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)

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FINAL June 30, 2020

Table of Contents

List of Tables

List of Figures

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

[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):

Investor-Owned Utilities (IOUs)

1. Pacific Gas and Electric Company (PG&E)
   77 Beale Street
   San Francisco, CA 94105
   (415) 973-7000 (tel)

Publicly Owned Load Serving Entities (LSEs) and Publicly Owned Utilities (POUs)

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.

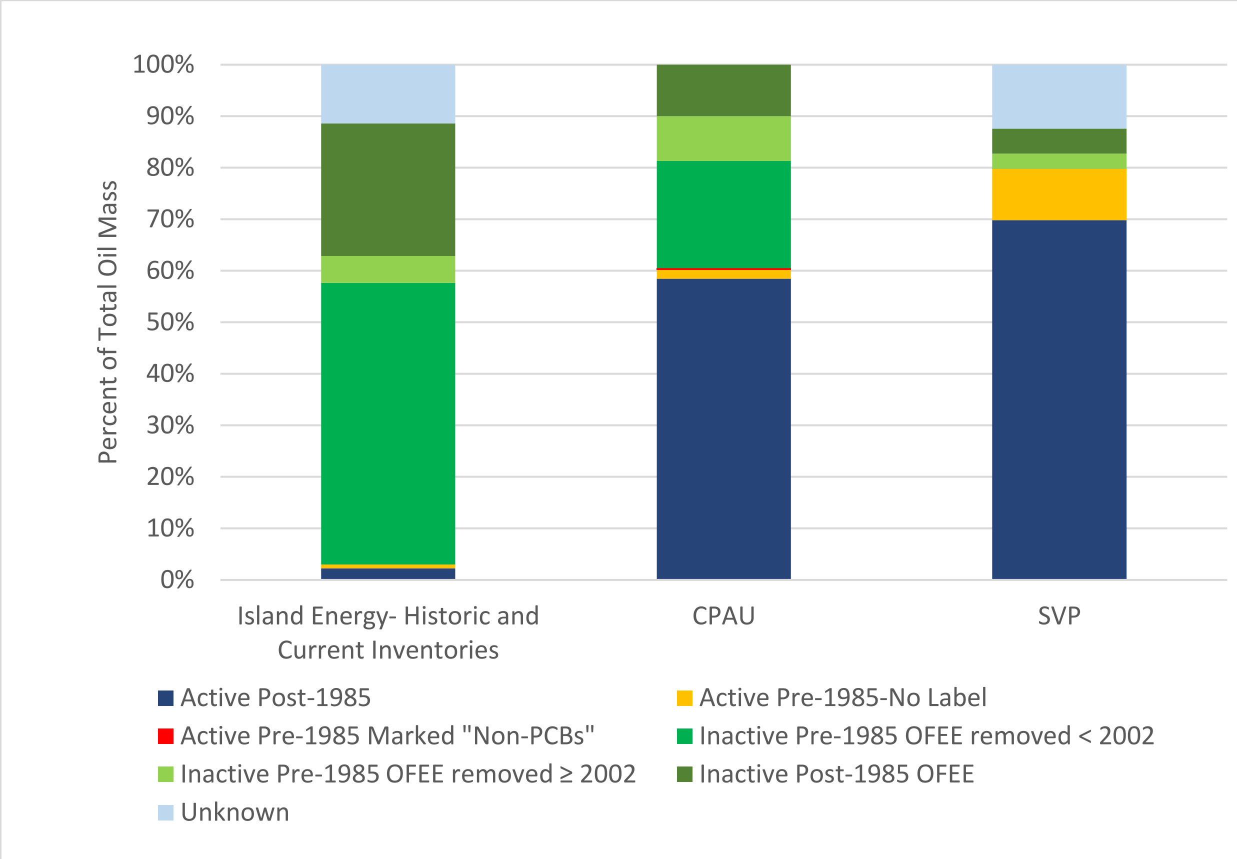

Figure 4.1 Distribution of the mass of oil in oil-filled electrical equipment (OFEE) in three municipally-owned electrical utility systems.

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)			Percent of Active OFEE that are pre-1985
		Pre-1985 OFEE	Post-1985 OFEE	TOTAL	
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.

