A Review of Select PCB Source Tracing Programs

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King County

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ACRONYMS AND ABBREVIATIONS

mg/Kg ....milligrams per kilogram

pg/L ....picograms per liter

µg/Kg ....micrograms per kilogram

ANOVA...................analysis of variance

BASMAA.................Bay Area Stormwater Management Agencies Association

BAT ....best available technology

CCMUA...................Camden County Municipal Utilities Authority

CERCLA ....Comprehensive Environmental Response, Compensation and Liability Act

CFR...........................Code of Federal Regulations

CHHSL.....................California Human Health screening level

CSLs ....cleanup screening levels

CSO...........................combined sewer overflow

CUPA........................Certified Unified Program Agency

CWA.........................Clean Water Act

DMI ....Dishman-Mica Interceptor

DRBC ....Delaware River Basin Commission

DTSC........................Department of Toxic Substances Control (California)

Ecology...................Washington Department of Ecology

ECSI..........................Environmental Cleanup Site Information (Oregon)

EHW.........................extremely hazardous waste

ELISA.......................enzyme-linked immunosorbent assay

EPA...........................Environmental Protection Agency

ESL ....Environmental Screening Level

GSP ....Georgetown Steam Plant

ISIS ....Integrated Site Information System

LDW.........................Lower Duwamish Waterway

MTCA.......................Model Toxics Control Act

NBF ....North Boeing Field

NJDEP......................New Jersey Department of Environmental Protection

NPDES....................National Pollutant Discharge Elimination System
NTR..........................National Toxics Rule
NVI ....North Valley Interceptor
NVIPS ....North Valley Interceptor Pump Station
ODEQ.......................Oregon Department of Environmental Quality
PAHs........................polycyclic aromatic hydrocarbons
PCB...........................polychlorinated biphenyls
PGE...........................Pacific Gas and Electric
PISCES.....................passive in-situ continuous extraction samplers
PMF..........................positive matrix factorization
PMPs........................Pollutant Minimization Plans
RCRA ....Resource Conservation and Recovery Act
RCW.........................Revised Code of Washington
RI/FS ....Remedial Investigation and Feasibility Study
ROD..........................Record of Decision
RM ....river mile
RMP ....Regional Monitoring Program
SCAP ....source control action plan
SCO...........................sediment benthic cleanup objectives
SCRWRF.................Spokane County Regional Water Reclamation Facility
SCWG.......................source control work group
SFEI..........................San Francisco Estuary Institute
SIUs..........................significant indirect users
SMS ....sediment management standards (Washington State)
SPU...........................Seattle Public Utilities
SRHD ....Spokane Regional Health District
SRRTTF ....Spokane River Regional Toxics Task Force
SVI ....Spokane Valley Interceptor
SVIPS ....Spokane Valley Interceptor Pump Station
SVRP ....Spokane Valley Rathdrum Prairie

TEF..........................toxic equivalency factor

TMDL.......................total maximum daily load

TSCA........................Toxic Substances Control Act

WAC.........................Washington Administrative Code

WDOH.....................Washington Department of Health

EXECUTIVE SUMMARY

Although their manufacture was banned in 1979, polychlorinated biphenyls (PCBs) continue to be a persistent contaminant pervading natural habitats and posing health impacts to humans and wildlife. One of the greatest challenges associated with efforts to reduce PCB contamination is identifying the location of sources. To this end, source tracing programs have been initiated in regions across the United States with PCB contamination. Source tracing programs are only one component of an overall source control program which may include other tools (e.g., treatment, site remediation) to remove or minimize the impact of PCB sources. Source tracing involves using investigative tools to locate previously unidentified sources.

This document provides a summary of select PCB source tracing programs in Washington and Oregon as well as two additional programs that provide a national perspective: one in the San Francisco Bay area and the other in the Delaware River Basin. Information on each program covered by this report was obtained through literature review, online research and personal interviews with staff from several agencies. The objectives were to summarize and compare/contrast source tracing approaches, as well as identify the successes and challenges for each program to enable information exchange and provide a resource to those interested in PCB source tracing. This report represents the first known compilation of PCB source tracing approaches and tools from these geographic regions.

To provide regulatory context, important parts of federal and Washington State laws and regulations applying to PCB source tracing and source control activities are summarized first in the report. At the federal level, these include sections of the Toxic Substances Control Act (TSCA) (15 USC 2601 et seq.), the Clean Water Act (CWA) (33 USC 1251 et seq.), the Resource Conservation and Recovery Act (RCRA) (42 USC 6901 et seq.), and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC Part 103). Related aspects in Washington State's Hazardous Waste Management Act, Ground Water and Surface Water regulations and the Sediment Management Standards are also briefly summarized. Key exemptions to PCB use are that TSCA allows PCBs at high concentrations (>50 mg/kg) in enclosed sources that remain in-use or in storage (e.g. PCB transformers) and allows inadvertent manufacture of PCBs in new products if less than 50 mg/Kg. These kinds of legal exemptions increase the number of potential sources of ongoing PCBs to the environment.

The programs reviewed focus on source tracing within stormwater and wastewater systems. Each source tracing program is unique in the combination of elements selected as tools to locate where PCBs (and other contaminants) enter separated or combined sewer systems. At least two of the following tools were/are used in various combinations in each program:

- Status and trends monitoring in receiving waters.
- Long-term monitoring of water and/or solids in the system.
- Initial spatial survey of PCBs.

- Track-down inline sampling (stormwater and combined sewer overflows) using:
    - Sediment traps
    - Catch basin sediments
    - Grab or composite water sampling
- Influent and effluent wastewater sampling.
- Historical records review (e.g., chemistry and land use data, property use history, cleanup site locations).
- Business visits and inspections (can include sampling).
- Visual surveys.
- Pipe cleaning (to identify ongoing sources).
- Street level soils sampling.
- Fingerprinting by homologue analysis or PMF.
- Product testing.
- Analysis of contaminated materials in building and road structures or in the conveyance system.

The most common challenges facing PCB source tracing programs include a lack of public awareness of PCBs as a significant environmental contaminant that can have historical and ongoing sources, sampling logistics, laboratory analytical issues (e.g., detection limits, blank contamination), and a lack of clear legal and/or regulatory authority to complete source identification and control. The professionals interviewed recommended establishing partnerships and collaborations, combining resources and building on the work of others to most efficiently conduct PCB source tracing. Several jurisdiction staff also suggested planning ahead for data management, for both database design and funding.

PCB source tracing is undoubtedly challenging, resource-intensive, and time consuming. It is a process of surveying (or monitoring), prioritization, and focused investigation, likely requiring repetition of these steps. All the programs described in this report used a variety of tools with no one tool or combination being consistently effective. However, solids sampling by trap or catch basin grabs is a commonly used tool to characterize stormwater basins and trace upstream sources. Line cleaning and resampling can be effective to test the presence of ongoing versus legacy sources. Many programs have also found historical data (e.g., former land use, contaminated site databases) helpful in concert with conveyance system PCB chemistry to guide prioritization of more focused investigations. Business inspections have varied results and their success depends, in part, on owner experience and the strength of their relationship with inspectors. The final steps of source identification and control can be critically dependent on the available legal authority structure to grant property access and enforce cleanup actions.

Sources of PCBs are often industrial with metals recyclers and businesses associated with transformers among those identified by the reviewed source tracing programs. However, contaminated sites that were historically remediated can remain active PCB sources. In

addition, in-use construction materials (e.g., caulk, sealant, paint) have been found to contain very high PCB concentrations (e.g., at a scale of 100,000 mg/Kg). The current TSCA regulations allow products to contain less than 50 mg/Kg and laboratory testing has confirmed some PCB congeners are present in off-the-shelf products. While legal, the inadvertent production of PCBs represents a new type of PCB source – different from the legacy Aroclor sources typically targeted by source control programs. These products contain fewer congeners and the relative importance of these as sources to the environment are unknown, at least with regard to toxicity. Regardless of source type, the stormwater pathway is often a major pathway of PCBs to receiving waters.

Given the resource-intensive nature of PCB source tracing, tools and strategies that optimize efficiency are needed to improve success. For this to occur, it will be critical to continue sharing information, including challenges and successes, between and among source tracing communities.

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1.0 INTRODUCTION

Although their manufacture was banned in 1979, polychlorinated biphenyls (PCBs) continue to be a persistent contaminant pervading natural habitats and posing health impacts to humans and wildlife. One of the greatest challenges associated with efforts to decrease PCB sources is identifying their location. PCBs were used in a wide variety of industrial and commercial applications which included products that remain in active use today. Examples of uses include insulation in electrical, heat transfer and hydraulic equipment; plasticizer in paints, plastics and rubber products; and as extenders in wax casting and pesticide application (Erickson and Kaley 2011, Ecology and WDOH 2015). The multitude of PCB uses, combined with their persistence, has resulted in buildings and properties that still contain PCB-contaminated surfaces, materials or soils that serve as PCB sources to the environment. In addition, PCBs have been detected in new products due to inadvertent production during manufacturing (Ecology and WDOH 2015).

