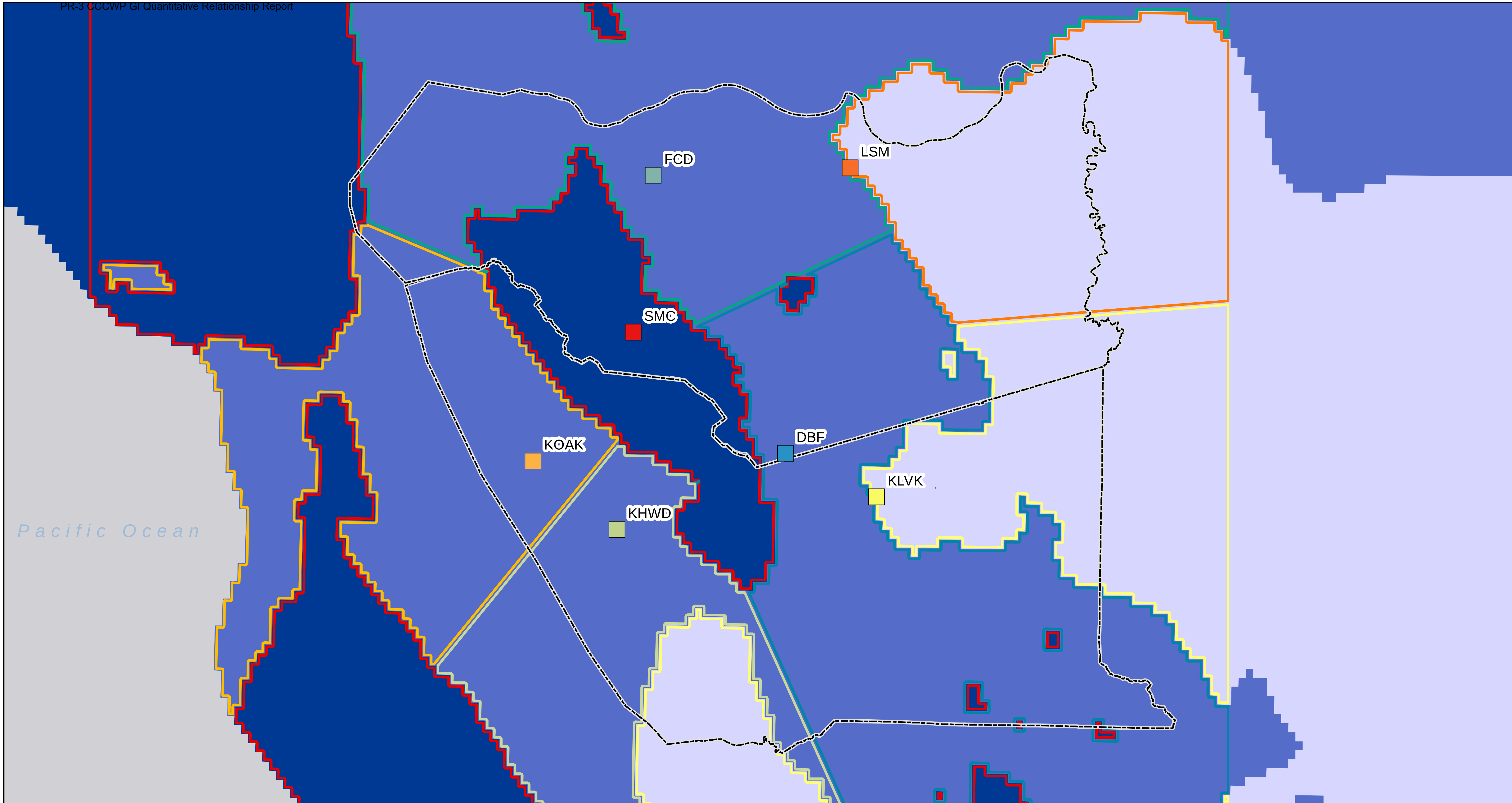
APPENDIX A

Modeling Inputs and Data Exhibits



Rain Gauge ID

- Rain Gauge ID
- County Boundary

Mean Annual Precipitation (in)

- < 16
- 16 - 25
- > 25

Rain Gauge Zones

- DBF
- FCD
- KHWD
- KLVK
- KOAK
- LSM
- SMC

Precipitation Zones for Baseline Runoff Period (WY 2000-2009)

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland	July 2018

Exhibit 1

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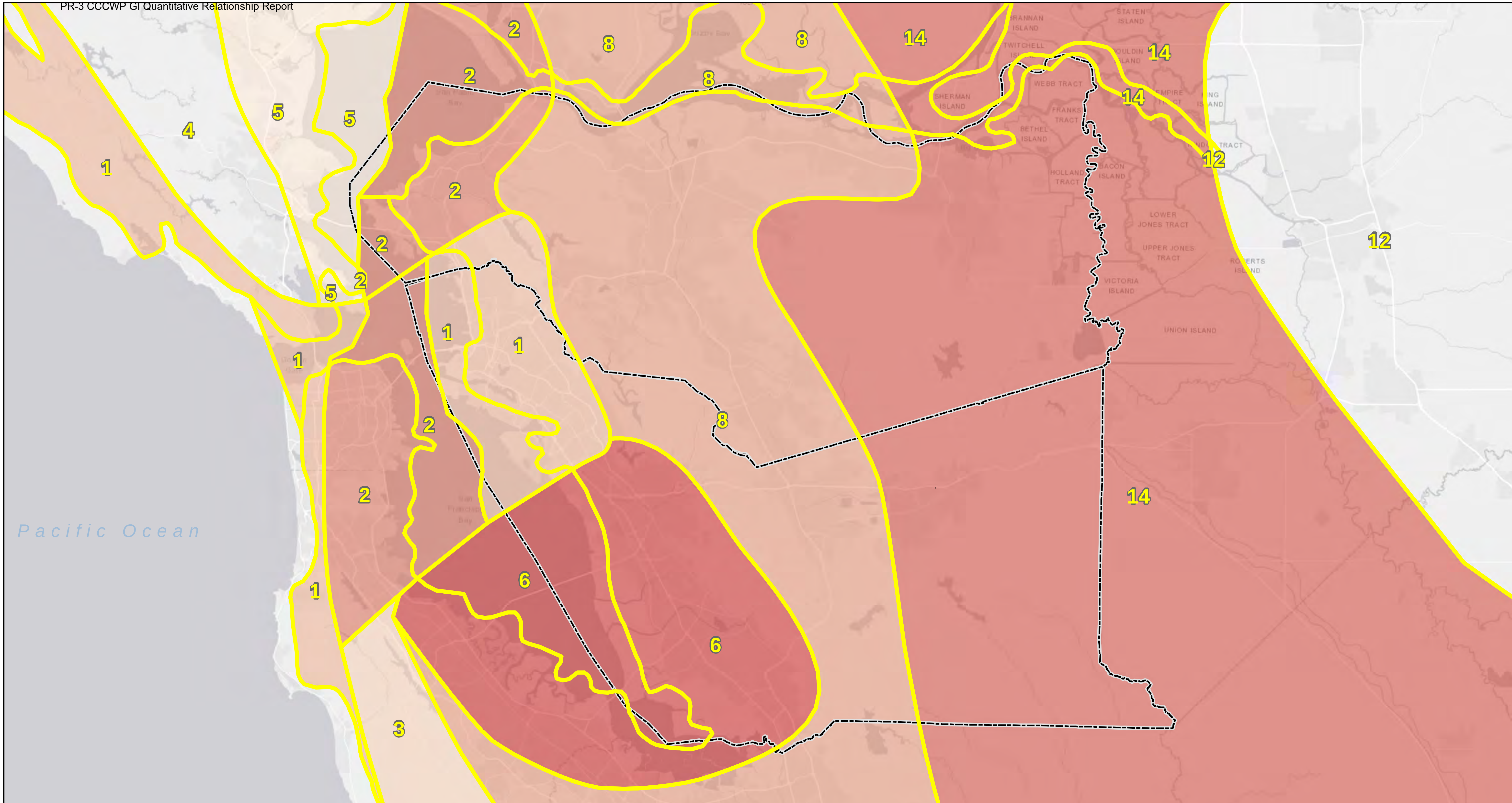


County Boundary
CIMIS ET Zone Boundary

CIMIS ET Zone

- 1
- 2
- 3
- 5
- 6
- 8
- 14

N

0 6 12 Miles

CIMIS Evapotranspiration Zones

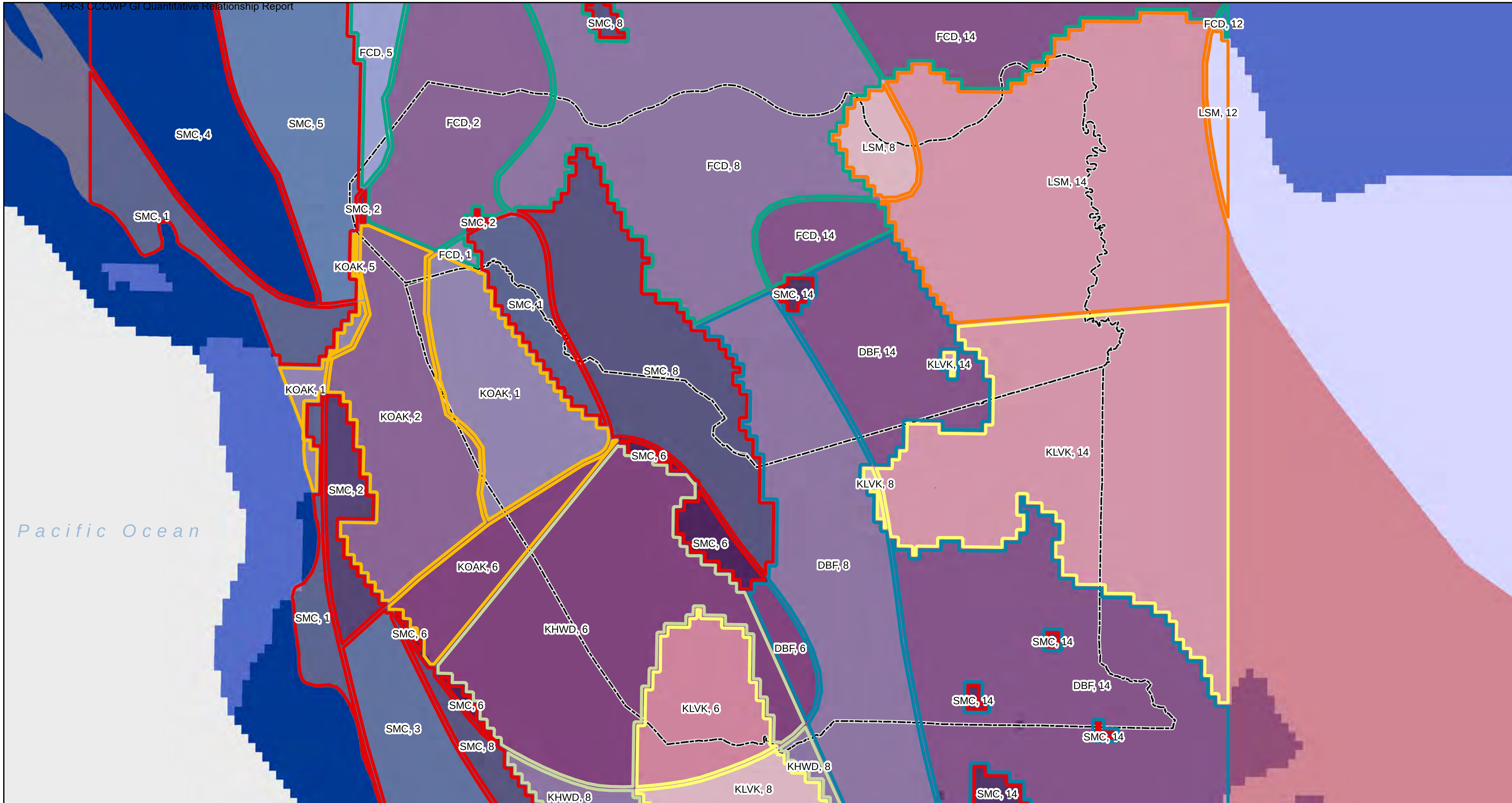
Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 2

P:\GIS\Bay_Area_RAA\Project\GI_Load_Reduced_Report_Exhibits\Figure_3_ET_Zones.mxd 7/5/2018 6:00:18 PM



County Boundary

Mean Annual Precipitation (in)

- < 16
- 16 - 25
- > 25

CIMIS ET Zone

- 1
- 2
- 3
- 5
- 6
- 8
- 14

Climate Zones are created by overlapping precipitation zones and ET zones.The unique climate zones that occur in Contra Costa and Alameda County are labeled as "Gauge ID, ET Zone".

N

0 6 12 Miles

Climate Zones for Baseline Runoff Period (WY 2000-2009)

Alameda County and Contra Costa County
California

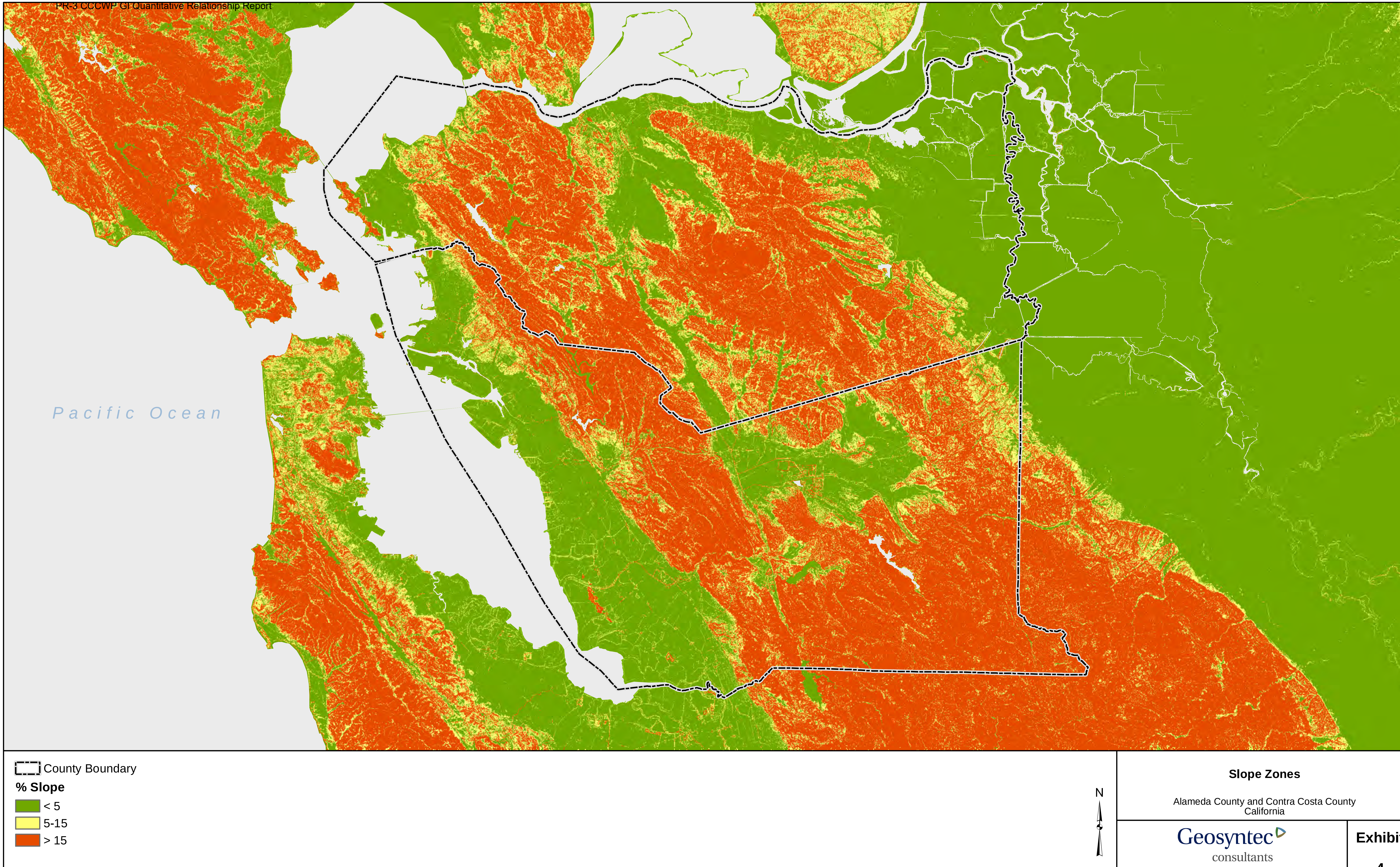
Geosyntec consultants

Exhibit

3

Oakland | July 2018

P:\GIS\Bay_Area_RAA\Project\GI_Load_Reduced_Report_Exhibits\Figure_4_Climate_Zones.mxd 7/5/2018 6:00:27 PM