		Pre-1985 OFEE Oil in Inactive/Removed OFEE (kg)			**Pre-1985 OFEE Removed Between 2002 and 2019**			
Utility System	**Equipment Type or**	**Removed prior to 2002**	**Removed in 2002 or Later**	**TOTAL REMOVED**	**Overall Removal Rate**	**Annual Average Removal Rate**	**Pre-1985 OFEE removed since installation**	**Estimated time to remove all pre-1985 OFEE (years)**
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

OFEE Category	PCBs (kg)				
	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.

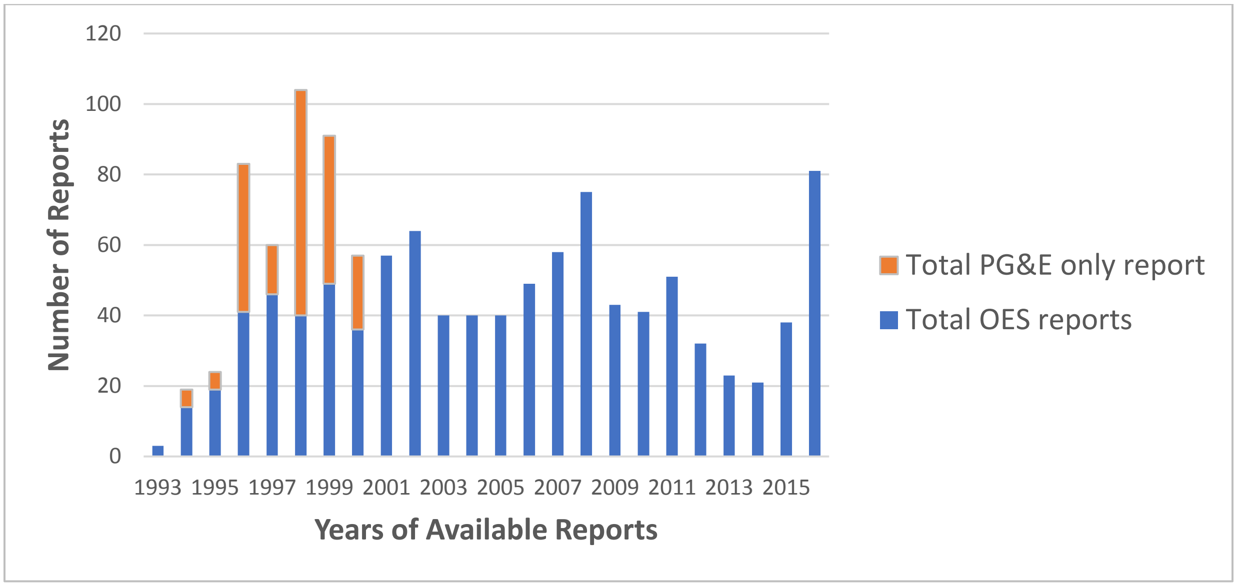

Figure 4.2 Oil-filled electric equipment spills reported to the California Office of Emergency Services (Cal OES) and/or identified through internal Pacific Gas & Electric (PG&E) reports between 1993 and 2017.

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.