PCBs are a contaminant of concern at many contaminated sediment sites and impaired water bodies across the country including the Lower Duwamish Waterway (LDW) Superfund Site, Commencement Bay and the Spokane River, in Washington State. This has led to development of source tracing programs to locate upland PCB sources in the Pacific Northwest cities of Seattle, Spokane, Tacoma, and Portland. This document provides a summary of some major PCB source tracing programs in Washington and Oregon, as well as two additional programs that provide a national perspective: one in the San Francisco Bay area and the other in the Delaware River Basin. Source tracing is an element of a source control program that involves using investigative tools to locate previously unidentified sources. In some of these areas, PCBs are the single contaminant of interest for source tracing. However, in many programs, other contaminants are also important and source tracing efforts can include multiple chemicals.

The objectives of this report were to summarize and compare/contrast source tracing approaches, as well as identify the successes and challenges for each program. This enables information exchange and provides a resource to those interested in PCB source tracing. This report represents the first known compilation of PCB source tracing approaches and tools from the aforementioned geographic regions.

For purposes of this report, source tracing includes activities conducted to investigate and identify where sources are located. Source tracing is only one component of source control. Source control programs can include source tracing, but also include all the activities that progress toward removing sources or minimizing their impact. For example, these can include site remediation, institutional controls (i.e., restrictions on site use or access), treatment facility construction, and/or public and business owner education. While these are all valuable components of a source control program, they are not source tracing activities. The source control programs highlighted in this report were selected because they have identified PCB sources using source tracing techniques. Selection of these programs for this report in no way diminishes the contributions made by other parties who

operate source control programs in the same region and may conduct source tracing activities as part of these programs.

The methods used to compile information presented in this report are described in Section 2.0. Prior to summarizing the source tracing approaches of the various programs (described in Section 4.0), an overview of the related federal and Washington state laws and regulations that drive and shape objectives for PCB reduction is provided in Section 3.0. Due to their complex chemical mixture, there are multiple analytical methods available to measure PCBs. Section 5.0 provides a brief summary of the most commonly used analytical methods mentioned in this report. Section 6.0 discusses the common challenges that jurisdictions have faced while implementing source tracing programs and the lessons learned from their experience. Additional resources are provided in Appendices A and C that describe products and materials containing PCBs, test results, and where to find further information for the source tracing programs discussed. Lastly, Appendices B and D provide an example of a public education tool for PCBs.

2.0 COMPILATION METHODS

Information on each program covered by this report was obtained through literature review, online research, and personal interviews with staff from several agencies. The staff interviewed are employed (or were employed when source tracing activities were conducted) by the following agencies: Seattle Public Utilities (SPU) in the City of Seattle, King County, City of Spokane, Spokane County, Spokane Regional Health District (SRHD), City of Tacoma, City of Portland, Washington Department of Ecology (Ecology), the Environmental Protection Agency (EPA) Region 10 Office, San Francisco Estuary Institute (SFEI), Delaware River Basin Commission (DRBC), and Rutgers University. Interviews were conducted to obtain a general overview of the source tracing strategy used, information on funding sources, lessons learned from their experience, and recommendations for others conducting PCB source tracing.

A small number of peer-reviewed journal articles were utilized for this report; however, most of the information was obtained from local, state, and federal agency documents. This information was provided directly by the agencies or obtained through websites. Some references are not downloadable and only available in online form; for these references, the link is provided in the reference section. Maps and figures included in this report were reprinted with permission from existing published documents.

3.0 OVERVIEW OF STATE AND FEDERAL REGULATIONS OF PCBS

This chapter describes the existing state and federal regulations regarding PCBs. These statutes and rules provide the basis for the source control programs described elsewhere in this report. While source control programs in Oregon, California and the Mid-Atlantic states are also covered in this report, for brevity, only laws and regulations applicable to Washington State are summarized here. While regulations relating to PCBs are complex, a key point to understand is that the regulations governing PCBs (as with many other contaminants) begin with a determination of whether the material is an in-use product (e.g., paint or caulk), a waste intended for disposal (e.g., catch basin solids after cleaning, broken PCB-containing light ballasts), or environmental media contaminated by a release of PCBs (e.g., contaminated river sediment). Where specific mass or concentration values are cited in this section, the reader is encouraged to check the referenced laws or rules to ensure that revisions or changes have not been adopted since completion of this document.

3.1 Federal Laws & Regulations

Numerous federal laws and implementing regulations address PCBs in some fashion. The four most applicable to PCB sources and source tracing are:

- The Toxic Substances Control Act (TSCA) (15 USC 2601 et seq.),
- The Clean Water Act (CWA) (33 USC 1251 et seq.),
- The Resource Conservation and Recovery Act (RCRA) (42 USC 6901 et seq.), and
- The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC Part 103).

3.1.1 Toxic Substances Control Act

TSCA gives EPA the authority to regulate new and existing chemicals and mixtures through required reporting, record-keeping, testing, and use restrictions. While this section provides an overview of TSCA as it regulates PCBs, it is very important to TSCA to ensure that PCB-containing materials discovered through source tracing efforts are expeditiously removed and remediated. The TSCA thresholds defining "containing PCBs" are discussed in more detail below.

TSCA is the primary federal law addressing PCB production and the remaining PCB uses in the United States. PCB regulations are in Title I, Section 6, of the Act and EPA's detailed implementing regulations are in Title 40, Part 761 of the Code of federal Regulations (CFR). Section 6(e)(2)(A) of TSCA states that "…effective one year after January 1, 1977, no person may manufacture, process, or distribute in commerce or use any polychlorinated biphenyl in any manner other than in a totally enclosed manner." Section 6 of TSCA prohibited the manufacture of all PCBs by 1979, but allowed the EPA administrator to authorize certain

ongoing uses of PCBs manufactured before 1979 if the Administrator determined that such activity did not present an unreasonable risk of injury to health or the environment.

Continued use and disposal of existing PCBs is controlled by their form (e.g., liquid, solid or semisolid), the amount in each form, and the original source in cases of their release. Under several sections, TSCA regulates PCBs in the following manner:

- Prohibits manufacture, sale, and distribution of PCBs, with some exceptions.
- Mandates proper disposal for any PCBs unauthorized for use.
- Does not require testing to identify PCB sources, but does require proper use and disposal of identified PCB contaminated items.
- Limits use of PCBs to certain "totally enclosed" uses, such as transformers and capacitors, or concentrations below 50 mg/Kg in bulk product. Various other regulatory thresholds exist for remediation waste and other limited uses, typically with EPA approval.
- Requires all known transformers containing PCBs >500 mg/Kg be registered with EPA by December 1998.

TSCA allows many forms of PCB waste to be disposed of as municipal solid waste, including:

- Small non-leaking PCB capacitors.
- Plastics (such as plastic insulation from wire or cable; radio, television and computer casings; vehicle parts; or furniture laminates); preformed or molded rubber parts and components; applied dried paints, varnishes, waxes or other similar coatings or sealants; caulking; Galbestos; non-liquid building demolition debris; or non-liquid PCB bulk product waste from the shredding of automobiles or household appliances from which PCB small capacitors have been removed (shredder fluff).
- Other PCB bulk product waste that leaches PCBs at <10 μg/L in water measured using a procedure simulating leachate generation.
- PCB bulk product waste other than those materials listed above if the PCB bulk product waste is segregated from organic liquids disposed of in a landfill.
    - Leachate is collected from the landfill and monitored for PCBs.

TSCA requires labels identifying electrical equipment containing over 500 mg/Kg PCBs and also requires EPA authorization for commercial storage of PCBs. Non-commercial storage does not always require EPA oversight.

A complete list of TSCA rules, with the associated notices, drafts, etc. can be found on the EPA website at http://www.epa.gov/wastes/hazard/tsd/pcbs/pubs/laws.htm. The current regulations are in CFR part 761. One of the most salient rules developed under TSCA authority is the exclusions and exemptions for inadvertent PCB generation. These rules, promulgated in 1984, are contained in 49 FR 28172. They require that the

concentration of inadvertently generated PCBs in products, including recycled paper, must have an annual average of <25 mg/Kg, with a maximum of 50 mg/Kg. Detergent bars are treated differently as they are consumer products with a high potential for exposure, and are limited to 5 mg/Kg (soap and deodorant are regulated by the Food and Drug Administration). There are several additional criteria in the inadvertent production rule:

- Releases to ambient air must be <10 mg/Kg.
- Discharges to water must be <0.1 mg/Kg, except from recyclable paper the limit is 3 μg/Kg total Aroclors.
- There are no detectable PCBs from materials potentially containing PCBs in recycled asphalt.