Slope Zones

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 4

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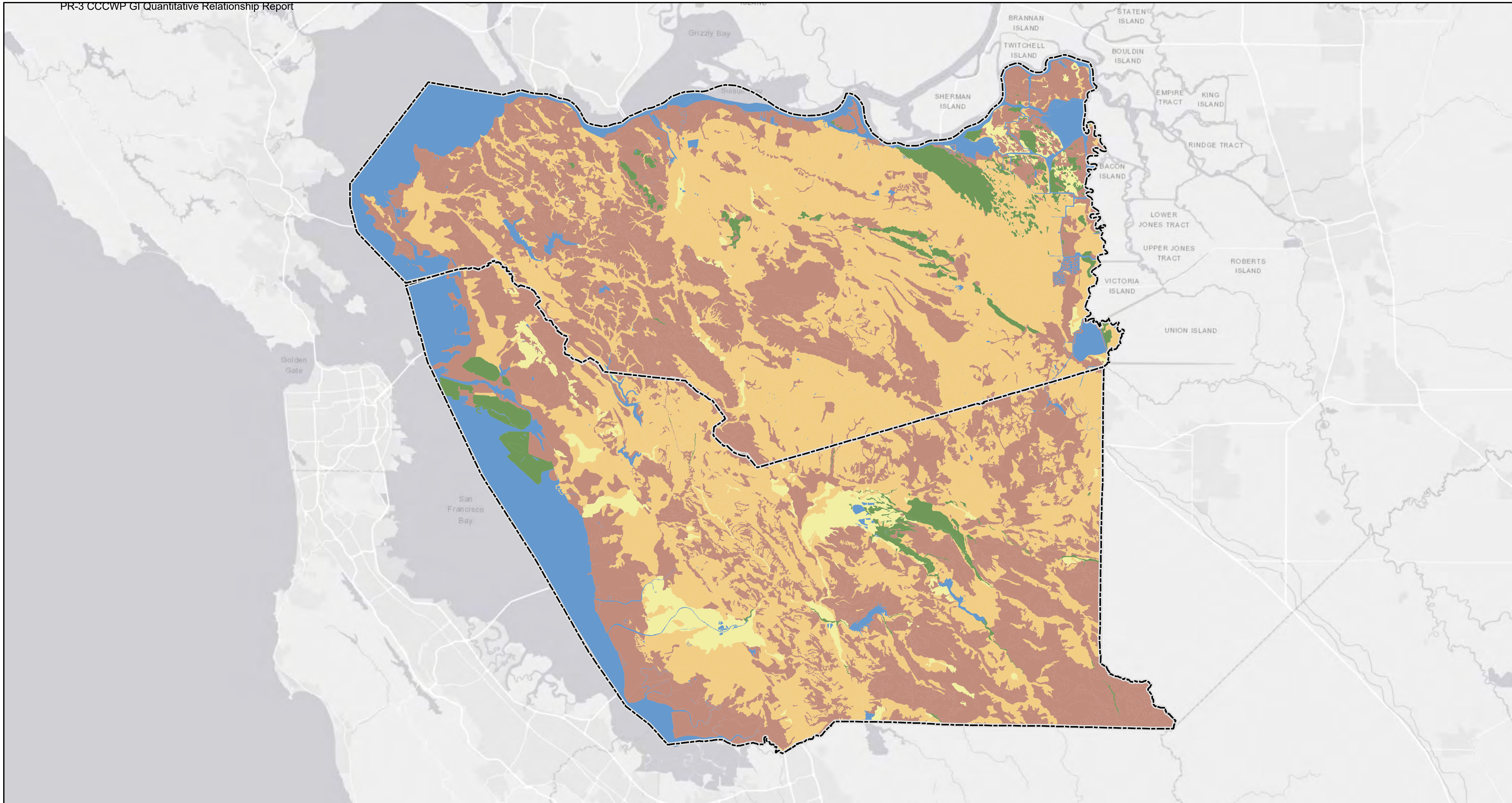


County Boundary

HSG

- A
- B
- C
- D
- W

Note: Area within the county with no HSG assignment was assigned the HSG of the most prominant adjacent soil group.

N

0 6 12 Miles

Hydrologic Soil Group

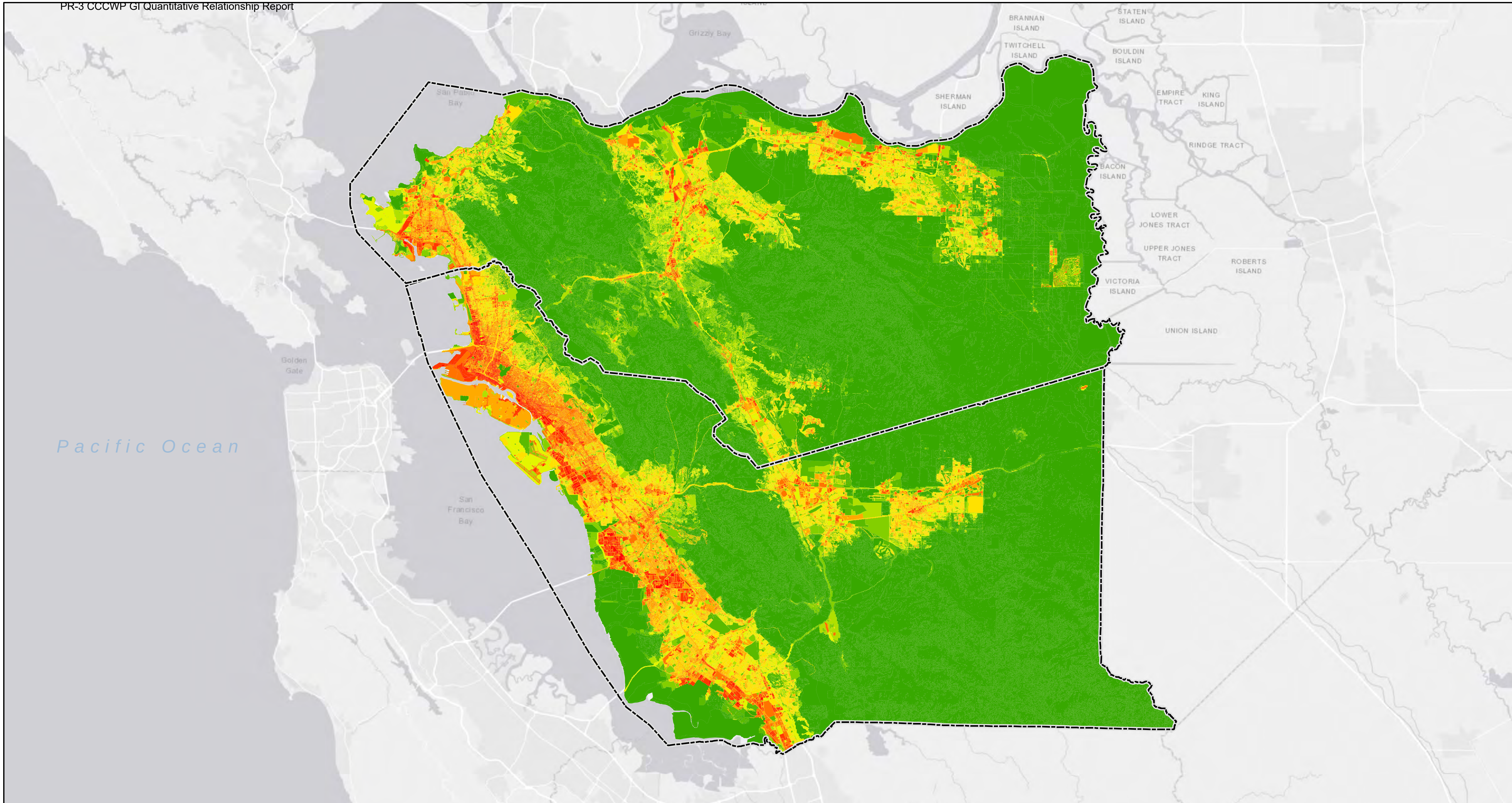
Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit

5



County Boundary

ABAG 2005 Imperviousness

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100

Note:
Imperviousness is assigned to ABAG 2005 landuse based on the NLCD 2006 Impervious Cover layer. These values may be adjusted during calibration for certain categories of ABAG landuse.

For purposes of calculating runoff from areas with compacted soil, developed areas and agricultural uses were assumed to be compacted to 0.75 times the underlying saturated soil conductivity (ksat). These areas generally have percent imperviousness > 20%.

N

0 6 12 Miles

Regional Imperviousness

Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 6

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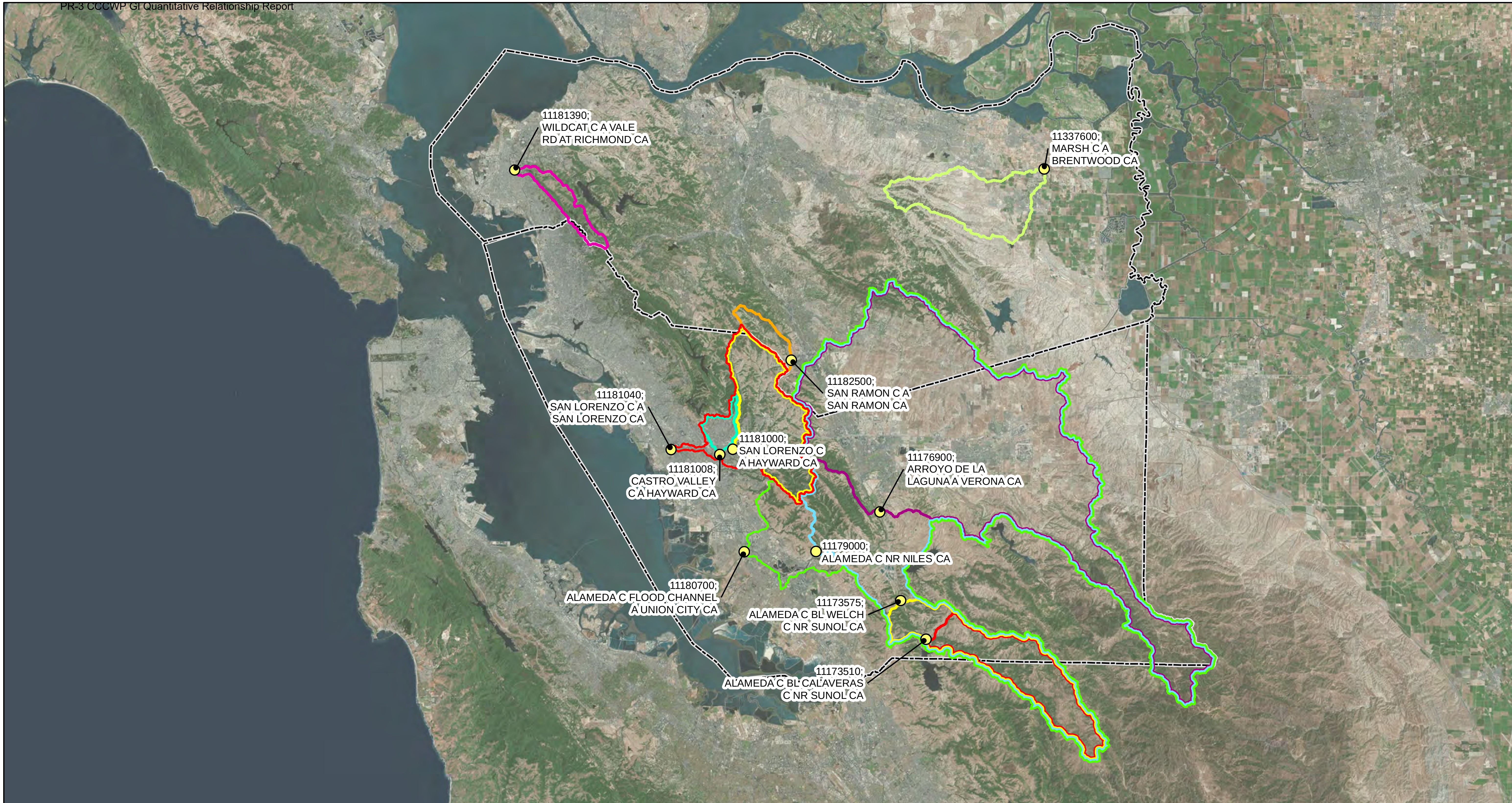


	Group 1	Group 2	Group 3	Group 4	Group 4
County Boundary	11181040	11180700	11182500	11337600	11181390
Gauge Location	11181000	11179000			
	11181008	11173575			
		11176900			
		11173510			

N

0 6 12 Miles

Candidate Calibration Watersheds

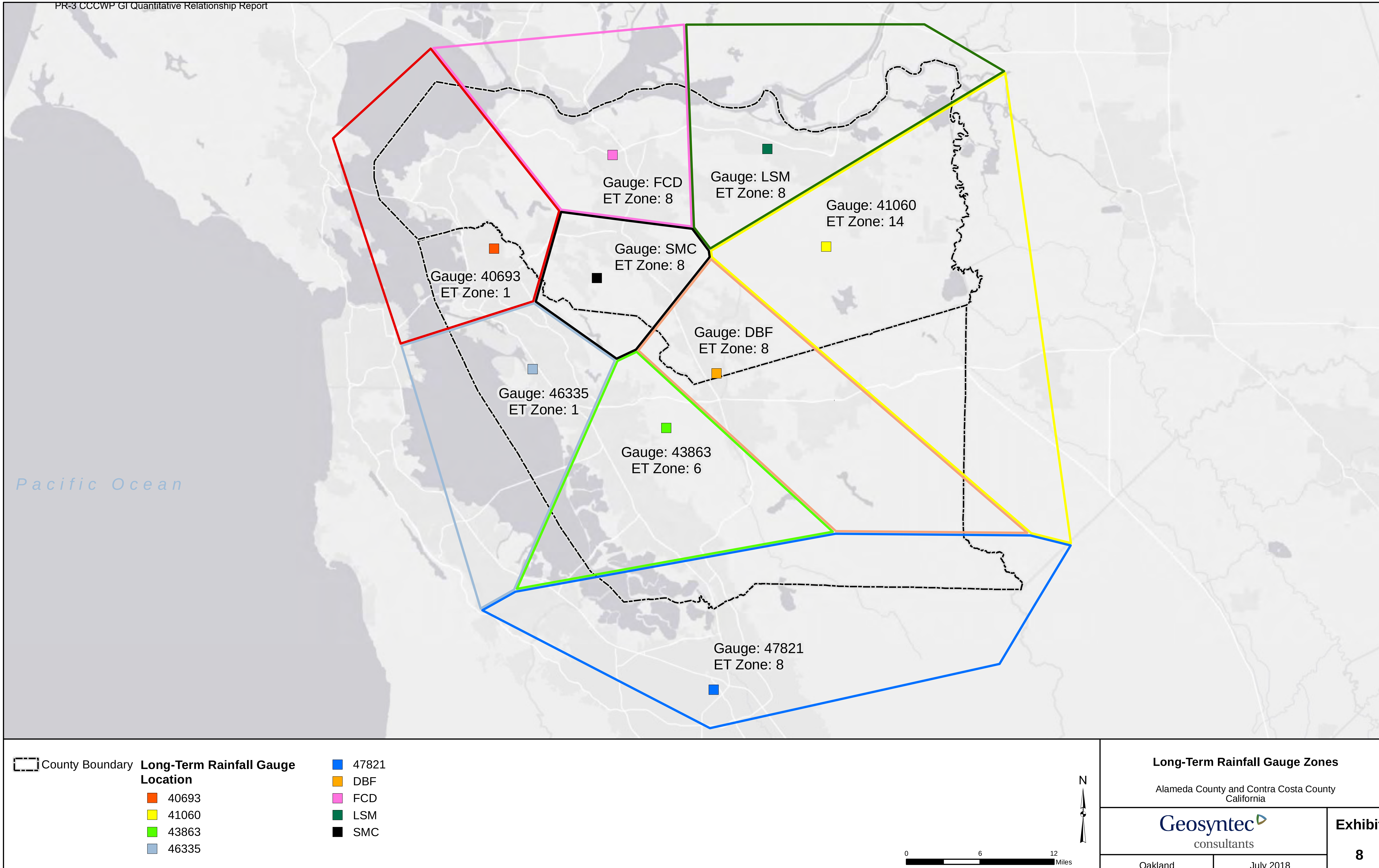
Alameda County and Contra Costa County
California