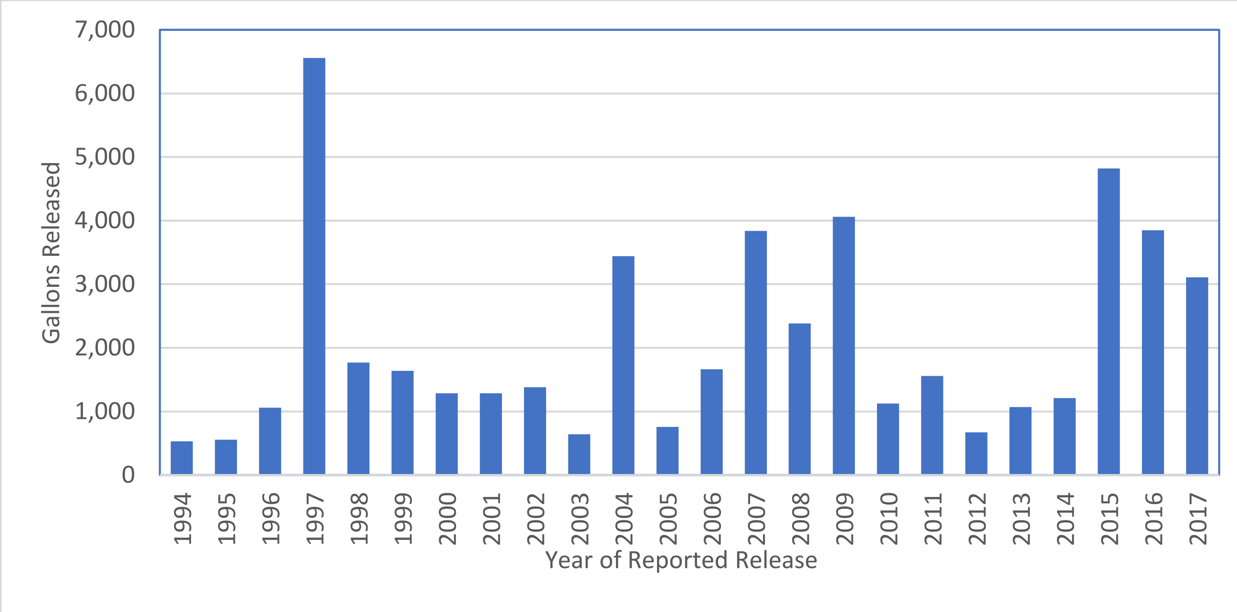

Figure 4.3 Total reported gallons of oil released each year (1994 – 2017) from spills from PG&E electrical utility equipment in the Bay Area.

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.

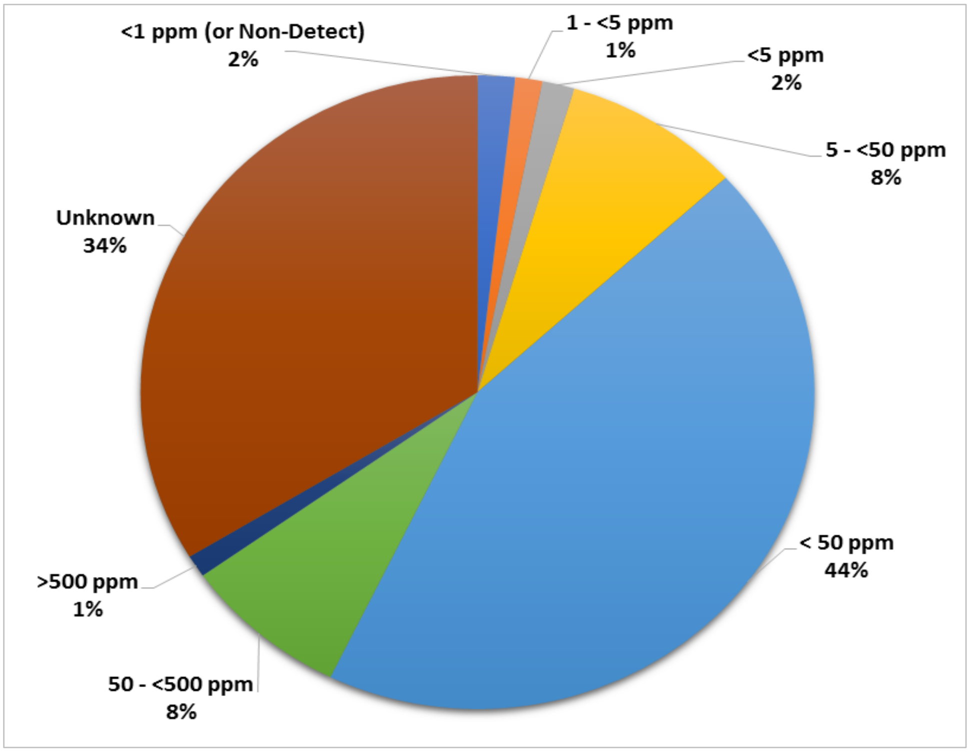

Figure 4.4 PCB Concentration data reported for releases from PG&E electrical equipment between 1993 and 2016. Each category identified above is independent (e.g., the "< 50 ppm category" does not include reports that provided more specific concentration data that was < 50 ppm).

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.

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[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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