In general, TSCA does not specify the analytical methods required to address these criteria. EPA Method 8082 is typically used for TSCA analysis (as total Aroclors) since TSCA-regulated PCB concentrations are in parts per million. See Section 5.0 for additional information about PCB analysis methods.

In 2013, EPA clarified the definition of "Excluded PCB Products" to allow for recycling plastics separated from (automotive) shredder residue containing <50 mg/Kg PCBs. Voluntary procedures to prevent the introduction of PCBs in shredder residue are (1) documented source control programs and (2) documented output control. EPA's review was done at the request of the Institute of Scrap and Recycling Industries to clarify whether the plastic material should be managed as an "Excluded PCB Product" or as a "PCB Remediation Waste." This interpretation reiterates EPA's "generic exclusion" for processing, distribution in commerce, and use, based on the Agency's determination that the use, processing, and distribution in commerce of products with <50 mg/Kg concentration will not generally present an unreasonable risk of injury to health or the environment" (FR Vol. 78, No. 66, April 5, 2013).

Several rules on transformers and other electrical equipment have been developed over the years. The current regulations are in CFR part 761 and include several important definitions:

- "Non-PCB Transformer" means any transformer that contains <50 mg/Kg PCBs.
- "PCB-Contaminated" refers to liquid and non-liquid material containing PCBs at concentrations ≥50 mg/Kg but <500 mg/Kg, and non-porous surface having a surface concentration >10 μg/100 cm^2 but <100 μg/100 cm^2.
- "PCB Transformer" means any transformer that contains ≥500 mg/Kg PCBs.

Owners of PCB transformers (≥500 mg/Kg) were required to register their transformers with the EPA by Dec. 28, 1998. Wide tolerance was allowed in this registration as:

- There is no requirement to test a transformer to determine if it is a PCB transformer.

- There is no requirement to register a transformer if the owner takes ownership after 1998.
- There is no requirement to register a PCB-contaminated transformer (50 to 500 mg/Kg PCBs).
- There is no requirement to request a registered transformer be removed from the database if it is physically removed from service.
- Other equipment, such as bushings with ≥500 mg/Kg PCBs, are not required to be registered.

While testing for PCBs is not required, the regulations do assume a PCB concentration based on the age and size of the equipment. These assumptions include:

- Transformers with <3 pounds (1.36 kg) of fluid, circuit breakers, reclosers, oil-filled cable, and rectifiers whose PCB concentration is not established are assumed to contain PCBs at <50 mg/Kg.
- Mineral oil-filled electrical equipment manufactured before July 2, 1979, and whose PCB concentration is not established is assumed to be PCB-Contaminated Electrical Equipment (i.e., contains ≥50 mg/Kg PCB, but <500 mg/Kg PCB). This includes all pole-top and pad-mounted distribution transformers manufactured before July 2, 1979.
- Electrical equipment manufactured after July 2, 1979, is assumed to be non-PCB (<50 mg/Kg PCBs).
- If the date of manufacture of mineral oil-filled electrical equipment is unknown, it must be assumed to be PCB-Contaminated.
- A transformer manufactured prior to July 2, 1979, that contains 1.36 kg (3 pounds) or more of fluid other than mineral oil and whose PCB concentration is not established, is considered a PCB Transformer (i.e., ≥500 mg/Kg). If the manufacturing date and type of dielectric fluid are unknown, it is assumed that the transformer is a PCB Transformer.
- A capacitor manufactured prior to July 2, 1979, whose PCB concentration is not established is assumed to contain ≥500 mg/Kg PCBs.
- A capacitor manufactured after July 2, 1979, is assumed to be non-PCB (i.e., <50 mg/Kg PCBs).
- If the date of manufacture is unknown, capacitor is assumed to contain ≥500 mg/Kg PCBs.

EPA has been reconsidering these existing PCB uses for more than five years (75 FR 17645). At some point in the future, the existing PCB use authorizations are likely to change, particularly:

- The continued use, distribution in commerce, marking, and storage for reuse of liquid PCBs in electric and non-electric equipment.
- The 50 mg/Kg threshold level for excluding PCB products.

- The use of non-liquid PCBs such as paints or caulks which are currently excluded from on-going use.
- The continued use of porous surfaces contaminated by PCBs such as concrete even though they have been sealed with two layers of solvent and water repellent coatings as required by current law to prevent PCB release (e.g., a concrete transformer vault).
- The marking requirements for PCB articles in use.

In this rulemaking (75 FR 17645), EPA has considered adding use authorizations for paints and caulks containing PCBs >50 mg/Kg. Under TSCA, paints and caulks with >50 mg/Kg PCBs cannot remain in use and must be remediated as PCB bulk product waste. Because of this requirement, many landowners may be reluctant to test their paints, caulks, ceiling tiles and other building materials as these cannot remain in use if PCBs >50 mg/Kg are detected in them.

The TSCA rules are extensive and have been amended and clarified many times. Jurisdictions establishing PCB source tracing programs or pursuing PCB sources as part of other investigations are urged to consult with Ecology and EPA to confirm that all aspects and requirements of TSCA are followed.

3.1.2 Clean Water Act

EPA has established PCB water quality criteria to protect human health and aquatic life. In many cases, states (e.g., Oregon) have adopted substantially equivalent criteria and assumed primary responsibility for human health criteria within their borders. At this time, Washington State has not adopted state human health water quality criteria. Thus, EPA's 1993 National Toxics Rule (NTR) (40 CFR 131.36) marine and freshwater water PCB criterion of 0.00017 μg/L (170 pg/L) applies in Washington.

To protect water quality, the CWA and its amendments prohibit discharge of pollutants from a point source without a National Pollutant Discharge Elimination System (NPDES) permit. EPA authorizes states to issue and monitor compliance with these permits and their conditions. The CWA also directs EPA to establish technology-based standards, known as Best Available Technology (BAT) requirements to prevent the discharge of harmful amounts of pollutants. Stormwater from certain industries and municipalities is also considered a point source of pollution that requires NPDES permitting. PCBs from various sources that were spilled on land or are deposited on land from air deposition or other sources and washed into storm drains are all regulated under these NPDES stormwater permits.

Per EPA requirements, Washington State's stormwater regulations establish two phases for the stormwater permit program:

- Phase I stormwater permits generally cover discharges from certain industries, construction sites involving five or more acres, incorporated cities with a population

of more than 100,000, and unincorporated counties with a population of more than 250,000 (according to the 1990 census).

- Phase II stormwater permits cover all remaining urban municipalities and construction sites between one and five acres. EPA rules also require an evaluation of cities outside of urbanized areas that have a population over 10,000, to determine if a permit is necessary for some or all of these cities.

The Phase I and II stormwater permits do not authorize the discharge of PCBs or any other pollutants in stormwater which cause or contribute to a water quality violation. Compliance is presumed if the permit-required actions are in place. If a stormwater permittee learns of a permit water quality violation for PCBs or any other constituent, reporting and additional adaptive management obligations are required (Phase I and II municipal stormwater permits, Section S4F).

3.1.3 Resource Conservation and Recovery Act

Under the authority of the RCRA (42 USC 6901 et seq.), EPA implements regulations pertaining to solid waste, hazardous waste, and underground storage tanks (40 CFR parts 239-299).

Hazardous wastes are managed under RCRA from the point of generation until proper disposal or treatment. To be regulated under RCRA, materials must first be a solid waste under 40 CFR § 261.2. Under RCRA, a waste meeting one of three criteria is also identified as hazardous if it: (1) is a waste specifically listed as hazardous, (2) exhibits hazardous characteristics, as determined by a Toxicity Characteristic Leaching Procedure (TCLP) test, or (3) exhibits the characteristics of ignitability, corrosivity, reactivity, or toxicity. PCBs are not typically regulated under RCRA authority in Washington State as EPA regulates PCBs under TSCA and Ecology regulates PCBs under state authority via the Model Toxics Control Act (MTCA).

Standards for the Management of Used Oil (40 CFR Part 279) include management standards for generators, transporters, processors, burners, and marketers of used oil containing PCBs at <50 mg/Kg. Used oil containing more than 50 mg/Kg of PCBs is regulated under TSCA (40 CFR part 761).

In Washington State, EPA has delegated Ecology RCRA release and cleanup authority under the MTCA (RCW Chapter 70.105D) and related rules (WAC Chapter 173-340). In general, PCB sites come under both TSCA and RCRA/MTCA programs for approval of the waste cleanup. More information about Washington State's MTCA is presented in Section 3.2 below.

3.1.4 Comprehensive Environmental Response, Compensation and Liability Act

Passed in 1980, CERCLA, also known as "Superfund" (42 USC Part 103), is the primary federal authority used to regulate and cleanup historic hazardous waste sites. The statute

and implementing regulations establish procedures for the long-term remediation of such sites, but also provides authority to clean up hazardous waste sites in need of immediate action. The law has subsequently been amended, by the Superfund Amendments and Reauthorization Act of 1986, and the Small Business Liability Relief and Brownfields Revitalization Act of 2002.