Geosyntec consultants

Oakland | July 2018

Exhibit 7

P:\GIS\Bay_Area_RAA\Project\GI_Load_Reduced_Report_Exhibits\Figure_8_Stream_Gauges.mxd 7/5/2018 6:00:55 PM



Long-Term Rainfall Gauge Zones

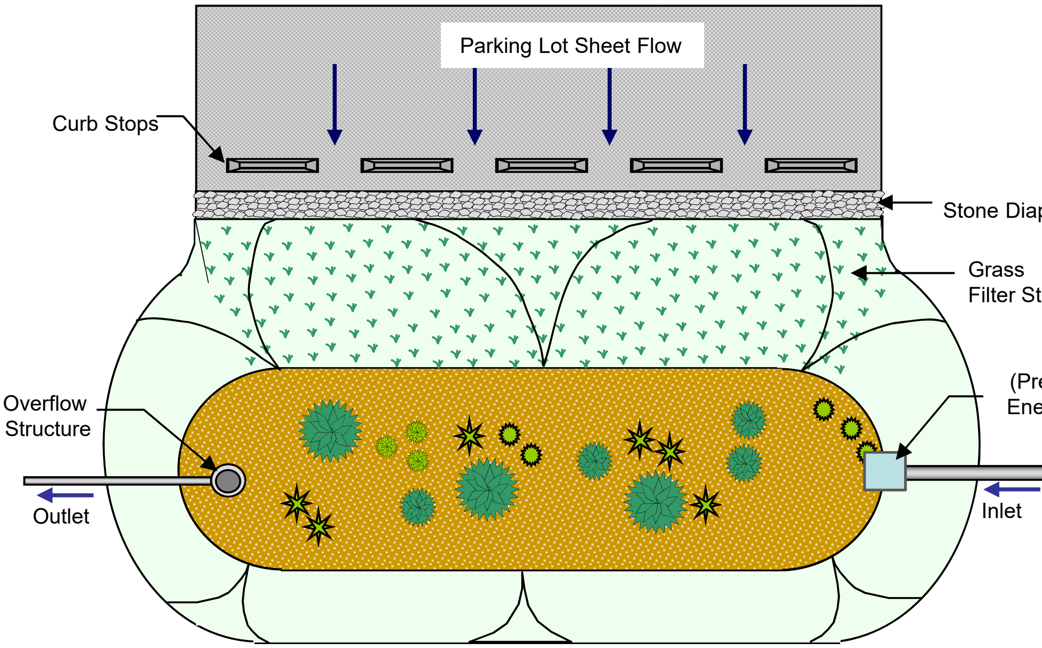
Alameda County and Contra Costa County
California

Geosyntec consultants

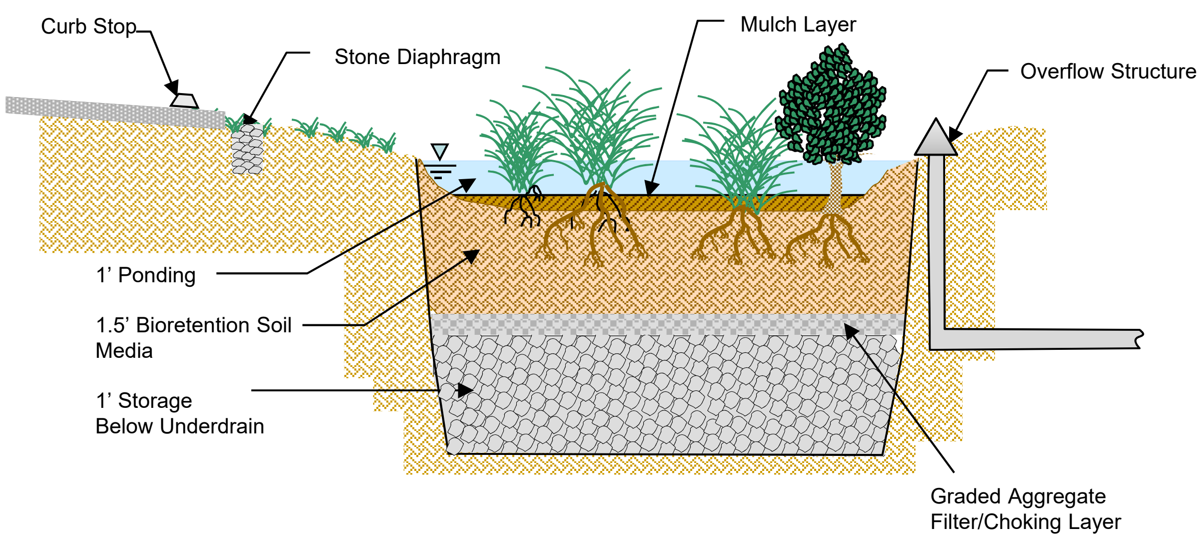
Oakland | July 2018

Exhibit 8

Plan View



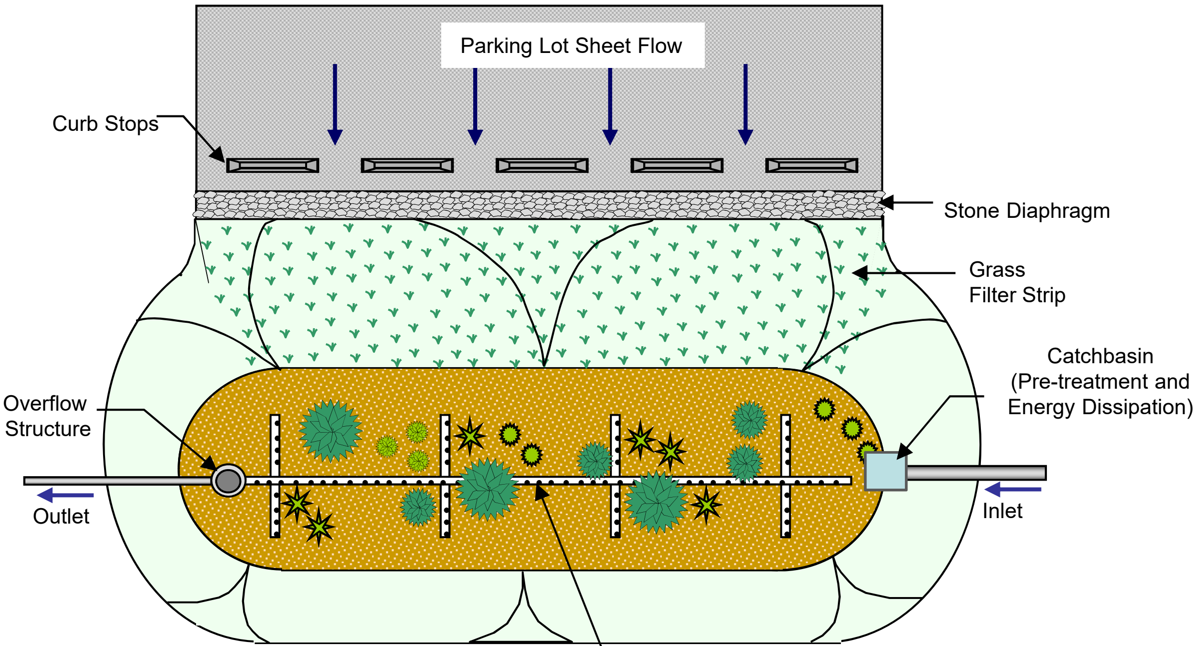
Profile



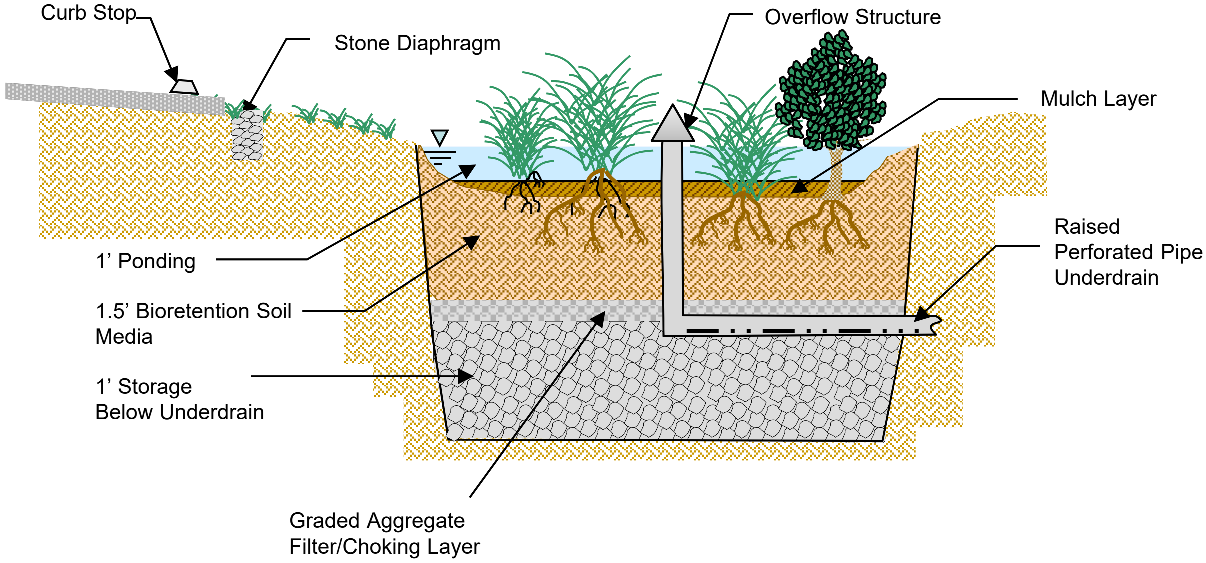
Note: Plan and Profile views are not to scale

Conceptual Illustration of an Infiltration Facility		
Geosyntec consultants		Exhibit 9
Oakland	July 2018	

Plan View



Profile



Note: Plan and Profile views are not to scale

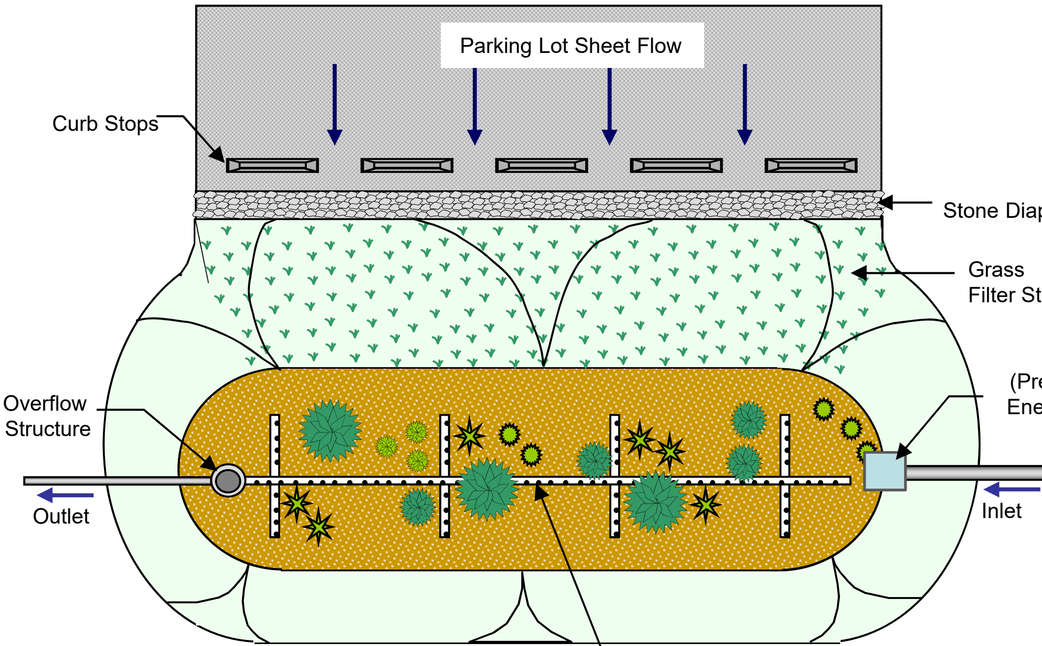
Conceptual Illustration of a Bioretention/Bioinfiltration Facility

Geosyntec consultants

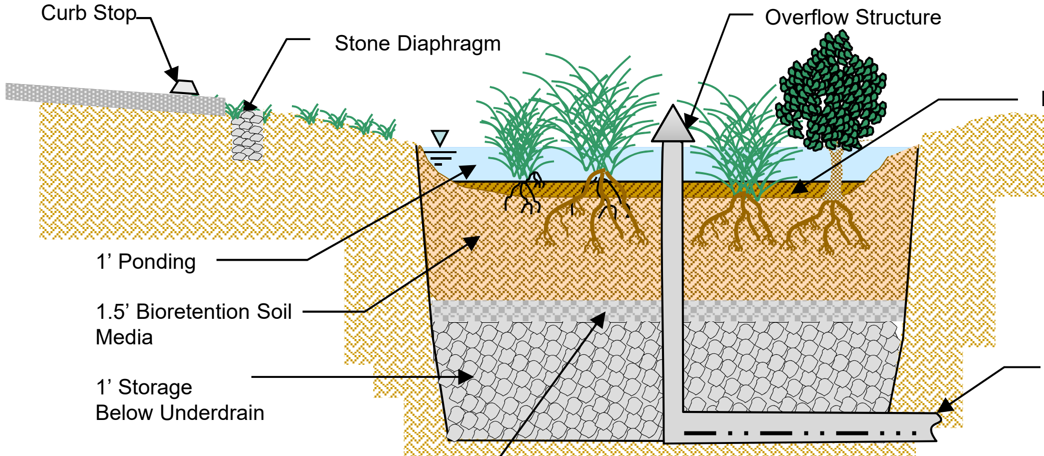
Exhibit 10

Oakland | July 2018

Plan View



Profile



Note: Plan and Profile views are not to scale

Conceptual Illustration of a Biofiltration Facility		
Geosyntec consultants		Exhibit 11
Oakland	July 2018	

PR-4 USEPA Stormwater Management Model Manual Excerpts

falls directly on them and do not capture runoff from other impervious areas in their subcatchment.

The second approach allows LID controls to be strung along in series and also allows runoff from several different upstream subcatchments to be routed onto the LID subcatchment. If these single-LID subcatchments are carved out of existing subcatchments, then once again some adjustment of the Percent Impervious, Width and also the Area properties of the latter may be necessary. In addition, whenever an LID occupies the entire subcatchment the values assigned to the subcatchment's standard surface properties (such as imperviousness, slope, roughness, etc.) are overridden by those that pertain to the LID unit.