Under CERCLA Section 103, release of a hazardous substance is required to be reported to the National Response Center if they exceed a substance's "reportable quantity," which is 1 pound for PCBs. CERCLA cleanups and decisions implement TSCA as an Applicable or Relevant and Appropriate Requirement (ARAR), without need for separate approval under TSCA for PCB waste disposal.

3.2 Washington State Laws and Regulations

In addition to the Hazardous Waste Management program, Washington State regulates PCBs under three additional sets of standards or rules: the Groundwater Standards, the Surface Water Standards, and the Sediment Management Standards. These programs and state standards which limit PCBs in the environment are summarized below. Ecology's air quality program addresses PCBs under the Clean Air Act, however, this program is not relevant to most source tracing investigations and is not summarized here.

3.2.1 Hazardous Waste Management Act

The Hazardous Waste Management Act (HWMA) is articulated in RCW Chapter 70.105, and the Dangerous Waste Regulations WAC Chapter 173-303. Through the HWMA, Ecology is authorized by the EPA to implement RCRA within Washington State. Therefore, all federal RCRA requirements are also part of the state's dangerous waste regulations, although often using different terminology. In addition, this WAC chapter also contains specific state-only requirements for any dangerous waste generator or waste disposed of within the state.

In Washington State, PCB waste may be regulated as a state criteria dangerous waste or as a state-listed dangerous waste. State criteria dangerous wastes are defined by exceeding a numeric value (i.e., criteria) reflecting the quantity of particular chemicals in a waste. In contrast, state listed dangerous wastes are defined as wastes generated from particular industrial or manufacturing processes or products and on a designated dangerous waste list. The recycling of used oil, which can also contain PCBs, is regulated under HWMA separately from state criteria of state listed dangerous wastes. The definitions of these PCB wastes under HWMA, including concentrations, are summarized in this section. Consultation with Ecology is recommended to understand the requirements of handling and disposing of dangerous wastes when needed. MTCA also establishes procedures and standards for the identification, investigation, and cleanup of facilities contaminated with hazardous wastes. The cleanup methods for hazardous waste sites are also summarized in this section.

3.2.1.1 PCBs as a state listed dangerous waste

To address the management of some of the more problematic PCB wastes (i.e., liquid PCBs in transformers, bushings and capacitors), RCW 70.105.105 gives Ecology the authority to regulate PCBs as a dangerous waste. In 1985, Ecology amended the Dangerous Waste Regulations to include certain PCB wastes under the state-only waste code WPCB[1]. WPCB only applies to discarded transformers, capacitors or bushings containing 2 mg/Kg or greater PCBs (except when drained of all free flowing liquid). WPCB also applies to transformer capacitor or bushing cores, core paper wastes, cooling fluids, and insulation fluids generated from salvaging, rebuilding, or discarding of transformers, capacitors or bushings when PCBs are ≥2 mg/Kg (WAC 173-303-9904).

PCB wastes may be managed under TSCA instead of under HWMA in specific circumstances per WAC 173-303-071. It is best to consult with Ecology about the applicability of this exclusion for a given product or waste. If a waste meets the definition of special waste (WAC 173-303-040), then some listed WPCB wastes and some state-only persistent criteria waste (due to PCBs) can be managed this way.

3.2.1.2 PCBs as a state criteria dangerous waste

Washington State has additional state-only (i.e., not regulated under federal regulations) toxicity and persistent criteria based on presence of total halogenated compounds, which include PCBs. WAC 173-303-100(5) requires PCB waste to be evaluated for mammalian and aquatic toxicity and provides a process to designate a specific waste stream based upon the toxicity of the individual components. In this evaluation, toxicity must be considered with other waste constituents to determine if the waste stream should be designated as a state-only toxic waste and assigned the waste codes of WT02, as dangerous waste, or WT01, as extremely hazardous waste (EHW). At >0.01% and ≤1% total halogenated compounds, a waste is considered a persistent dangerous waste (waste code WP02). Examples of PCB persistent waste may include caulking, tar, and rubber stripping at airport runways. If the concentration of total halogenated compounds exceeds >1% (waste code WP01), the waste is recognized as an EHW with additional requirements and/or prohibitions regarding its management.

3.2.1.3 Used oil recycling

Chapter 70.95I RCW, Used Oil Recycling provides that used oil is conditionally regulated under the dangerous waste regulations as long as (1) it is not contaminated with chlorinated solvents or PCBs, and (2) it is managed appropriately. If used oil is not contaminated, it may be recycled or burned for energy recovery. Used oil with ≥2 mg/Kg PCBs is prohibited from being burned under the Dangerous Waste regulations for energy recovery. WAC 173-303-515 contains the management standards for used oil.

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[1] Wastes designated as state-specific PCB sources, as identified in WAC 173-303-9904. (Former W001 waste code).

3.2.1.4 Cleanup – Model Toxics Control Act

Chapter 70.105D RCW establishes the framework and authority for Ecology to address the cleanup of sites contaminated with toxic chemicals including PCBs. The MTCA Cleanup Regulation (WAC 173-340), issued in 1991, establishes procedures and standards for the identification, investigation and cleanup of sites contaminated with hazardous wastes. MTCA provides several methods for setting cleanup levels[2]. Under MTCA Method A, pre-calculated protective cleanup levels are available in tables within the regulation for use at relatively simple sites. Method B is the universal method to determine cleanup levels for all media at all sites. A target cancer risk level of one in one million (10^{-6}) is used when calculating cleanup levels under Method B. The toxic equivalency factor methodology (Van Den Berg et al. 2006) may also be used to evaluate PCB toxicity where the mixture is considered a single hazardous substance. Method C cleanup levels are established when cleanup levels established under Method A or B may be impossible to achieve or may cause greater environmental harm. For PCB cleanups, consultation with the EPA is required under TSCA and may be required with Ecology under MTCA. Early coordination with relevant agencies is recommended.

3.2.2 Ground Water Regulations

Chapter 90.48 RCW Water Pollution Control Act in conjunction with Chapter 173-200 WAC Water Quality Standards for Ground Waters regulate the current and future beneficial uses of groundwater. These rules and regulations are intended to protect groundwater from deleterious effects, degradation, and actively maintain higher quality in waters that exceed water quality criteria. The PCB groundwater standard is 0.01 μg/L and all discharges to groundwater in excess of this concentration are prohibited absent an Ecology-approved permit and point of compliance (WAC 173-200-040, Table 1).

3.2.3 Surface Water Regulations

The current EPA NTR (discussed in Section 3.1.2) is the applicable human health surface water criteria in Washington State at this time (170 pg/L for PCBs). WAC Chapter 173-201A (Water quality standards for surface waters of the state of Washington) dictates the narrative and numeric criteria for surface water quality, an anti-degradation policy, and use-based protection measures in Washington State. There are both marine and freshwater acute and chronic PCB standards to protect aquatic life (Table 1). All four values are 24-hour averages not to be exceeded. Ecology enforces these standards and rules through their NPDES permitting program.

[2] Cleanup levels are concentrations in soil, sediment, water, and air which are protective of human health and the environment under certain exposure conditions.

Table 1. Washington state PCB aquatic life standards in µg/L

Water Type	Acute	Chronic
Freshwater	2	0.014
Marine	10	0.030

3.2.4 Sediment Management Standards

Chapter 173-204 WAC, Sediment Management Standards, was created in 1991 under RCW Chapters 90.48, 70.105D, 90.70, 90.52, 90.54, and 43.21 and establishes marine, low salinity, and freshwater surface sediment management standards (SMS). The purpose of the SMS chapter is to reduce health threats to humans and biological resources resulting from surface sediment contamination. Marine and freshwater sediment benthic cleanup objectives (SCOs) and cleanup screening levels (CSLs) are shown in Table 2 along with their respective units. There are no regulatory criteria for the protection of human health through direct sediment exposure or bioaccumulation from sediments into organisms, such levels are typically derived through the development site-specific exposure assumptions and risk assessment.

Table 2. Washington State PCB sediment standards

Sediment Type	Sediment Cleanup Objective (SCO)	Sediment Cleanup Screening Level (CSL)	Units
Marine	12	65	µg/Kg OC-normalized
Marine[1]	130	1,000	µg/Kg dry weight
Freshwater	110	2500	µg/Kg dry weight

[1] The SMS for many organic compounds are based on total organic carbon (TOC)-normalized concentrations. However, because storm drain solids samples typically contain relatively high TOC concentrations, the dry-weight equivalent SMS values (i.e., LAET and 2LAET) are used for source tracing purposes. The typical assumption is that sediments between 0.5 and 3 or sometimes 4% organic carbon are suitable for organic carbon normalizing (Michelsen 1992, Ecology 2015a). Catch basin and inline sediments frequently far exceed these upper bounds.

The SCO and CSL are used to guide cleanup decisions in marine and fresh waters (e.g., directly under MTCA and as an applicable state regulation under CERCLA). In comparison, sediment quality standards are used to regulate under the CWA, e.g., 303d listings. The marine sediment quality standard for PCBs is the same as the SCO, 12 µg/Kg OC-normalized. There are no sediment quality standards specifically for freshwater or brackish sediments.

These marine sediment standards typically apply to permits and regulatory actions. They are rarely enacted independent of an NPDES permitting action, MTCA, and/or CERCLA remedial action.

4.0 SOURCE TRACING PROGRAMS

This section describes major PCB source tracing programs conducted by public agencies in four areas of the Pacific Northwest (Seattle, Tacoma, Spokane, and Portland). In addition, to these regional programs, two other areas (San Francisco Bay and Delaware River Basin) are reviewed to provide a national perspective. For each geographic area, context is provided on the key drivers of PCB source tracing and the major organizations conducting source tracing. The source tracing approach is then described for each program, discussing the techniques applied. Some specific examples of source investigations resulting from source tracing efforts are also described. Lastly, the PCB concentrations detected during the source investigations are summarized including environmental media and contaminated materials identified as likely sources. All solids concentrations in this report are presented on a dry weight basis.

For each program, regulatory environmental goals (sediment, water or tissue concentrations in receiving waters) are provided for background, but it is acknowledged that there are no legal thresholds set for in-pipe source tracing applications outside of Total Maximum Daily Load (TMDL) discharge limits. TMDL discharge limits can provide end-of-pipe thresholds for source tracing, although they are not legal thresholds for source tracing. Regulatory environmental goals are not directly applicable to permitted discharges or upstream in-pipe concentrations. Each jurisdiction attempts to prioritize areas for source tracing based on the relative distribution of their system's PCB concentrations. Therefore, the term "elevated" is often used in this section to refer to results that are higher or highest relative to other results. Best professional judgment is used in lieu of legal screening thresholds to determine which results indicate a potential PCB source that needs control. Exceptions occur when street level solids[3] are sampled. These can be compared to local or state residential and/or industrial soil screening levels and result in legal action.

4.1 Pacific Northwest Programs

The Pacific Northwest is home to a number of source control programs that regularly conduct PCB source tracing. Source tracing in the City of Portland, Spokane region, and the Lower Duwamish Waterway (LDW) are all associated with contaminated rivers, while the City of Tacoma's program addresses recontamination of Commencement Bay in Puget Sound.

4.1.1 Duwamish River and Lower Duwamish Waterway

The City of Seattle, the Port of Seattle, The Boeing Company (Boeing), and King County signed a Consent Order in 2000 agreeing to conduct a Remedial Investigation and Feasibility Study (RI/FS) in the LDW. The LDW is a subarea of the larger Duwamish River

[3] Street level solids refer to soils/dust from streets, or paved/unpaved properties. These are in contrast to solids from conveyance systems.

and was added to EPA's National Priorities List (also known as The Superfund Site List) in 2001 and to Ecology's Hazardous Sites List (also known as The MTCA Site List) in 2002. PCBs are one of the main contaminants of concern for the LDW Superfund site, driving human health risk through resident seafood consumption (Windward 2010). The LDW extends across 5 miles from the south end of Harbor Island to just upstream from the turning basin. The site covers approximately 441 acres. The LDW does not include the East and West Waterways or those portions of the Duwamish River from RM 6 to the confluence with the Black River at RM 11. Approximately 29% of the greater Duwamish River estuary subwatershed, extending from RM 11 at the confluence with the Black River to Elliott Bay, is used for commercial/industrial purposes, and approximately 36% is residential (AECOM 2012).

Ecology is the lead agency for source control for the LDW Superfund Site and is leading the efforts to control sources of sediment pollution in the LDW in cooperation with the City of Seattle, King County, and EPA. Ecology also leads the interagency LDW Source Control Work Group (SCWG) formed in 2002 (Ecology 2004). The SCWG includes Ecology, the City of Seattle[4], King County, Port of Seattle, EPA, and more recently the City of Tukwila, Puget Sound Clean Air Agency, and Washington State Department of Transportation joined the group. The SCWG shares information, discusses strategy, develops action plans, implements source control measures, and tracks progress. The LDW site crosses multiple jurisdictions, including King County and the cities of Burien, Renton, SeaTac, and Tukwila; however, SPU and Ecology are the primary agencies tracing PCB sources in the LDW on a broad geographic scale.

Through the RI/FS and Ecology's source control analyses, a total of 24 source control areas, including seven early action areas, have been identified (Figure 1) (Ecology 2012a; Ecology 2012b). The majority of these areas fall within the city boundaries of Seattle (~80%; King County unpublished data); the remainder is within unincorporated King County (~10%) or the cities of Burien, Renton, SeaTac, or Tukwila (King County 2014). For each source control area, Ecology worked with the SCWG to summarize existing information in Data Gaps Reports and develop Source Control Action Plans (SCAPs) (https://fortress.wa.gov/ecy/gsp/CleanupSiteDocuments.aspx?csid=1643). These plans describe sources of potential contaminants (including PCBs), the actions needed to control them, and whether these sources may be ongoing and have the potential to recontaminate the LDW. Also, these plans describe planned or current source control actions and sampling or monitoring activities planned to identify additional sources. The monitoring described in these plans is the major source tracing activity led by Ecology. As the lead agency, the majority of Ecology's activities are better categorized as source control actions on sites and sources identified by other Lower Duwamish Waterway Group (LDWG) parties (e.g., Port of Seattle, Boeing, SPU, and King County). The LDW Superfund process has included a number

[4] Within the City of Seattle, SPU is the agency that implements source control actions and participates in the SCWG.

of early action sediment cleanups and a 2014 record of decision (ROD) (EPA 2014), which describes the additional remedial actions required.

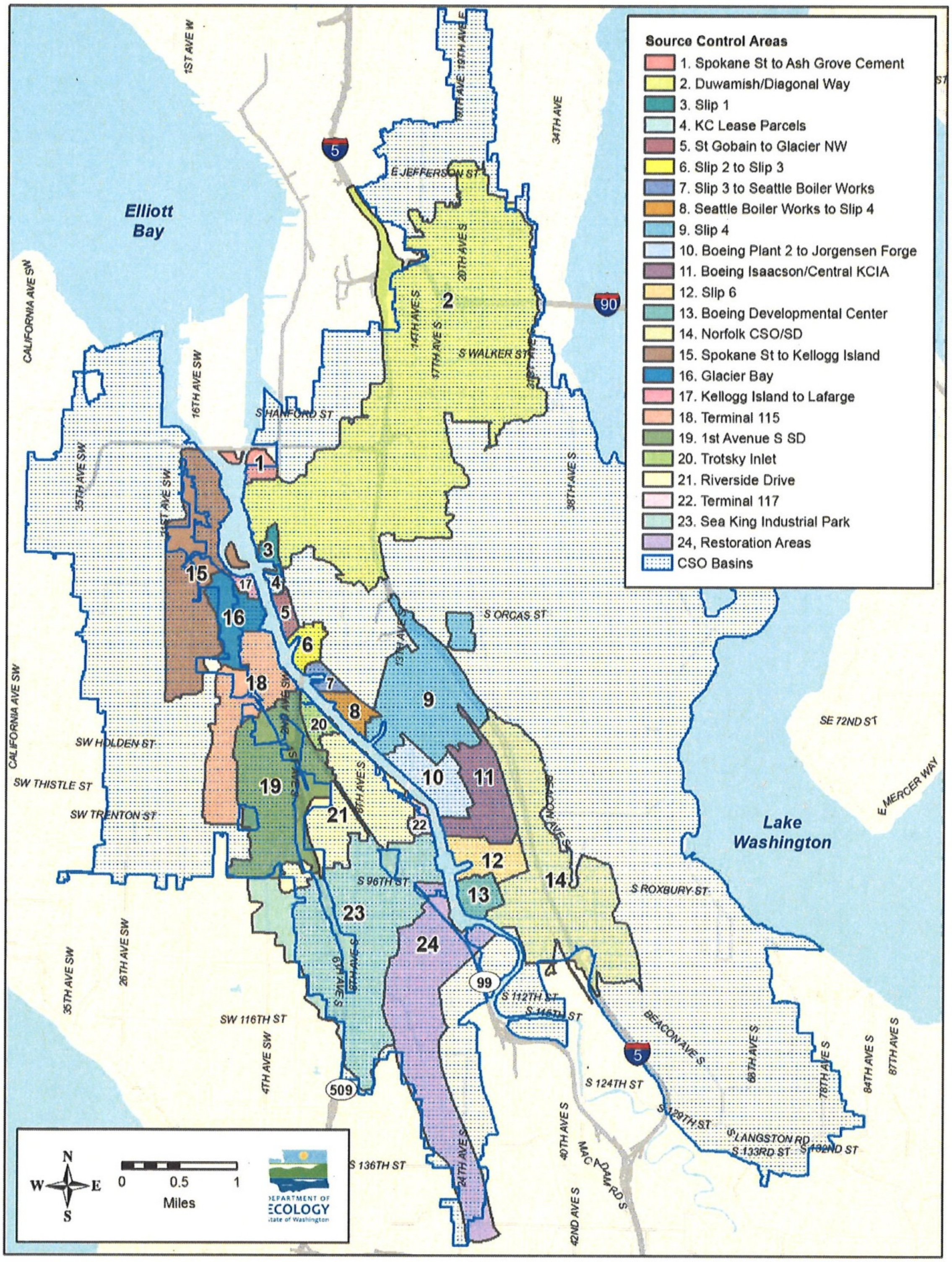

Figure 1. Source control basins within the Lower Duwamish Waterway Source Area (Figure from Ecology 2012a)