Normally both surface and drain outflows from LID units are routed to the same outlet location assigned to the parent subcatchment. However one can choose to return all LID outflow to the pervious area of the parent subcatchment and/or route the drain outflow to a separate designated outlet. (When both of these options are chosen, only the surface outflow is returned to the pervious sub-area.)

3.4 Computational Methods

SWMM is a physically based, discrete-time simulation model. It employs principles of conservation of mass, energy, and momentum wherever appropriate. This section briefly describes the methods SWMM uses to model stormwater runoff quantity and quality through the following physical processes:

- Surface Runoff
- Groundwater
- Flow Routing
- Water Quality Routing
- Infiltration
- Snowmelt
- Surface Ponding

3.4.1 Surface Runoff

The conceptual view of surface runoff used by SWMM is illustrated in Figure 3-7 below. Each subcatchment surface is treated as a nonlinear reservoir. Inflow comes from precipitation and any designated upstream subcatchments. There are several outflows, including infiltration, evaporation, and surface runoff. The capacity of this "reservoir" is the maximum depression storage, which is the maximum surface storage provided by ponding, surface wetting, and interception. Surface runoff per unit area, Q, occurs only when the depth of water in the "reservoir" exceeds the maximum depression storage, d_s, in which case the outflow is given by Manning's equation. Depth of water over the subcatchment (d) is continuously updated with time by solving numerically a water balance equation over the subcatchment.

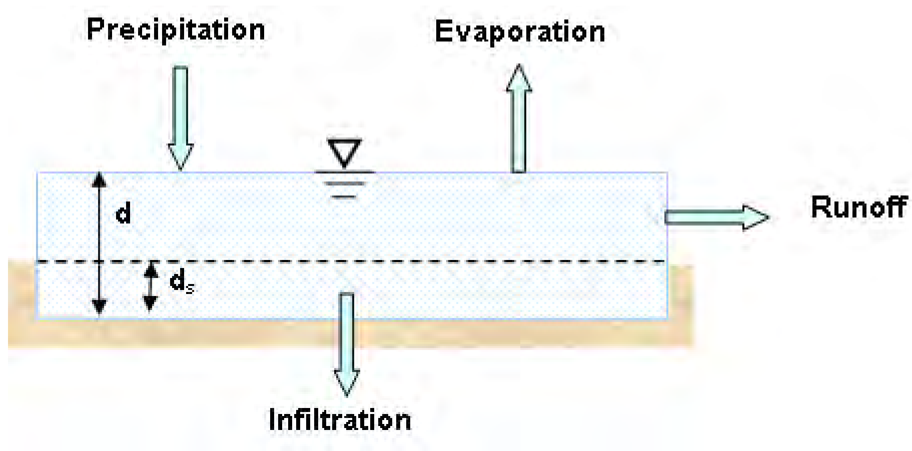


Figure 3-7 Conceptual view of surface runoff

3.4.2 Infiltration

Infiltration is the process of rainfall penetrating the ground surface into the unsaturated soil zone of pervious subcatchments areas. SWMM offers four choices for modeling infiltration:

Horton's Method
This method is based on empirical observations showing that infiltration decreases exponentially from an initial maximum rate to some minimum rate over the course of a long rainfall event. Input parameters required by this method include the maximum and minimum infiltration rates, a decay coefficient that describes how fast the rate decreases over time, and a time it takes a fully saturated soil to completely dry.

Modified Horton Method
This is a modified version of the classical Horton Method that uses the cumulative infiltration in excess of the minimum rate as its state variable (instead of time along the Horton curve), providing a more accurate infiltration estimate when low rainfall intensities occur. It uses the same input parameters as does the traditional Horton Method.

Green-Ampt Method
This method for modeling infiltration assumes that a sharp wetting front exists in the soil column, separating soil with some initial moisture content below from saturated soil above. The input parameters required are the initial moisture deficit of the soil, the soil's hydraulic conductivity, and the suction head at the wetting front. The recovery rate of moisture deficit during dry periods is empirically related to the hydraulic conductivity.

Modified Green-Ampt Method
This method modifies the original Green-Ampt procedure by not depleting moisture deficit in the top surface layer of soil during initial periods of low rainfall as was done in the original method. This change can produce more realistic infiltration behavior for storms with long initial periods where the rainfall intensity is below the soil's saturated hydraulic conductivity.

Curve Number Method

This approach is adopted from the NRCS (SCS) Curve Number method for estimating runoff. It assumes that the total infiltration capacity of a soil can be found from the soil's tabulated Curve Number. During a rain event this capacity is depleted as a function of cumulative rainfall and remaining capacity. The input parameters for this method are the curve number and the time it takes a fully saturated soil to completely dry.

SWMM also allows the infiltration recovery rate to be adjusted by a fixed amount on a monthly basis to account for seasonal variation in such factors as evaporation rates and groundwater levels. This optional monthly soil recovery pattern is specified as part of a project's Evaporation data.

3.4.3 Groundwater

Figure 3-8 is a definitional sketch of the two-zone groundwater model that is used in SWMM. The upper zone is unsaturated with a variable moisture content of θ. The lower zone is fully saturated and therefore its moisture content is fixed at the soil porosity ϕ. The fluxes shown in the figure, expressed as volume per unit area per unit time, consist of the following:

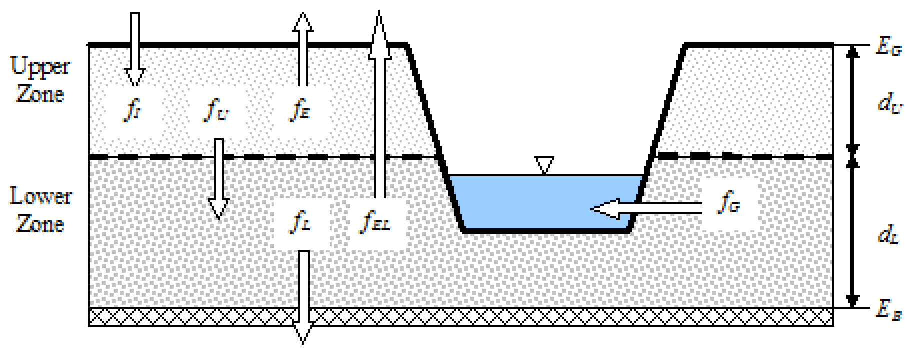


Figure 3-8 Two-zone groundwater model

f_I infiltration from the surface

f_{EU} evapotranspiration from the upper zone which is a fixed fraction of the un-used surface evaporation

f_U percolation from the upper to lower zone which depends on the upper zone moisture content θ and depth **d_U**

f_{EL} evapotranspiration from the lower zone, which is a function of the depth of the upper zone **d_U**

f_L seepage from the lower zone to deep groundwater which depends on the lower zone depth **d_L**

f_G lateral groundwater interflow to the drainage system, which depends on the lower zone depth **d_L** as well as the depth in the receiving channel or node.

where C = IMD . S, ft of water,
t = time, sec, and
1,2 = subscripts for start and end of time interval respectively.

This equation must be solved iteratively for F_2, the cumulative infiltration at the end of the time step. A Newton-Raphson routine is used.

The infiltration volume during time step $(t_2 - t_1)$ is thus $(t_2 - t_1) \times i$ if the surface does not saturate and $(F_2 - F_1)$ if saturation has previously occurred and a sufficient water supply is at the surface. If saturation occurs during the time interval, the infiltration volumes over each stage of the process within the time steps are calculated and summed. When rainfall ends (or falls below infiltration capacity) any water ponded on the surface is allowed to infiltrate and added to the cumulative infiltration volume.

Recovery of Infiltration Capacity (Redistribution)

Evaporation, subsurface drainage, and moisture redistribution between rainfall events decrease the soil moisture content in the upper soil zone and increase the infiltration capacity of the soil. The processes involved are complex and depend on many factors. In SWMM a simple empirical routine is used as outlined below; commonly used units are given in the equations to make the description easier to understand.

Infiltration is usually dominated by conditions in the uppermost layer of the soil. The thickness of this layer depends on the soil type; for a sandy soil it could be several inches, for a heavy clay it could be less. The equation used to determine the thickness of the layer is:

$$L = 4 \cdot \sqrt{K_s} \tag{20-73}$$

where L = thickness of layer, in, and
K_s = saturated hydraulic conductivity, in/hr.

Thus for a high K_s of 0.5 in/hr (12.7 mm/hr) the thickness is 2.83 inches (71.8 mm). For a soil with a low hydraulic conductivity, say K_s = 0.1 in/hr (2.5 mm/hr), the computed thickness is 1.26 inches (32.1 mm).

A depletion factor is applied to the soil moisture during all time steps for which there is no infiltration from rainfall or depression storage. This factor is indirectly related again to the saturated hydraulic conductivity of the soil and is calculated by:

$$DF = \frac{L}{300} \tag{20-74}$$

where DF = depletion factor, hr^{-1}, and

L = depth of upper zone, in.

Hence, for K_s = 0.5 in/hr (12.7 mm/hr), DF = 0.9% per hour; for K_s = 0.1 in/hr (2.5 mm/hr) DF = 0.4% per hour. The depletion volume (DV) per time step is then:

$$DV = DF \cdot FU_{max} \cdot \Delta t \tag{20-75}$$

where FU_{max} = L · IDM_{max} = saturated moisture content of the upper zone, in,
IDM_{max} = maximum initial moisture deficit, in/in, and
Δt = time step, hr.

The computations used are:

$$FU = FU - DV \quad for \quad FU \geq 0 \tag{20-76}$$

$$F = F - DV \quad for \quad F \geq 0 \tag{20-77}$$

where FU = current moisture content of upper zone, in, and
F = cumulative infiltration volume for this event, in.

To use the Green-Ampt infiltration model in continuous SWMM, it is necessary to choose a time interval after which further rainfall will be considered as pn independent event. This time is computed as:

$$T = \frac{6}{100 \cdot DF} \tag{20-78}$$

where T = time interval for independent event, hr.

For example, when K_s = 0.5 in/hr (12.7 mm/hr) the time between independent events as given in the last equation is 6.4 hr; when K_s = 0.1 in/hr (2.5 mm/hr) the time is 14.3 hr. After time T has elapsed the variable F is set to zero, ready for the next event. The moisture remaining in the upper zone of the soil is then redistributed (diminished) at each time step by the two previous equations in order to update the current moisture deficit (IMD). The deficit is allowed to increase up to its maximum value (IMD_{max}, an input parameter) over prolonged dry periods. The equation used is

$$IMD = \frac{FU_{max} - FU}{L} \; for \; IMD \leq IMD_{max} \tag{20-79}$$

When light rainfall ($i \leq K_s$) occurs during the redistribution period, the upper zone moisture storage, FU, is increased by the infiltrated rainfall volume and IMD is again updated using the last equation.

Guidelines for estimating parameter values for the Green-Ampt model are given elsewhere in this manual. As is also the case for the Horton equation, different soil types can be modelled for different subcatchments.

Program Variables

The infiltration computations are performed in subroutines WSHED and GAMP in the RUNOFF Module. Correspondence of program variables to those of this subsection is as follows:

S = SUCT(J)	L = UL(J)
IMD_{max} = SMDMAX (J)	DF = DF(J)
K_s = HYDCON(J)	i = RI
FU_{max} = FUMAX(J)	t = time
FU = FU(J)	Δt = DELT
IMD = SMD(J)	DV = DEP
F = F(J)	F_s = FS

20.5.4 Green-Ampt Infiltration Input Data

Although not as well known as the Horton equation, the Green-Ampt equation (1911) has the advantage of physically based parameters that, in principle, can be predicted a priori. The Mein-Larson (1973) formulation of the Green-Ampt equation is a two-stage model. The first step predicts the volume of water, F_s which will infiltrate before the surface becomes saturated. From this point onward, infiltration capacity, f_p, is predicted directly by the Green-Ampt equation. Thus,

$$For\ F < F_s : f = i\ and\ F_s = \frac{S_u\ IMD}{i/K_s - 1}\ for\ i > K_s; \tag{20-80}$$

No calculation of F_s for $i \le K_s$.

$$For\ F \ge F_s : f = f_p\ and\ f_p = K_s(1 + \frac{S_u\ IMD}{F}) \tag{20-81}$$

where
- f = infiltration rate, ft/sec,
- f_p = infiltration capacity, ft/sec,
- i = rainfall intensity, ft/sec,
- F = cumulative infiltration volume, this event, ft,
- F_s = cumulative infiltration volume required to cause surface saturation, ft,
- S_u = average capillary suction at the wetting front (SUCT), ft water,
- IMD = initial moisture deficit for this event (SMDMAX), ft/ft, and

PR-5 Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation Memo

Geosyntec consultants

1111 Broadway, 6th Floor
Oakland, California 94607
PH 510.836.3034
FAX 510.836.3036
www.geosyntec.com

Memorandum

Date: November 13, 2019

To: Jim Scanlin, Alameda Countywide Clean Water Program, and Courtney Riddle, Contra Costa Clean Water Program

Copy: Karin Graves and Lucile Paquette, Contra Costa Clean Water Program

From: Kelly Havens, Senior Engineer, Austin Orr, Engineer, Lisa Austin, Principal, and Marc Leisenring, Principal

Subject: Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation
Geosyntec Project Numbers: WW2127 and WW2407

1. INTRODUCTION

This memorandum provides an expanded description and summary results for the calibration and validation conducted as for the development of the Alameda Countywide Clean Water Program (ACCWP) and Contra Costa Clean Water Program (CCCWP) Reasonable Assurance Analysis (RAA) model. This memorandum provides additional information to that provided in the Alameda Countywide Clean Water Program Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions Report and the Contra Costa Clean Water Program Quantitative Relationship Between Green Infrastructure Implementation and PCBs/Mercury Load Reductions Report (i.e., “GI Quantitative Relationship Reports”; ACCWP, 2018 [PR-2] and CCCWP, 2018 [PR-3]) for the purpose of peer review. As such, this memorandum references information and sections in those reports.

2. CALIBRATION APPROACH AND PARAMETERS

As described in the GI Quantitative Relationship Reports [PR-2; PR-3], the baseline pollutant loading model utilized for the RAA is based on continuous simulation hydrology model run in EPA’s Stormwater Management Model (SWMM) version 5.1, combined with land use-based runoff concentrations to obtain the average annual loading of mercury and PCBs in stormwater runoff from Alameda and Contra Costa counties during the TMDL baseline period (i.e., 2003 – 2005). The hydrologic model utilizes generic hydrologic response units (HRUs), as described in Sections 2.2.1 and 3.1.1 of the GI Quantitative Relationship Reports [PR-2; PR-3]. Calibration of the generic HRU models was conducted on the average annual discharge volume for water years

(WYs) 2000-2009, utilizing available stream flow records. The objective of the calibration was to reasonably match the average annual runoff volume for this 10-year period.

The acceptable percent difference between simulated and observed annual volumes included in the *Bay Area RAA Guidance Document* (BASMAA, 2017) are provided in Table 1 below. These ranges were used to verify model results and evaluate whether parameters have been adequately calibrated.

Table 1: Allowable Difference between Simulated and Observed Annual Volumes

Model parameters	Average % difference between simulated annual results and observed data		
	Very Good	Good	Fair (lower bound, upper bound)
Hydrology/Flow	<10	10-15	15-25

A summary of the observed data and the parameters used to conduct the calibration with the simulated (modeled) results are provided in the following subsections.

2.1 Observed Data

2.1.1 Flow Gauges Used for Calibration

A list of candidate flow gauge sites were identified for potential use in calibration in the GI Quantitative Relationship Reports [PR-2; PR-3]. For the purposes of calibration, the candidate gauge sites that were identified in the GI Quantitative Relationship Reports included stream depth rating curves and daily mean records for the WY 2000 – 2009 period, and all are USGS gauges. The flow gauges used in calibration are summarized in Table 2 and shown in Figure PR-5A (all figures are provided at the end of the memo).