Ecology is the lead agency for upland (non-sediment) source control in the LDW CERCLA process (Thomas et al. 2012). Ecology asked Seattle and King County to develop and submit agency-specific source control implementation plans. These plans set each agency's priorities for source control in the systems they own and operate for the near-term (next 5 years) and the long-term (extending into the period after the Superfund cleanup is constructed). These implementation plans describe actions planned by both parties to control sources under their existing authorities and emphasize coordination at two levels:

- Inter-departmental coordination within each agency, and
- Inter-agency coordination with the SCWG.

Each agency's plan will be tailored to the different regulatory obligations (e.g., NPDES permits, orders, MTCA cleanups), implementation and enforcement of local codes and rules (e.g., local business inspections), and intra-agency coordination. Regulatory requirements, permits, and cleanup orders form the basis for each implementation plan including Seattle's. Each agency's plan will become appendices to Ecology's Source Control Strategy (Ecology 2012a) and made publically available.

4.1.1.1 Washington State Department of Ecology

Ecology produced the initial LDW Source Control Strategy in 2004 (Ecology 2004). This strategy outlined a framework and process for identifying source control issues and implementing effective controls. Source control actions that would minimize the potential for LDW sediment to exceed state sediment contaminant standards and cleanup goals were the focus. Cleanup of early action areas were the highest priority at this stage, but source control action plan (SCAP) development for all source control areas was included in the strategy.

The SCAPs for each basin have guided Ecology's source control program in the LDW. Although most source control actions have been conducted by LDWG members, Ecology has coordinated with them on these actions. Since 2007, Ecology has completed source control status reports that summarize source control related activities conducted for the LDW since the last status report (e.g., Ecology 2011a).

Background

As lead of the LDW SCWG, Ecology has conducted a number of their own source tracing studies to help refine and target future source control investigations on subbasins and properties contributing PCBs and other contaminants of concern to the LDW. One of the most comprehensive syntheses was the 2011 LDW Source Tracing Data Evaluation of the Stormwater Pathway (SAIC and Newfields 2011). This report was a synthesis of chemistry data for stormwater, baseflow water, stormwater solids (including sediment trap, bedload trap, catch basin grabs, and filtered solids), oil water separator and treatment vault solids collected by jurisdictions in the LDW watershed. Because of the limited number and variability of the water samples, only the sediment and storm drain solids data were used in the evaluation. The intent was to provide a comprehensive look across the data collected by all agencies and jurisdictions to identify correlations between in-water sediments and

the solids in storm drains. This was used to identify data gaps and priorities for source tracing. As part of this effort, Ecology also conducted an outfall inventory, updated in 2014 (Leidos 2014a). This effort identified and mapped 288 outfalls (some were inactive), the facilities with associated NPDES permit discharges, and their ownership and regulatory status, comparing their locations to LDW surface sediment concentrations nearby. Ecology has also conducted studies of PCB-containing materials that may be contributing as ongoing sources. These included surveys of building materials (SAIC and Newfields 2011) and goose guano (Leidos 2014b), as well as product testing (Ecology 2014a). The majority of Ecology source control studies in the LDW area have resulted in similar types of syntheses.

King County and Seattle's source control implementation plans work in concert with Ecology's studies and actions. In general, Ecology relies on its own inspectors and local jurisdictions to conduct source control investigations. Some of these have been funded by Ecology and are subject to Ecology review and approval. Ecology's routine business inspections generally focus on NPDES permits in the LDW. While the general NPDES stormwater permit analyte list does not include PCBs, Ecology has sampled 24 facilities with stormwater permits that were likely to have PCBs because of materials they handle. Ecology also conducts studies to identify sources and pathways at contaminated sites under MTCA orders. An example of an Ecology-led investigation at North Boeing Field is described below.

Source Tracing Approach

Work conducted as part of the North Boeing Field (NBF)/Georgetown Steam Plant (GSP) RI/FS is an example of a source tracing investigation overseen by Ecology. This investigation was conducted over numerous phases in pursuit of PCB sources to LDW Slip 4, a sediment site ranked as warranting an early remedial action prior to EPA's CERCLA ROD. To facilitate this investigation, Ecology entered into an Agreed Order with the City of Seattle, the Boeing Company (Boeing), and the King County International Airport (Ecology 2008). This agreement allowed Ecology and their contractors to access the various parcels and leased properties to conduct the RI/FS. Many of the source tracing activities in the RI/FS targeted other LDW Contaminants of Concern (COC) such as polycyclic aromatic hydrocarbons (PAHs) and metals. Because this source tracing effort was part of the much larger NBF/GSP RI/FS, it included a variety of other iterative investigations of many different matrices and materials such as: electrical equipment, groundwater, contaminated concrete, soil, stormwater solids, building materials, and fuel storage tanks both above and below ground. Only three of these components are discussed below to illustrate Ecology's source tracing efforts.

Ecology, their contractors, Boeing, King County Airport, and the City of Seattle have all conducted portions of the work involved to identify sources of PCBs to Slip 4. This has involved sampling and analysis of soil, groundwater, inline sediments, stormwater, and building materials. The examples summarized below address two of the several PCB sources to Slip 4 from NBF/GSP found to date. Information on other sources can be found in Ecology (SAIC 2009).

Georgetown Steam Plant Flume

Several sources were known to contribute PCBs to Slip 4 sediments from at least the mid-1980s (SAIC 2009). One of these was the GSP flume. This 7-foot-wide by 5-foot-deep open ditch with wood-lined and culverted sections had conveyed cooling water from the GSP to Slip 4 from about 1918 until 1971 when the plant was deactivated from regular use. Sediments in the flume contained PCBs as high as 2,500,000 µg/Kg (Table 3); however, most of the sediments were removed in 1985. This drainage structure was complex with numerous inlets, some relic and some in use. Many of the connections contained residual solids which remained a PCB source to the flume and eventually to Slip 4. Thus, the remainder of the sediments (~250 cubic yards), the flume itself, old pipes and connections to the flume, and some of the adjacent soils were all removed in 2008 to eliminate this PCB source to Slip 4 (SAIC 2009). A new drainage system, connected to only the necessary and active inlets, was installed in its place.

Storm drain solids

Sampling and analysis of storm drain solids for PCB Aroclors began in the mid-1980s at NBF in response to a number of oil spills and to ensure appropriate characterization and disposal of solids generated from routine maintenance (SAIC 2009). This effort predated the NBF/GSP RI/FS and later sediment trap sampling, but detection of high PCB concentrations (primarily Aroclor 1254) led to a number of follow-up investigations, nearby soil sampling, and numerous storm line cleanings.

Boeing cleaned the stormwater pipes and catch basins at NBF in 1984, 1985, 1992, 1996, 1997 and 1998. However, following these efforts PCBs were subsequently detected in storm drain solids in catch basins, manholes and the King County pump station at concentrations greater than a SMS-based screening threshold of 1,000 µg/Kg. For example, initial catch basin PCB sediment concentrations in 1992 were up to 1,240,000 µg/Kg in the flight line area. Depending on the catch basin and time period, recontamination reached 905,000 µg/Kg PCBs, although concentrations in most recontaminated storm drain solids were 100,000 to 250,000 µg/Kg (SAIC 2009). The repeated cleanings demonstrated that an ongoing PCB source greater than SMS screening levels was present at NBF, and that the contaminated storm drain solids in catch basins were not a relic of historic spills.

Caulk

After an investigation at a Boeing property in Everett indicated the presence of PCBs in caulk material used to fill expansion joints, Boeing initiated a study in October 2000 to characterize the extent of PCBs in material used to fill concrete expansion joints at NBF. The NBF investigation consisted of the following phases:

- October/November 2000: Visual inspection of joint materials; ten joint material types (designated A through J) were identified, based on observed physical properties; collection of 48 joint material samples for PCB analysis (Landau 2001a as cited by Ecology). One sample of Type A joint material contained 23,000,000 µg/Kg PCBs; two samples of Type G joint material contained 35,300,000 and 50,000,000 µg/Kg PCBs, respectively; and one sample of Type H joint material

contained 164,000 µg/Kg PCBs. All other samples contained less than 50,000 µg/Kg PCBs (Landau 2001a).