Table 2: Flow Gauges Used for RAA Model Calibration

Gauge ID	Gauge Name	Location	County	Data Frequency
11182500	San Ramon Creek	San Ramon	Contra Costa	Daily
11181390	Wildcat Creek[1]	Richmond / San Pablo	Contra Costa	Daily
11181040	San Lorenzo Creek	San Lorenzo	Alameda	Daily
11181008	Castro Valley Creek	Hayward	Alameda	Daily
11181000	San Lorenzo Creek	Hayward	Alameda	Daily
11180700	Alameda Creek Flood Channel	Union City	Alameda	Daily
11179000	Alameda Creek	Fremont	Alameda	Daily
11176900	Arroyo de la Laguna	Verona	Alameda	Daily

1. The Wildcat Creek gauge record is incomplete and contains data only for the four-year period WY 2006-2009. Geosyntec used the available years of gauge data to inform the calibration effort, but it was not ultimately used to assess the overall fitness of the model at representing the RAA baseline period regional hydrology.

Three other gauges were identified for potential use in calibration in the GI Quantitative Relationship Reports, but were ultimately not used for calibration, as described below. These included:

- Gauge number 11337600, Marsh Creek, which had considerable quantities of dry weather flows recorded with significant variability, such that baseflow removal techniques were not successful in isolating flows associated with rainfall;
- Gauge number 11173575, Alameda Creek Below Welch Creek, which contained significant data gaps in the record, as well as erratic stream flows likely caused by dam influence; and
- Gauge number 11173510, Alameda Creek Below Calaveras Creek, which contained significant data gaps in the record, as well as erratic stream flows likely caused by dam influence.

Given the data availability, calibration was conducted for both Alameda County and Contra Costa County areas simultaneously.

The area tributary to each flow gauge was delineated using the USGS StreamStats online tool (U.S. Geological Survey, 2016). These delineations were intersected with the HRU layer to select generic HRU's from across the two counties for use in the calibration, including multiple different rainfall and climate zones, soil classifications, surface slopes, and land uses. The watershed areas tributary to the gauges used are shown in Figure PR-5A and summarized in Table 3.

Table 3: Calibration Watershed Tributary Area Characteristics

Gauge ID	Gauge Name	Area (acres)	Percent Developed	Percent Impervious
11182500	San Ramon Creek	3,878	21%	2%
11181390	Wildcat Creek	4,999	22%	5%
11181040	San Lorenzo Creek	29,989	38%	12%
11181008	Castro Valley Creek	3,531	93%	44%
11181000	San Lorenzo Creek	24,203	24%	5%
11180700	Alameda Creek Flood Channel	237,946	29%	10%
11179000	Alameda Creek	224,072	28%	9%
11176900	Arroyo de la Laguna	164,679	35%	12%

2.1.2 Baseflow Removal Process

Calibration of land surface runoff hydrology to stream gauge records requires that baseflow be computed and accounted for throughout the period of record, as the RAA model does not include storm flow routing, groundwater inflow/outflow, diversions, or reservoirs. Where baseflow constitutes a large percentage of total flow, baseflow accounting allows for isolation and calibration of just the flow gauge runoff response to a rainfall event, which is dependent on land surface features. A variety of methods exist for separating baseflow from runoff. For those flow gauges requiring baseflow separation, two methods were identified as appropriate for the flow gauges used for Alameda County and Contra Costa County RAA model calibration. The methods and gauge characteristics corresponding to the use of the method include:

1. Base-Flow Index (BFI) modified: BFI modified is a timeseries analysis which locates minimum values in the hydrograph over five-day increments. For each identified minimum, if 90% of its value is less than both adjacent minimums, it is identified as a hydrograph ‘turning point’. The baseflow hydrograph is established by connecting the turning points with straight lines (Barlow et., al, 2015). This method was used to remove baseflow from calibration watersheds with appreciable development.
2. PART (short for partitioning): PART is an iterative timeseries analysis that identifies daily streamflow values that are not affected by surface runoff, assigns these values as baseflow, then removes baseflow from all days to compile the baseflow-corrected record used for surface runoff calibration. Daily streamflow values are identified as baseflow if they are preceded by N days of continuous streamflow recession (Barlow et., al, 2015); N is identified through the pattern of recession of streamflow measurements. This method was used to remove baseflow from large calibration watersheds influenced by significant impoundments.

The gauges for which no baseflow separation was conducted were estimated to have very little or no potential for baseflow to influence the calibration to mean annual volume since the streams are largely undeveloped, aren’t actively managed with significant impoundments, and typically run dry in the month of September. The most appropriate method for separating baseflow was determined on a gauge-specific basis, depending on the variability in the flow record and the occurrence of confounding factors that affect baseflow such as dam releases and other dry weather inflows.

A summary of the baseflow separation method used for each flow gauge is provided in Table 4.

Table 4: Calibration Flow Gauge Baseflow Removal Methods Used

Gauge ID	Gauge Name	Baseflow Separation and Removal Method	Notes	Total Watershed Area Including Impoundments (acres)	Impounded Area in Watershed (acres)
11182500	San Ramon Creek	No Baseflow Removal	Small, mostly undeveloped, typically dry in August or September	3,878	None
11181390[1]	Wildcat Creek	No Baseflow Removal	Small, mostly undeveloped, typically dry in August or September. Data only available for WY 2006-2009	4,999	None
11181040	San Lorenzo Creek	BFI Modified	Contains significant urban development	29,989	None
11181008	Castro Valley Creek	BFI Modified	Contains significant urban development	3,531	None
11181000	San Lorenzo Creek	No Baseflow Removal	Small, mostly undeveloped, typically dry in August or September	24,203	None
11180700	Alameda Creek Flood Channel	PART	Used only WY 2002, 2003, and 2005 – 2009 due to missing and erroneous data in other WYs. Large watershed with impoundments.	418,788	180,809
11179000	Alameda Creek	PART	Large watershed with impoundments.	404,913	180,809
11176900	Arroyo de la Laguna	BFI Modified	Contains significant urban development	258,121	93,419

1. The USGS does not report discharge for this gauge more recently than 1996. Balance Hydrologics began recording measurements for this gauge in 2005; this record was used for WY2006-2009.

2.2 Modeled Results - Model Calibration Parameters

To conduct the calibration, modeled annual storm flow produced from the delineated watersheds draining to the stream gauges (see Figure PR-5A) was compared to annual flow in the stream gauge records, with baseflow separated as described in Section 2.1.2, for WYs 2000 – 2009. Modeled annual storm flow was predicted by area-weighting the runoff output from generic HRU models in proportion to the areas of those generic HRUs within the watersheds draining to the stream gauges.

HRU calibration parameters were adjusted in three phases. The first phase entailed establishing the general range and sensitivity of the hydrologic model to saturated soil hydraulic conductivity (Ksat) for HSG C and D type soils for the generic HRUs within the three undeveloped watersheds tributary to identified calibration flow gauges (see Tables 2, 3, and 4). The second phase involved exploring sensitivity to changes in soil infiltration recovery time for the identified range of Ksat values. The third phase incorporated soil parameter value combinations identified in the first two phases in models for all eight calibration watersheds. National Land Cover Dataset (NLCD) imperviousness data were initially considered as a calibration parameter but were not ultimately used (see further discussion in Section 2.2.3 below).

Identified model parameters were adjusted for each phase until the average percent difference between modeled and measured average annual storm flow volumes (with baseflow removed as described in Table 4) was less than 25% - the acceptable range as summarized in Table 1. Once the average percent difference for all the calibration watersheds were within the acceptable range, the HRU model parameters were finalized.

2.2.1 Soil Hydraulic Conductivity

Soil Ksat was primarily calibrated in the watersheds draining to flow gauges 11182500 (San Ramon Creek), 11181390 (Wildcat Creek), and 11181000 (San Lorenzo Creek) because these watersheds are primarily undeveloped and thus provide greater isolation of the pervious area runoff and loss response to rainfall. Given the percent total area of hydrologic soil group (HSG) C and D type soils in these watersheds, soil Ksat was adjusted only for HSG types C and D. The Ksat for soil groups A and B were assigned by area-weighting literature values corresponding with the texture classes that are present within Alameda County and Contra Costa County. It was found that adjusting HSG A and B Ksat model input values resulted in minimal changes to average annual volume in the watersheds given that A and B type soils each cover less than 5% of the Alameda County and Contra Costa County areas modeled.

2.2.2 Soil Recovery Pattern

The same three watersheds used for Ksat calibration were also used to calibrate soil recovery time. This parameter is associated with the soil drying effects caused by evapotranspiration and determines how many days it takes for a soil to recover its full infiltrative capacity during the dry period following a rainfall event. In SWMM, this parameter is a function of both the subbasin's Ksat and expected soil recovery time and can be defined on a monthly basis as part of the climatological parameters. See SWMM5 Users Guide 13th Edition pg. 462-463 (James et., al, 2010; provided in PR-4) for information on the Green Ampt Equation and the Recovery of Infiltration Capacity.

2.2.3 Calibration for Developed Watersheds

Imperviousness (associated with specific Association of Bay Area Governments [ABAG] land use types, see Section 3.1.1. of the GI Quantitative Relationship Reports [PR-2; PR-3]) was considered as a parameter for calibration, but NLCD-derived imperviousness was found to produce modeled results within the acceptable range, so no adjustment to imperviousness was applied as part of calibration. Imperviousness values were assigned for each individual polygon in the ABAG 2005 Geospatial Information System (GIS) dataset by area-weighting the NLCD 2006 imperviousness values associated with the polygon. Each parcel and right-of-way (ROW) segment had roughly the same spatial resolution.

Soil parameters calibrated to undeveloped watersheds were adjusted for soil compaction assumed to occur during development (see Section 3.1.1 of the GI Quantitative Relationship Reports [PR-2; PR-3]) and were used to develop area-weighted average annual HRU runoff output for the other more developed and impervious watersheds associated with identified flow gauges. Coupled with the NLCD-derived imperviousness method for identifying representative HRUs for the watersheds, these calibrated soil parameters were found to produce results within the acceptable calibration range for the more developed and impervious watersheds used for calibration.

3. CALIBRATION RESULTS

3.1 Parameter Adjustment

To identify the region of best fit between modeled and measured average annual runoff for the identified calibration parameters, a large range of values were input into the generic HRU models representative of the areas within the calibration watersheds.

3.1.1 Soil Hydraulic Conductivity and Recovery Time

Soil Ksat values between 0.025 – 0.35 inches per hour (in/hr) for HSG C and D soils were examined as part of the first phase of calibration. Varying combinations of Ksat values for the two soil types were tested for the undeveloped calibration watersheds. Each pair of parameters represent hundreds of individual continuous HRU SWMM models. This calibration exercise revealed that the best fit values for HSG C and D type soil in the three undeveloped calibration watersheds likely falls between 0.1 and 0.2 in/hr for HSG C soils, and between 0.05 and 0.125 in/hr for HSG D type soils.

This range of parameters was explored further in the second phase of calibration, in which soil recovery time was adjusted for three different values: 7 days, 14 days, and 18 days. The calibration percent difference results corresponding to the combinations of HSG C and D soil Ksat values and soil recovery times are shown in Figure PR-5B. Darker blue areas indicate a lower percent difference between modeled runoff volume and measured total discharge volume (with baseflow removed per Table 4) in the three undeveloped calibration watersheds. Over 11,800 continuous simulation HRU model runs were evaluated in order to create the grid of values, shown in Figure PR-5B.

The darkest blue areas of the three plots in Figure PR-5B indicate the least percentage difference between modeled and measured average annual runoff volume for all three undeveloped stream gauge records during the period from WY 2000 - 2009. The percentage difference in total annual average runoff volume is quite sensitive to changes in HSG C and D type soils for the range of Ksat values searched during this exercise, but the model is not very sensitive to soil recovery time as indicated by the small differences in the three plots.

From this calibration phase two investigation, it was identified that the most appropriate soil Ksat values ranged from 0.125 – 0.15 in/hr for HSG C soils, 0.075 – 0.1 in/hr for HSG D soils. A soil recovery pattern equivalent to a 14-day soil recovery time for HSG C soils was also identified to be the most appropriate for the calibration watersheds.

Phase three of the calibration used this tighter range of HSG C and D soil Ksat values to evaluate percent difference between average annual modeled runoff and measured discharge at all of the calibration gauges (as corrected for baseflow removal per Table 4). The best-fit soil Ksat parameters for all eight of the calibration gauges are shown in Table 5 below.

Table 5: Final Soil Ksat Values for the Eight Calibration Gauge Tributary Watersheds

HSG	Undeveloped Soil Ksat (in/hr)	Developed Soil Ksat[1] (in/hr)
A[2]	2.5	1.875
B[2]	0.3	0.225
C	0.15	0.1125
D	0.1	0.075

[1] Ksat is decreased by 25% to account for soil compaction expected to occur during development.

[2] Ksat assigned by area-weighting literature values corresponding with soil texture classes present in the areas modeled.

3.2 Resulting Percent Difference between Modeled and Measured Average Annual Runoff

Utilizing the calibrated parameter values described in Section 3.1 and summarized in Table 5, the percent difference between average annual modeled runoff and average annual measured runoff for the period of record (WY 2000 – 2009) was found to be within the required threshold (Table 1) for most of the watersheds examined, with the exception of the Wildcat Creek gauge (gauge number 11181390). This gauge has an incomplete record and contains data for only four years, from WY 2006-2009. The available data from this gauge was used to inform the calibration parameters, but given the incomplete record, the percent difference between measured and modeled average annual runoff volume was not ultimately used to assess the overall fitness of the RAA hydrologic model for the full baseline time period (WY 2000-2009).

The percent difference between average annual modeled runoff and measured runoff (accounting for baseflow corrections per Table 4) for the RAA baseline period from WY 2000-2009 for each calibration gauge is shown in Figure PR-5C. Since the entire decade was modeled, some individual years within the period of record varied more than the 25% threshold; however, these percent differences are offset between wet years and dry years to provide an acceptable percent difference between average annual modeled and measured values.

4. VALIDATION

Following completion of baseline hydrologic calibration, baseline loads were validated using pollutant monitoring data collected as part of the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP; specifically, the Small Tributary Loading Strategy project) and the Surface Water Ambient Monitoring Program (SWAMP). Pollutant concentration data were obtained from the California Environmental Data Exchange Network (CEDEN). The validation analysis included 206 total PCBs and 291 total mercury results from various monitoring locations in Alameda and Contra Costa Counties with sample dates ranging from 2001 to 2014.

Samples were taken at load monitoring stations, mostly during wet weather. These stations are shown on Figures PR-5D (PCBs) and PR-5E (mercury) along with their respective watershed delineations. Where not provided by SFEI, watershed delineations were developed using the USGS StreamStats delineation tool (USGS, 2016). The land use composition of the validation watersheds is provided in Attachment A to this memo.

The validation exercise conducted combines the calibrated Contra Costa and Alameda County regional hydrology with the Regional Watershed Spreadsheet Model (RWSM) PCBs and mercury values estimated by SFEI (see section 2.1 and 2.2.2 of the GI Quantitative Relationship Reports [PR-2; PR-3] and Regional Watershed Spreadsheet Model Version 1.0 Results Summary Memorandum (Geosyntec, 2019). Because the RWSM concentrations used for the RAA water quality model are not modifiable for the regional RAA Modeling approaches, this validation exercise is purely qualitative, and is not expected to result in changes to the hydrologic or water quality model input parameters.

The validation process includes computing the area-weighted average annual runoff volume for each land use category within the validation watersheds and combining these results with the associated RWSM average annual pollutant concentration. The resulting land use-based pollutant loads are added together over all land uses to obtain the estimated average annual pollutant load for each validation watershed. This average annual pollutant load is divided by the average annual runoff volume for the validation watershed to obtain an average annual pollutant discharge concentration for each validation watershed. The values calculated from the model output were compared to monitoring data collected at the associated validation monitoring locations. Statistical summaries and the number of samples for PCBs and mercury concentrations measured at each validation monitoring location are shown in box plot format in Figure PR-5F and Figure PR-5G, respectively. The resulting average annual pollutant discharge concentration for each validation watershed is superimposed on the box plots of the measured values for comparison.