- February 2001: Characterization of joint material types A, E, G, and H, by documenting their location, extent, and condition; examination of the area near each joint sample location with total PCBs above 50,000 µg/Kg for possible spills; and identification of joint material types near storm drain system structures that have historically contained solid material with total PCBs above 10,000 µg/Kg (Landau 2001b).
- April 2001: Evaluation of the variability of PCB concentrations in three types of concrete joint material by collecting 39 additional joint material samples (Landau 2001c).

PCB concentration ranges are summarized in Table 3. Boeing removed PCB-contaminated caulking from several areas of North Boeing Field between 2002 and 2006 (Figure 2).

Source tracing follow-up

Despite the removal of contaminated caulking, PCB concentrations in storm drain solids continued to exceed the 1,000 µg/Kg screening threshold. Thus, beginning in 2005, SPU installed sediment traps for a period of 4 to 6 months to passively collect samples of suspended sediment present in the NBF stormwater runoff. Because it was difficult to collect adequate sediment volumes, chemical analyses were prioritized according to SPU's established hierarchy as described in Section 4.1.1.2 below. Traps were generally deployed in pairs upstream and downstream of suspected source areas. For instance, during the first deployment in 2005, the following locations (Figure 3) were selected in an attempt to isolate PCB sources to the pump station and/or Boeing leased areas at NBF.

- **T1 (MH-422):** Downstream end of the north and north-central lateral storm drain lines, upstream of the King County lift station.
- **T2 (MH-356) and T2A (MH-482):** Downstream and upstream, respectively, of the Boeing leased property along the south lateral.
- **T3 (MH-364) and T3A (MH-19C):** Downstream and upstream, respectively, of the Boeing leased property along south-central lateral.
- **T4 (MH-221A) and T4A (MH-229A):** Downstream and upstream, respectively, of the Boeing-leased property along the north-central lateral.
- **T5 (MH-363) and T5A (MH-178):** Downstream and upstream, respectively, of the Boeing leased property along the north lateral.

As of February 2009, nine rounds of sediment trap sampling had been completed; samples were collected in August 2005, March and October 2006, January, May, and October 2007, March, July, and December 2008. SPU and Ecology sampled upstream and downstream stormwater trap solids within the four major lateral lines at NBF: North Drain Line, North-Central Line, South-Central Line, and the South Line. As a result of this effort, SPU and Ecology were able to determine that storm drain solids in the North Lateral Line had the highest PCB concentrations and were contributing PCBs to the King County pump station

and eventually to Slip 4. Figure 3 illustrates the 2005-2008 storm drain solids trap locations and measured PCB concentrations.

Table 3. NBF PCB concentrations (µg/Kg) in stormwater solids, caulk, and flume sediments and residuals.

Sample Type	Minimum	Maximum
Flume residual materials, piping and connections	--	92,000
Flume sediments	--	2,500,000
Precleaning storm drain solids	--	1,240,000
Recontaminated storm drain solids after line cleanings	--	905,000
Subsurface soils near cracked and replaced storm lines	2,200	7,500
2005-2008 Storm drain sediment traps	<MDL	800,000
Contaminated Joint Caulk (approximate linear feet)		
Type A (3,500 LF)	780	79,000,000
Type B	<MDL	41,900
Type C	<MDL	13,000
Type D	770	2,700
Type E (943 LF)	530	5,200
Type F	<MDL	3,100
Type G (464 LF as primary caulk, 56,000 LF as residual)	6,100	61,000,000
Type H (64,000 LF as primary caulk; 56,000 LF as residual)	<MDL	2,240,000
Type J	<MDL	<1,000

-- = unknown, not reported
<MDL = less than method detection limit which was not provided

Figure 2. North Boeing Field caulk removal areas (2002-2006) (Figure from SAIC 2009).

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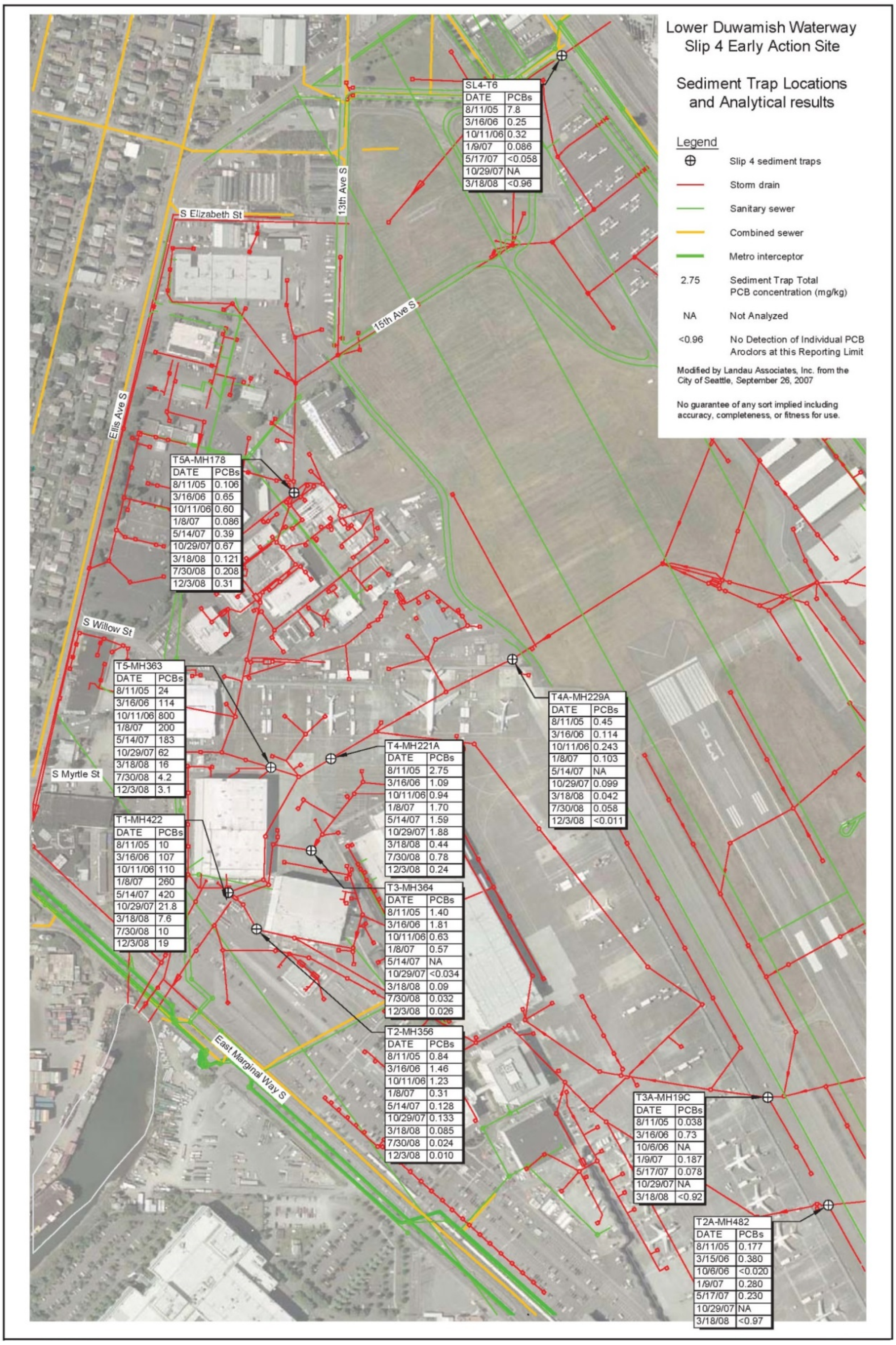

Figure 3. Initial North Boeing Field up and downstream sediment trap locations and results (Figure from SAIC 2009)

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4.1.1.2 City of Seattle

In 2003, SPU voluntarily implemented a program in the LDW to identify and control the sources of pollutants to the city-owned storm drain system to support cleanup activities in the LDW. This program has grown over the years to include business inspections, source tracing, and line cleaning activities. A description of SPU's source tracing operations is provided below.

Background

SPU has been tracing/controlling contaminant sources to the City of Seattle's stormwater system in the LDW since 2003 when it implemented a source control program for the LDW. The purpose of SPU's program is to minimize the potential for sediments in the waterway offshore of City outfalls to become recontaminated following the Superfund cleanup. SPU accomplishes this by identifying and controlling sources of pollution entering the City of Seattle's drainage system. The source tracing program includes business inspections and sample collection both on private properties and within the City of Seattle drainage system. Because the one remaining active City of Seattle CSO represents only 436 acres of the approximately 20,000 acres of combined sewer service area in the LDW, SPU has focused its efforts on the City of Seattle-owned separated stormwater system discharging to the LDW. The subbasins of Seattle's municipal separated storm sewer system (MS4) are shown on Figure 4 below.