The modeled PCBs concentrations are within the expected ranges for the validation watersheds examined (see Figure PR-5F). In some cases, the model slightly overpredicts the PCBs concentration in runoff, notably in the Ettie Street and Zone 5 Line M watersheds, and in other cases, underpredicts, such as in the Santa Fe Channel watershed. This is expected given the highly variable spatial distribution of PCBs contamination and storm-to-storm variability in runoff characteristics. The differences are largely attributable to the use of the regionally-characteristic land use-based RWSM values for modeling PCBs runoff concentrations and comparing average annual concentrations computed from annualized loads and volumes.

The validation exercise for mercury included many more watersheds than for PCBs. In general, the modeled values for mercury concentration are significantly higher than the measured values (see Figure PR-5G). The present RWSM land use-based concentration values for mercury appear to overestimate the observed concentration of mercury in the monitored watersheds within Alameda County and Contra Costa County.

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Attachment

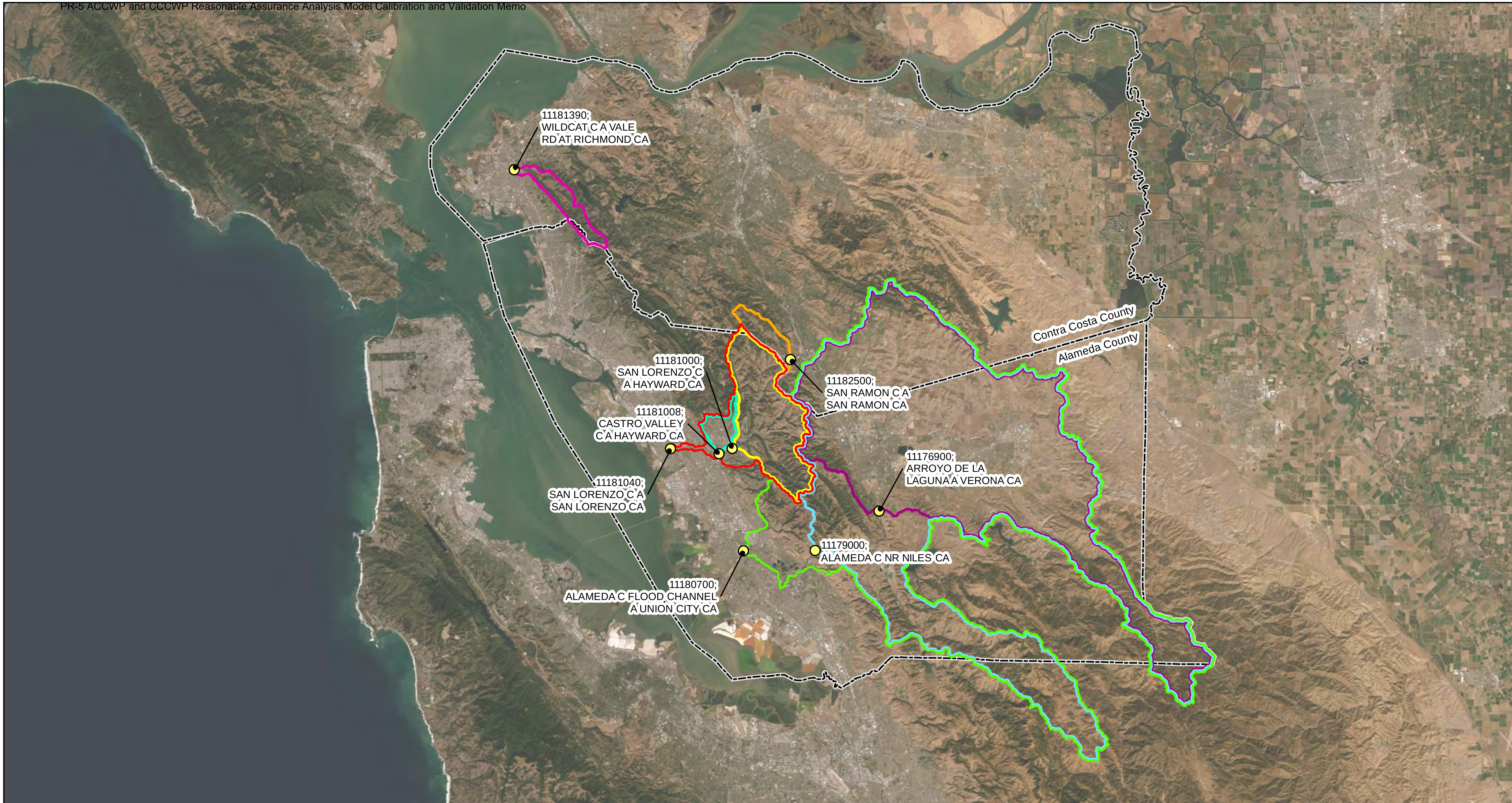
Alameda Countywide Clean Water Program and Contra Costa Clean Water Program Reasonable Assurance Analysis Model Calibration and Validation Memo

Attachment A: Land Use Breakdown, Validation Watersheds

November 8, 2019

Validation Watershed	POC	Total Acres by Land Use					Total Acres	Percent Area by Land Use				
		Old Industrial	Old Commercial/ Old Transportation	Old Residential	New Urban	Open Space		Old Industrial	Old Commercial/ Old Transportation	Old Residential	New Urban	Open Space
Ettie Street Pump Station_A	PCBs and Hg	356	187	580	47	13	1,183	30%	16%	49%	4%	1%
Santa Fe Channel-SFeCh	PCBs and Hg	197	240	1,012	43	35	1,527	13%	16%	66%	3%	2%
Zone 5 Line M-Z5LM	PCBs and Hg	162	79	645	100	858	1,843	9%	4%	35%	5%	47%
Hayward Ind Stdrn	PCBs and Hg	82	312	495	118	14	1,021	8%	31%	48%	12%	1%
Meeker Slough	PCBs and Hg	9	74	415	3	5	507	2%	15%	82%	<1%	<1%
San Leandro Creek	PCBs and Hg	49	243	4,750	617	23,052	28,710	<1%	<1%	17%	2%	80%
San Lorenzo Creek	PCBs and Hg	50	842	5,619	2,781	20,694	29,986	<1%	3%	19%	9%	69%
Lower Marsh Creek	PCBs and Hg	125		1,113	6,034	67,837	75,109	<1%	0%	1%	8%	90%
Walnut Creek	PCBs and Hg	88	2,284	18,655	5,558	28,004	54,590	<1%	4%	34%	10%	51%
Glen Echo Creek-GECr	PCBs and Hg		90	400	3	223	716	0%	13%	56%	<1%	31%
Port Chicago Highway	Hg Only	1,650	268	1,801	1,021	14,229	18,968	9%	1%	9%	5%	75%
Codornices at 2nd Street	Hg Only	61	24	893	3	2	983	6%	2%	91%	<1%	<1%
Kirker Creek at Floodway	Hg Only	23		204	99	105	431	5%	0%	47%	23%	24%
El Charro	Hg Only	981	1,027	2,792	4,653	44,201	53,654	2%	2%	5%	9%	82%
Cerrito at Creekside Park	Hg Only	27	119	1,626	17	89	1,879	1%	6%	87%	<1%	5%
Richmond Parkway	Hg Only	36	165	868	47	4,382	5,497	<1%	3%	16%	<1%	80%
3rd St. Bridge	Hg Only	123	339	6,804	911	18,576	26,753	<1%	1%	25%	3%	69%
Baxter at Booker	Hg Only	1	65	541	2	83	692	<1%	9%	78%	<1%	12%
Above Vulcan Bridge Zone 7	Hg Only	28	96	1,078	414	26,592	28,209	<1%	<1%	4%	1%	94%
Arroyo Viejo Rec. Center	Hg Only	2	130	1,841	64	1,400	3,438	<1%	4%	54%	2%	41%
Cesar Chavez Park	Hg Only	0	116	1,287	2	56	1,461	0%	8%	88%	<1%	4%
Strawberry Creek Park	Hg Only		98	822	75	454	1,448	0%	7%	57%	5%	31%
Sausal at E.22nd	Hg Only		140	1,822	6	545	2,513	0%	6%	73%	<1%	22%
Above Lake Temescal	Hg Only		37	817	49	202	1,105	0%	3%	74%	4%	18%
Kirker Creek Apartments	Hg Only		50		10	3,497	3,558	0%	1%	0%	<1%	98%
Mitchell on Oak St	Hg Only			97	0	2,729	2,826	0%	0%	3%	0%	97%

Figures



Legend

County Boundaries

Flow Gauge Location

San Lorenzo Ck.	Alameda Ck.	San Ramon Ck.	Wildcat Ck.
11181040	11180700	11182500	11181390
11181000	11179000		
11181008	11176900		

RAA Hydrologic Model Calibration

Watersheds Tributary to Flow Gauges Used for Comparison

Alameda County and Contra Costa County
California

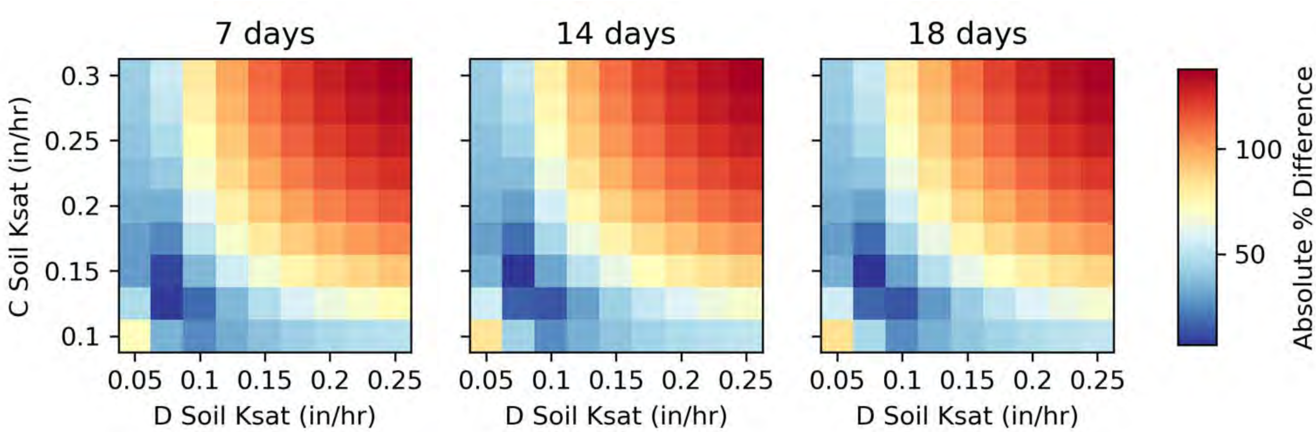
Geosyntec consultants

Oakland | August 2019

Figure

PR-5A

P:\GIS\Bay_Area_RAA\Project\Peer_Review_Documentation\PR-5A_Stream_Gauges.mxd 8/19/2019 12:18:22 PM



Calibration Matrix for HSG C and D Soils and Soil Recovery Time

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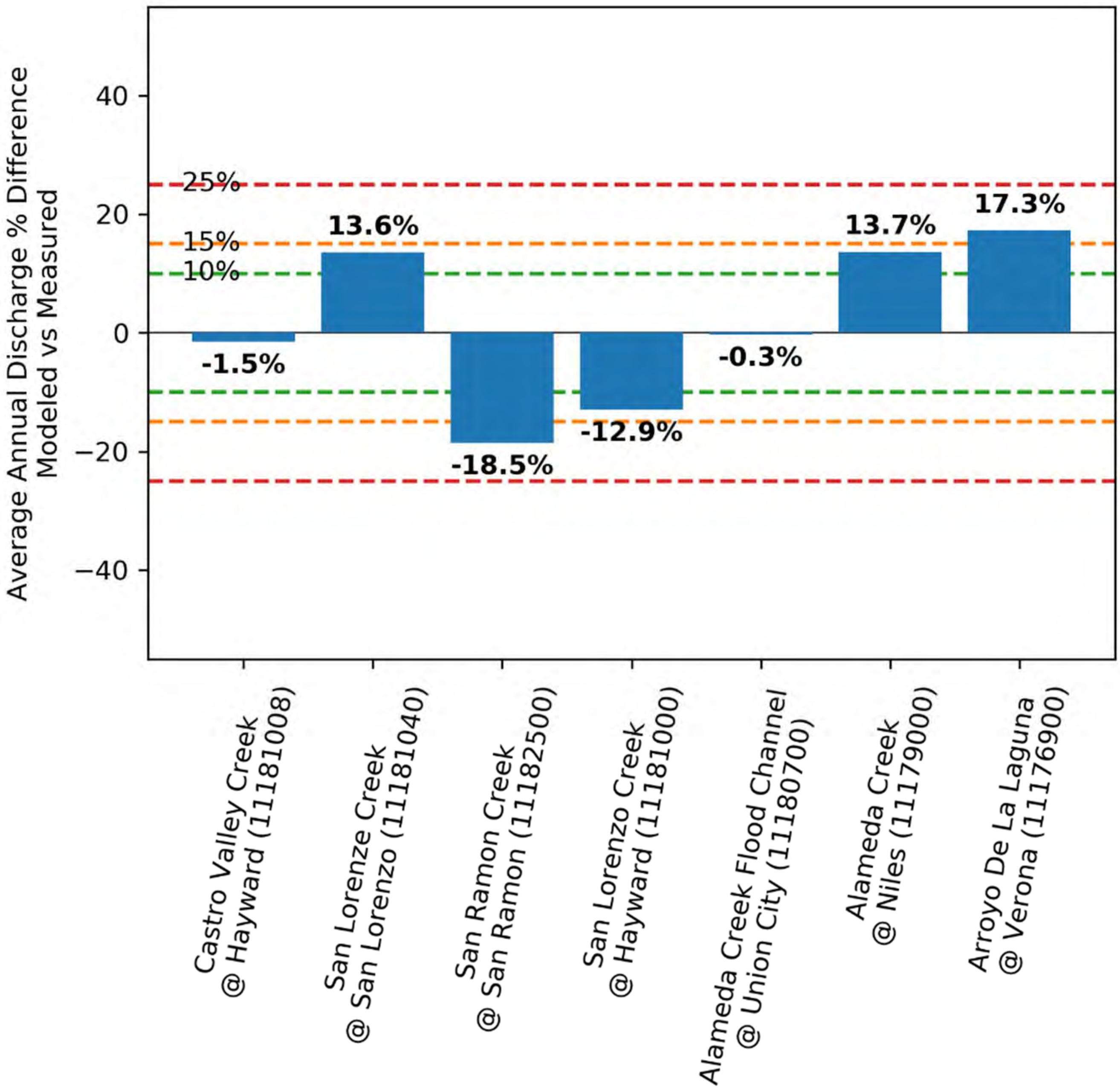
Figure PR-5B



Percent Difference Between Modeled and Measured Average Annual Runoff Volume for Each Calibration Watershed

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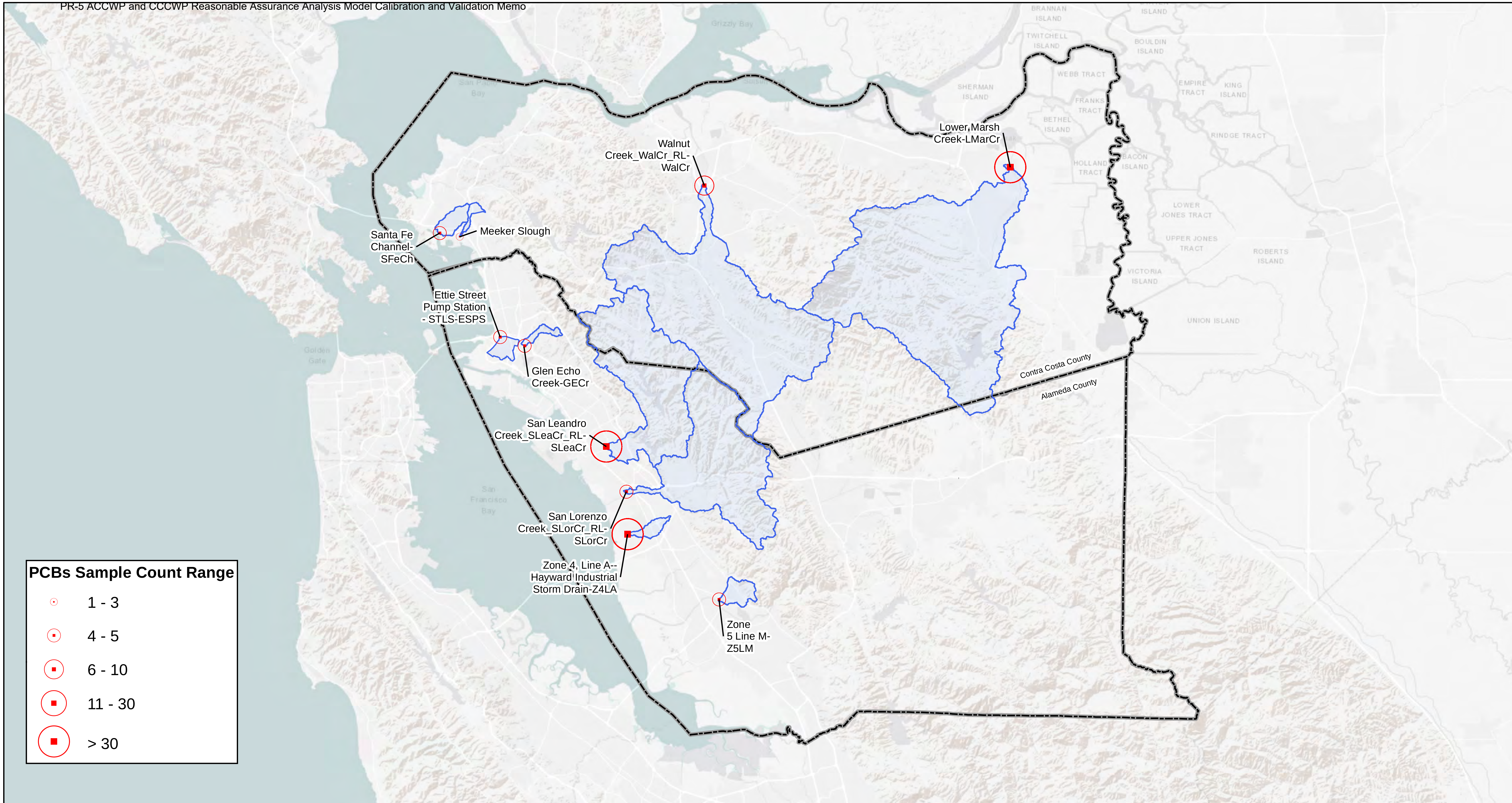
Figure PR-5C



Legend

County Boundary

Validation Watershed

Monitoring Location

N

0 3 6 12 Miles

RAA Water Quality Model Validation

Watersheds Tributary to Polllutant Monitoring Locations used for Comparison of PCBs

Alameda County and Contra Costa County California

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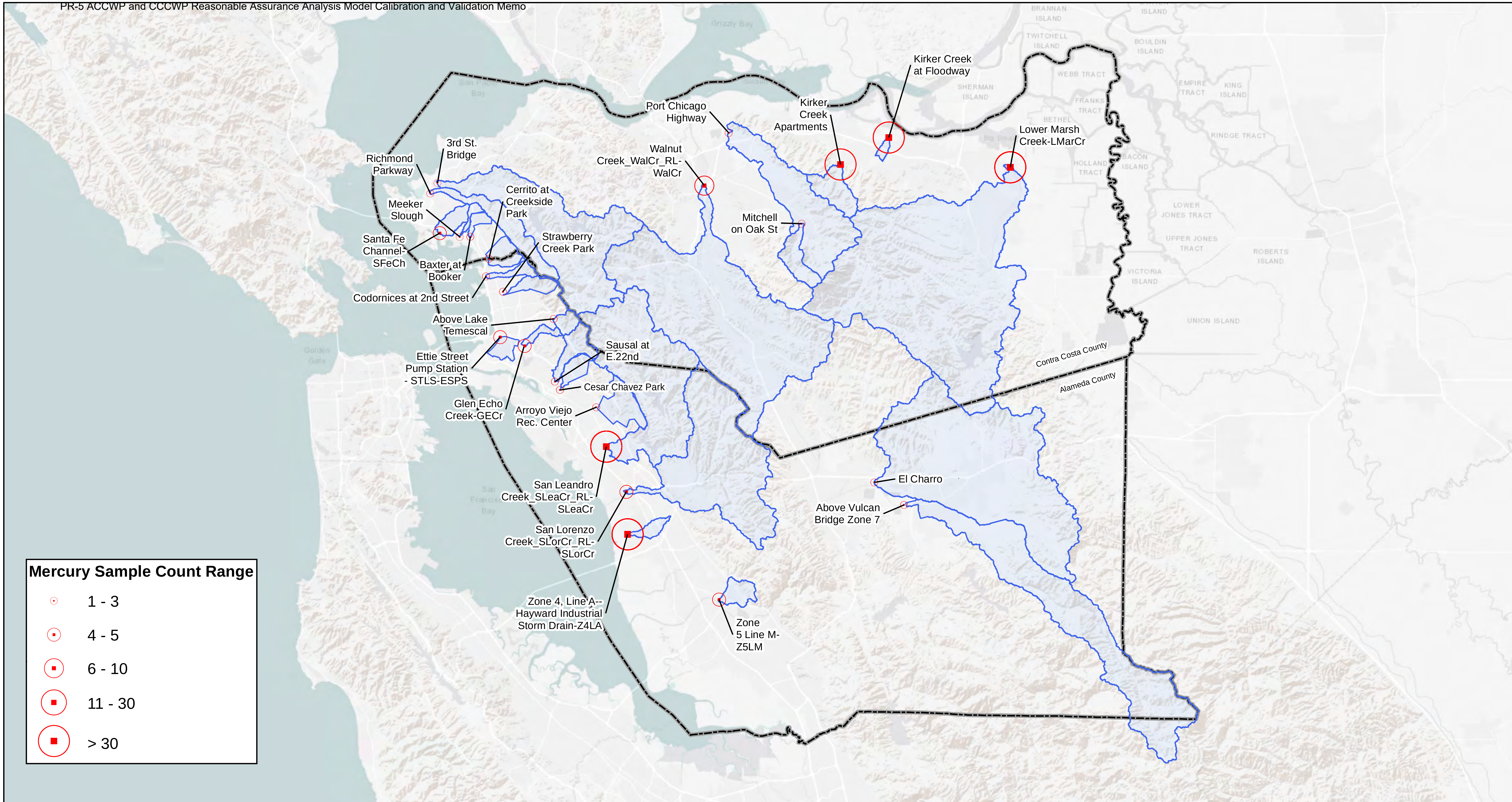
Figure PR-5D



Legend

County Boundary

Validation Watershed

N

0 3 6 12 Miles

RAA Water Quality Model Validation

Watersheds Tributary to Polllutant Monitoring Locations used for Comparison of Mercury

Alameda County and Contra Costa County California

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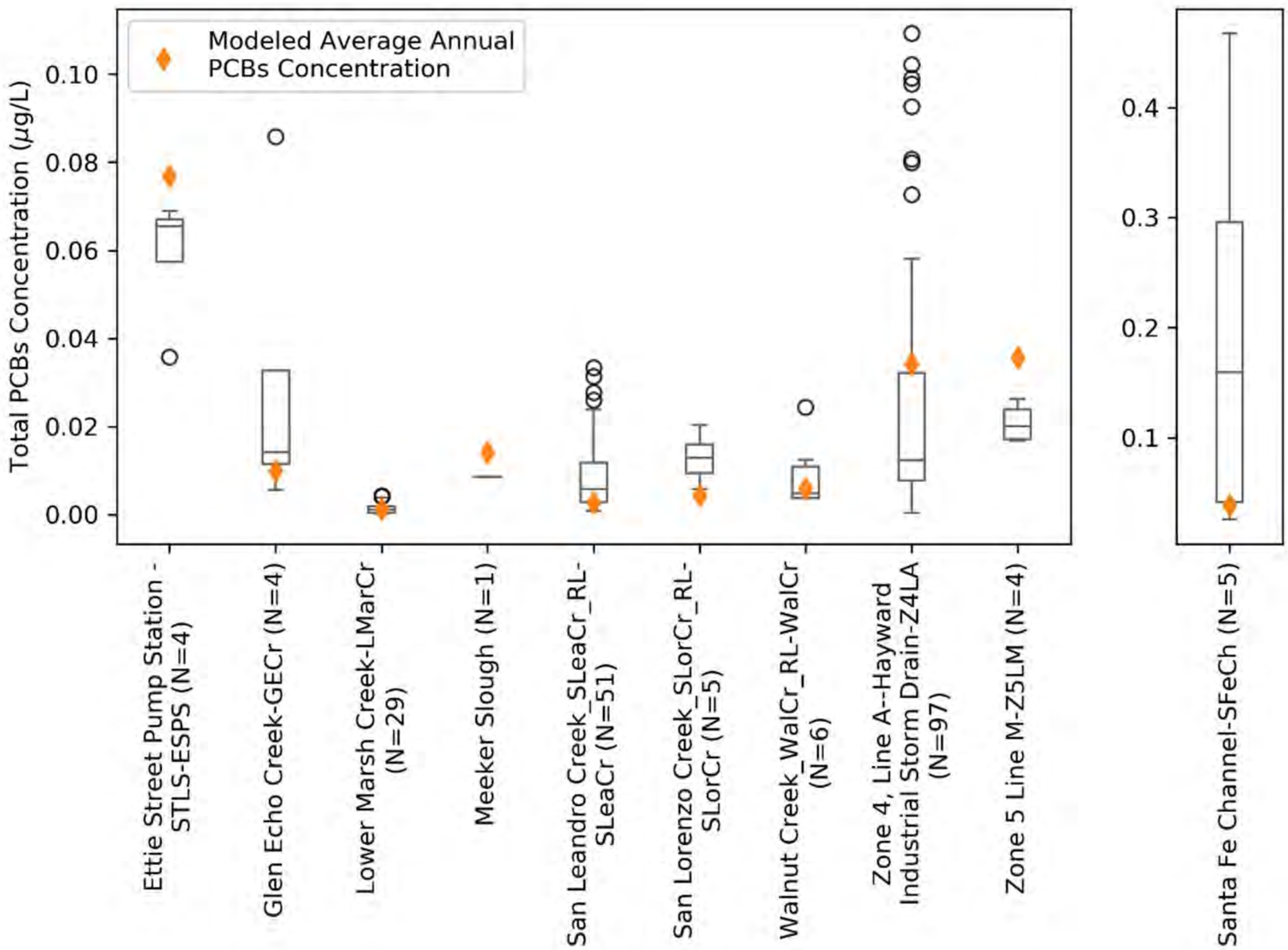
Figure PR-5E

P:\GIS\Bay_Area_RAA\Project\Peer_Review_Documentation\PR-5E_Validation_Watersheds Hg.mxd 8/19/2019 12:17:46 PM



Modeled and Measured PCBs Concentrations for Monitored Watersheds in Alameda County and Contra Costa County

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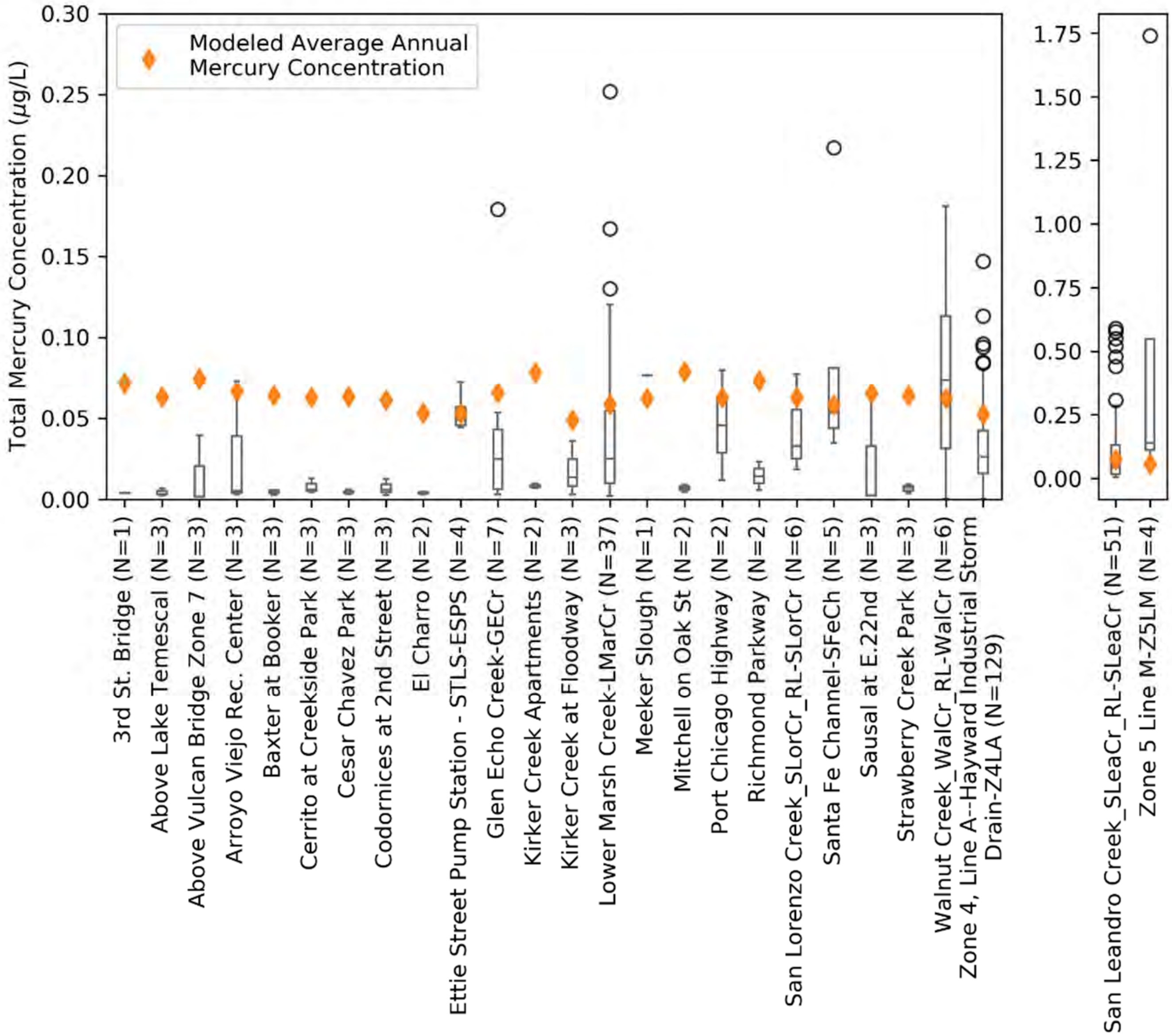
Figure PR-5F



Modeled and Measured Mercury Concentrations for Monitored Watersheds in Alameda County and Contra Costa County

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Figure PR-5G

APPENDIX F

List of NPDES Permittees Removed from Baseline

Table A-1: List of Phase II Permittees, and Facilities with Major or Minor NPDES Permits, in Alameda County

Permit Category	Facility Name	Facility Owner	City
Phase II	Bay Area Rapid Transit (BART)	Bay Area Rapid Transit District	Various
Phase II	Alameda Coast Guard	United States of America	Alameda
Phase II	Amtrak Oakland Maintenance Facility	National Railroad Passenger Corporation	Oakland
Phase II	Federal Correctional Instituion, Dublin (Camp Parks)	United States of America	Dublin
Phase II	Cal State East Bay Hayward Campus	State of California	Hayward
Phase II	Port of Oakland	City of Oakland	Oakland
Phase II	University of California, Berkeley	Regents of the University of California	Berkeley/Oakland
NPDES Major	City Of Livermore Sewage Treatment Plant	City Of Livermore	Livermore
NPDES Major	East Bay Mud Main WWTP	East Bay Municipal Utility District	Oakland
NPDES Major	Dublin-San Ramon WWTF	Dublin San Ramon Services District	Pleasanton
NPDES Major	EBDA Common Outfall	City Of San Leandro /East Bay Dischargers Authority	San Leandro
NPDES Minor	Alameda Sewer Collection System	City Of Alameda	Alameda
NPDES Minor	Albany Wet Weather Bypass	City Of Albany Public Facilities Financing Authority	Albany
NPDES Minor	City Of Berkeley Transfer Station	City Of Berkeley	Berkeley
NPDES Minor	Former Marchant Building	Lba Riv Co Xii LLC	Berkeley/Emeryville/Oakland
NPDES Minor	Carl Zeiss Meditec	Gpt Tpg 5160 Hacienda LP	Dublin
NPDES Minor	Dublin San Ramon Services District	Dublin San Ramon Services District	Dublin
NPDES Minor	Hexcel Corporation	Hexcel Corporation	Dublin
NPDES Minor	Emeryville Sewer Collection System	City Of Emeryville	Emeryville
NPDES Minor	Hayward Waste Water Treatment	City Of Hayward	Hayward
NPDES Minor	ACWD Newark Desalination Facility Discharges To Outfall E-14	Alameda County Water District	Newark
NPDES Minor	Oakland Sewer Collection System	Housing Authority Of The City Of Oakland	Oakland
NPDES Minor	Schnitzer Steel	Schnitzer Steel Products Of California Inc	Oakland
NPDES Minor	Piedmont Sewer Collection System	City Of Piedmont	Piedmont
NPDES Minor	Coopervision Inc	Black Mountain Properties LLC	Pleasanton
NPDES Minor	Rock Roll Auto Recycling	Guasco Richard L Tr	Pleasanton
NPDES Minor	Thoratec Corporation	Fox Thoratec LLC & 6035 Stoneridge Dr Asscs Etal	Pleasanton

Permit Category	Facility Name	Facility Owner	City
NPDES Minor	San Leandro Wpcp	City Of San Leandro	San Leandro
NPDES Minor	Former Mckesson Facility	Williams Brothers	Union City
NPDES Minor	Union Sanitary District Treatment Plant	Union Sanitary District	Union City

APPENDIX G

ACCWP Memo on Scenarios for Attaining PCBs Loads by 2030

Geosyntec consultants

1111 Broadway, 6th Floor
Oakland, California 94607
PH 510.836.3034
FAX 510.836.3036
www.geosyntec.com

Memorandum

Date:	August 19, 2020
To:	Jim Scanlin, Alameda Countywide Clean Water Program
From:	Lisa Austin, P.E., Principal; Kelly Havens, P.E., Senior Engineer; and Elai Fresco, P.E., Project Engineer
Subject:	ACCWP Reasonable Assurance Analysis – 2030 Scenario Geosyntec Project Number: LA0597

1. BACKGROUND

This memorandum presents the results of an analysis of scenarios that investigate the level of implementation needed to result in polychlorinated biphenyls (PCBs) load reductions sufficient to attain the PCBs total maximum daily load (TMDL) wasteload allocation for Alameda County by 2030.

Municipal Regional Permit (MRP) (SFBRWQCB; Order No. R2-2015-0049; as amended by Order No. R2-2019-0004) Provisions C.11.d and C.12.d require that a reasonable assurance analysis (RAA) be conducted for the PCBs and mercury control measures described in the countywide PCBs Control Measure Plan and Mercury Control Measure Plan. The RAA methodologies and estimated load reductions for the control measures plans are provided Section 6 of the *Alameda County PCBs and Mercury TMDL Control Measure Plan and Reasonable Assurance Analysis* report (ACCWP, 2020). The load reduction results are summarized in Table 1 below.

Table 1: Summary of Estimated PCBs Load Reductions Achieved through Control Measure Implementation

Control Measure	PCBs Load Reduction by 2030 (kg/yr)
Source Property Identification and Abatement	0.49
PCBs in Building Materials Management	0.63
PCBs in Electrical Utilities Management	0.20
PCBs in Infrastructure	0.01
Green Stormwater Infrastructure	0.38
Full Trash Capture Treatment Control Measures	0.22
Enhanced Operations and Maintenance	0.0002
Diversion to POTW	0.001
Total Load Reduced	**1.93**
Load Reduction Goal	**3.30**
Remaining Load to be Reduced	**1.37**

As shown in Table 1, the control measures described in the RAA Report are not estimated to provide the required load reduction (i.e., the load reduction goal of 3.30 kg/yr) to achieve the TMDL wasteload allocation by the TMDL compliance date of 2030 (although it is estimated to be achieved by 2090 in the RAA Report). The RAA estimates a deficit of 1.37 kg/yr of PCBs load reduction by 2030. The discussion below assesses the level of effort or change of assumptions that would result in compliance with the wasteload allocation by 2030.

An analysis of mercury is not included in this memorandum, as the RAA model estimates that the existing baseline mercury load is less than the TMDL wasteload allocation.

2. PCBS LOAD REDUCTION GOAL

The RAA baseline pollutant loading model is a representation of the loading of PCBs across the County during the TMDL baseline period (i.e., 2003 – 2005). The baseline load used to establish the PCBs TMDL load reduction goal for the Alameda MRP Permittees is the load for the MRP area (i.e., within Water Board Region 2) below dams, after deducting the estimated baseline load for the other NPDES-permitted stormwater dischargers within this area (i.e., NPDES major and minor permittees and Phase II permittees). The TMDL population-based wasteload allocation for Alameda County MRP Permittees is calculated based on distributing the total wasteload allocation between the MRP Permittees and other NPDES-permitted stormwater dischargers. Using the calculated MRP Permittee portion of both the wasteload allocation and the RAA-calculated baseline load, the load reduction goal is estimated to be 3.30 kg/yr. (For further detail, see Section 6 of the *Alameda PCBs and Mercury TMDL Control Measure Plan and Reasonable Assurance Analysis* report).

If additional non-MRP Permittee areas are accounted for, this load reduction goal would be reduced, as described in the sections below.

2.1 Adjustment for Caltrans Right-of-Way Area

An additional non-jurisdictional area within Alameda County is located in the right-of-way (ROW) area owned and operated by Caltrans, whose urban stormwater discharges are regulated under a separate NPDES permit. An analysis was conducted to estimate the difference in the MRP Permittees' TMDL load reduction goal if the Caltrans area is removed from the MRP Permittee portion of the RAA-calculated baseline load (Table 2).

Table 2: Alameda County Estimated PCBs Baseline Loads without Caltrans ROW

RWQCB Region	Above/Below Dam	Permit	Baseline Load PCBs (kg/yr)
Region 2	Below Dam	**MRP[1]**	**3.54**
		Caltrans	0.21
		NPDES[2]	0.04
		Phase 2[3]	0.45
	TMDL Baseline		2.36

[1] Municipal Regional Permit permitted areas, along with IGP facilities and facilities with individual NPDES Stormwater Industrial permits.
[2] Major and Non-Major dischargers with individual NPDES permits.
[3] Phase II General Permit permittees.

Table 3 below presents the wasteload allocation for the MRP Permittees after adjusting for the Caltrans portion of the baseline.

Table 3: TMDL Wasteload Allocations for Alameda County with Caltrans

Stormwater Discharger within TMDL Baseline Area[1]	Percentage of Baseline Load (%)	PCBs WLA (kg/yr)
MRP Permittees	83%	0.417
Caltrans	5%	0.024
NPDES Permittees	1%	0.005
Phase 2 Permittees	11%	0.053
Alameda County	100%	0.5

[1] All Water Board Region 2, above dams.
WLA – Wasteload Allocation

Using the calculated MRP Permittee portion of the wasteload allocation and RAA-calculated baseline load after removing the Caltrans portion, the adjusted load reduction goal would be 3.12 kg/yr (i.e., 3.54 kg/yr – 0.42 kg/yr), in contrast to 3.30 kg/yr with Caltrans included (a 0.18 kg/yr difference). If Caltrans was removed from the baseline and the wasteload allocation, the 2030 PCBs load reduction deficit would decrease from 1.37 kg/yr (see Table 1) to 1.19 kg/yr.

Including the Caltrans ROW area in the MRP Permittee baseline assumption is conservative (i.e., generates a greater overall load reduction goal), but allows the Permittees to take full credit for the loads reduced by control measures implemented by Caltrans within Alameda County. Leaving Caltrans baseline loads and wasteload allocations as part of the MRP Permittees load reduction goal calculations will also foster collaboration with Caltrans in implementing PCBs control measures going forward.

2.2 Adjustment for Non-Urban Open Space Area

A portion of Alameda County within Region 2 is comprised of open space located outside of the urban boundary as defined by the U.S Census. The estimated RAA baseline load for this area is 0.008 kg/yr. This load constitutes a very small fraction of the overall Permittee baseline load (0.2%). Although no control measures would be applied to this area and thus it could be removed from the Permittee baseline load estimate, it is such a small portion of the baseline load for PCBs that it would not affect the PCBs load reduction goal, so has not been removed.

3. APPLICATION OF ADDITIONAL CONTROL MEASURES BY 2030

3.1 Green Stormwater Infrastructure

The RAA model was used to estimate the total potential PCBs load reduction through application of GSI treatment to areas within the County, within Water Board Region 2, and below dams, that is not already treated or projected to be treated by 2030 (i.e., the public and private GSI Plan project areas projected to be implemented between 2030 and 2040 are still "available" for treatment through GSI). The results of this analysis are provided in Table 4 below. Table 5 lists the approximate area that would be needed for private parcels, public parcels, or right-of-way (ROW) to reduced PCBs loads by an additional 1.36 kg/yr by 2030 using the average load reduction from the RAA model for the projects constructed by 2020 or projected for 2030.

Table 4: PCBs Load Available for GSI Treatment by 2030

	Private Parcels	Public Parcels	Right-of-Way	Total
Available Area[1] (Acres)	240,299	123,757	30,456	394,512
Potential PCBs Load Reduction via GSI Treatment (kg/yr)	1.02	0.44[2]	0.45	2.68

[1] Results are for the areas within Alameda County that are within Water Board Region 2, below dams, and not already treated or projected to be treated by 2030.

[2] Excludes loads for area within the Alameda Naval Air Station, Old Industrial portion of Camp Parks, Lawrence Livermore National Lab, and Port of Oakland.

Table 5: PCBs Load Available for GSI Treatment by 2030

Alameda County Parameter	RAA Model Result
Average Modeled Load Reduction Potential – Available Private Parcels (g/yr/acre)	0.036
Available Private Parcel Area Needed to Reduce 1.37 kg/yr[1] (acres)	38,000
Average Modeled Load Reduction Potential – Available Public Parcels (g/yr/acre)	0.029
Available Public Parcel Area Needed to Reduce 1.37 kg/yr[1] (acres)	47,000
Average Modeled Load Reduction Potential – Available Public ROW (g/yr/acre)	0.026
Available ROW Area Needed to Reduce 1.37 kg/yr[1] (acres)	52,000

[1] Assumes average modeled load reduction for area category (i.e., private parcels, public parcels, or ROW) to calculate area needed to be treated.

[2] ROW = Right-of-Way.

The following conclusions can be drawn from the results provided in Table 4 and Table 5:

- As can be seen in Table 4, much more area and potential load reduction are available in private parcels than public parcels or rights-of-way.
- Sixty-one percent of the available area consists of privately-owned parcels. Approximately 38,000 acres of this area (15%) would need to be treated via GSI by 2030 to achieve an additional PCBs load reduction of 1.37 kg/yr. The RAA analysis currently predicts that 1,900 acres of private parcel area will redevelop between 2020 and 2030, therefore 20 times as much redevelopment would need to occur to achieve the 2030 TMDL WLA solely through private parcels. This much private redevelopment is highly unlikely to occur in the next decade.
- Thirty-one percent of the available area is comprised of public parcels. Approximately 47,000 acres would need to be treated via GSI by 2030 to achieve an additional PCBs load reduction of 1.37 kg/yr. The RAA analysis currently assumes 566 acres of public parcels will be retrofit between 2020 and 2030, therefore 83 times more public parcel area would need to be retrofit than the public parcel area included in the Permittees' Green Infrastructure Plans. Using the cost estimating methodology presented in the *Alameda PCBs and Mercury TMDL Control Measure Plan and Reasonable Assurance Analysis* report, which assumes a median capital cost of $121,000 per acre treated with GSI (2018 dollars), retrofitting 47,000 acres of public parcels would cost approximately 5.8 billion dollars. In addition to the large amount of funding that would be needed, installing this much GSI on public parcels in 10 years would be technically infeasible to implement due to the time needed to site projects, conduct preliminary and final engineering design, and go through the municipal procurement process. A typical municipal GSI project would take two to five years to go through this process. Additionally, it is unlikely that the number of contractors needed to construct this much GSI in such a short period of time would be available.

- Eight percent of the available area is public ROW; approximately 52,000 acres of ROW would need to be treated via GSI by 2030 to reduce PCBs load by 1.37 kg/yr. As with the discussion on public parcel area above, this is a highly unlikely scenario. The estimated capital cost for retrofitting 52,000 acres of ROW is seven billion dollars (assuming a median cost of $137,000 per acre treated). The same technical infeasibility constraints as outlined above for retrofitting public parcels applies to retrofitting large areas of public ROW.

3.2 Enhanced Operations and Maintenance

The RAA model was used to assess the potential load reduction that could be achieved by applying enhanced operations and maintenance (O&M) measures in Old Industrial areas that are not planned to be addressed by treatment control measures (i.e., GSI or full trash capture devices) by 2030. Enhanced inlet cleaning was selected as a representative enhanced O&M measure for the purpose of this analysis. The total PCBs load produced by these areas is estimated to be 1.07 kg/yr. Table 6 below presents the potential load reduction if all of this area were addressed through enhanced storm drain inlet cleanout (i.e., increasing the frequency of cleanout from annually to biannually) with and without the use of inlet-based full trash capture devices.

Table 6: Potential Load Reduction through Enhanced Inlet Cleaning in Old Industrial Areas Not Planned for Control Measures by 2030

County/ Region	Enhanced Cleaning Frequency for Inlets with FTC Devices -- No Device to Biannual		Enhanced Cleaning Frequency for Inlets without FTC Devices -- Annual to Biannual	
	Potential Load Reduction (kg/yr)	Potential Load Reduction Rate (g/yr per acre)	Potential Load Reduction (g/yr)	Potential Load Reduction Rate (g/yr per acre)
Efficiency Factor:	**18%**		**5%**	
Alameda Region 2	0.29	0.0466	0.080	0.01295

FTC – Full trash capture.

To achieve the additional required PCBs load reduction of 1.37 kg/yr using enhanced street inlet cleaning without inlet-based full trash capture devices, enhanced cleaning would be needed for approximately 105,000 inlets with an average tributary area of one acre (i.e., a 105,000-acre drainage area). The cost of implementing enhanced inlet cleaning without full trash capture for this scenario would be $10,500,000 per year for one additional cleanout per year (assumes $100/cleanout).

If new inlet-based full trash capture devices were implemented with biannual cleaning, then a total inlet drainage area of 29,172 acres would be required. Assuming an average one-acre tributary area and a capital cost of $1,000 per acre treated, the capital cost of implementing enhanced inlet cleaning with full trash capture for this scenario would be approximately

$29,100,000. The additional ongoing annual cost would be approximately $5,700,000, assuming $200 per year for biannual cleaning.

3.3 Conclusion

The analysis provided in this memorandum leads to a reasonable conclusion that it is technically and economically infeasible to achieve the PCBs TMDL wasteload allocation in Alameda County by 2030.

* * * * *