SPU has three to four business inspectors and conducts approximately 200 to 300 business inspections per year. However, not all inspections are for PCB source tracing as the business inspections are conducted to ensure that businesses comply with City of Seattle Stormwater Code requirements for pollution prevention (City of Seattle 2016, pers. comm.).

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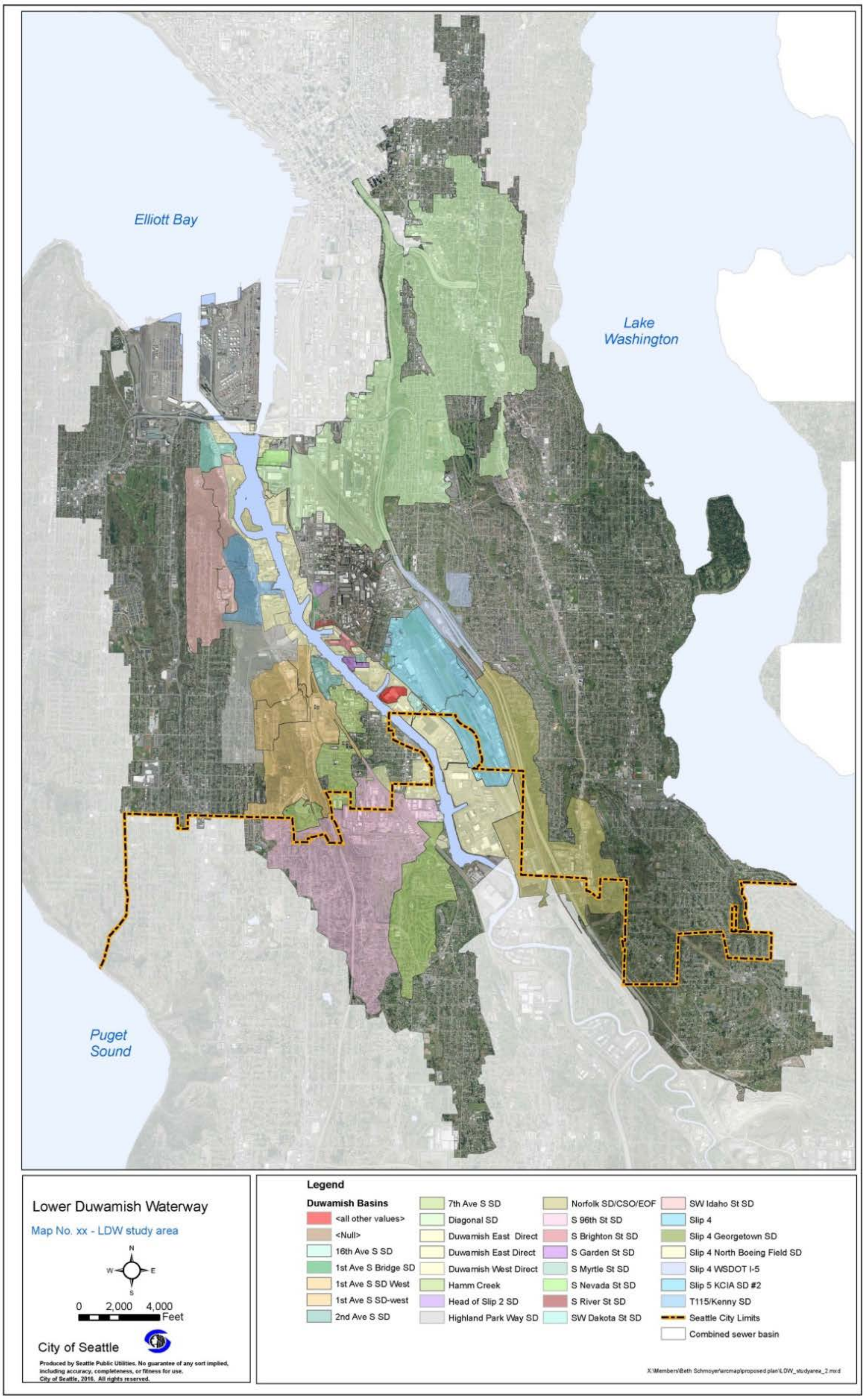

Figure 4. Source control basins within the Lower Duwamish Waterway Source Area (Figure from City of Seattle 2016, pers. comm.)

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Source Tracing Approach

SPU's program is designed to identify sources by sampling at key locations within the system. Sampling generally starts at the downstream end of a stormwater basin or at key junctions within the stormwater system and systematically moves upstream to identify sources. In addition, inspectors collect samples from catch basins on private property during business inspections if problems or unusual conditions are encountered during these inspections. SPU refers to these as "private onsite catch basin" samples.
Data generated by the sampling program are used to:

- Identify sources of contaminants to the City of Seattle-owned MS4,
- Characterize the quality of storm drain solids discharged to the LDW for use in recontamination analyses,
- Prioritize future source control activities, and
- Identify and prioritize city-owned storm drains or sections of storm drains for cleaning[5].

A variety of sampling techniques are used. Sediment (or storm drain solids) samples, rather than water samples, are generally preferred by SPU because:

- Storm drain solids samples provide a more direct measure of potential contaminant contributions to LDW sediment, because many contaminants of concern, including PCBs, are relatively insoluble and tend to attach to the particles present in stormwater;
- SPU has found storm drain solids samples can be collected relatively quickly using simple tools and equipment. By comparison, stormwater sampling requires more expensive automated samplers, which may require structural modifications to install, as well as considerable staff resources to operate and maintain;
- Solids that accumulate in the drainage system provide a measure of pollutant contributions over a longer time period (generally what has been deposited since the system was last cleaned), whereas water samples provide only a snapshot of a single event; and
- Unlike stormwater samples, storm solids samples do not usually present detection limit problems for SPU's analytical laboratory. Contaminants present in storm drain solids can usually be quantified, which makes it easier to evaluate and interpret the sample results.

SPU collects solids samples from various locations within the drainage system. Sampling solids enables source tracing efforts to maximize coverage of the LDW drainage system and to gather information on the extent and location of contaminants within the system.

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[5] SPU routinely jets and cleans storm drain lines to remove accumulations of contaminated sediment to prevent this material from being flushed into the LDW during larger storm events. Between 2008 and 2015, SPU cleaned 12 miles of storm drains in the LDW.

Each type of sample represents a different geographic scale and a different component of the sediment in the drainage system. SPU uses the following four sample types to track and identify potential pollutant sources to the City of Seattle's MS4:

- Inline Sediment Traps: SPU's sediment traps consist of a bracket mounted inside the conveyance system that contains a Teflon® bottle to passively collect suspended particulate material that passes by the sampling station. The Teflon® bottle is 8 inches tall, thus traps are only used in pipes that are 18-inches or larger in diameter.[6] Traps are generally left in place for 12 months to collect a sufficient mass for chemical analysis. Sampling stations are selected to isolate specific drainage subbasins or capture contributions from the entire drainage basin (e.g., generally greater than 50 acres for a separated storm basin). Sediment traps are typically installed to identify potential problem areas within a drainage system, and are followed up with more intensive sampling to identify potential specific contaminant sources (e.g., inline grabs and private onsite catch basin samples). SPU currently maintains 21 sediment traps in 8 drainage basins in the LDW (Figure 5).
- Inline Sediment Grab Samples: Inline sediment samples are grab samples collected from maintenance holes or other structures in the drainage system where sediment may accumulate. Like sediment traps, inline grab samples also represent contributions on a basin-wide or subbasin scale. However, inline grabs typically represent the heavier material that accumulates and is transported in the bedload material that moves along the bottom of the pipe. These samples are collected from areas where sufficient sediment is present using a long-handled scoop. Inline sediment samples are usually collected prior to installing a sediment trap or prior to cleaning the drain to characterize the chemical quality of sediment in the drainage system. SPU also uses these data to trace sources in systems that are not large enough to install a sediment trap.
- Catch Basin Solids: Catch basin samples are grab samples of solids that have accumulated in the catch basin, usually from a small (<0.5 acre) area. These structures are equipped with a small sump to capture solids and other large debris before it can enter the stormwater conveyance system. Catch basin samples are collected either from a specific site or property (private onsite) or from the public right-of-way (ROW). The samples represent potential inputs from the small catchment area.
- Soil/Street Dust: Soil and street dust samples are collected to confirm offsite transport of contaminants from adjacent properties to the City of Seattle ROW and in areas where there is no formal storm drain system to collect/convey street runoff. Like catch basin samples, soil and street dust samples are considered to represent contributions from a small local area.

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[6] SPU is currently conducting a pilot test, funded by Ecology, to develop a new sediment trap that is capable of being deployed in small diameter pipes. Prototype designs have been tested in a laboratory flume and will undergo field testing in 2016.

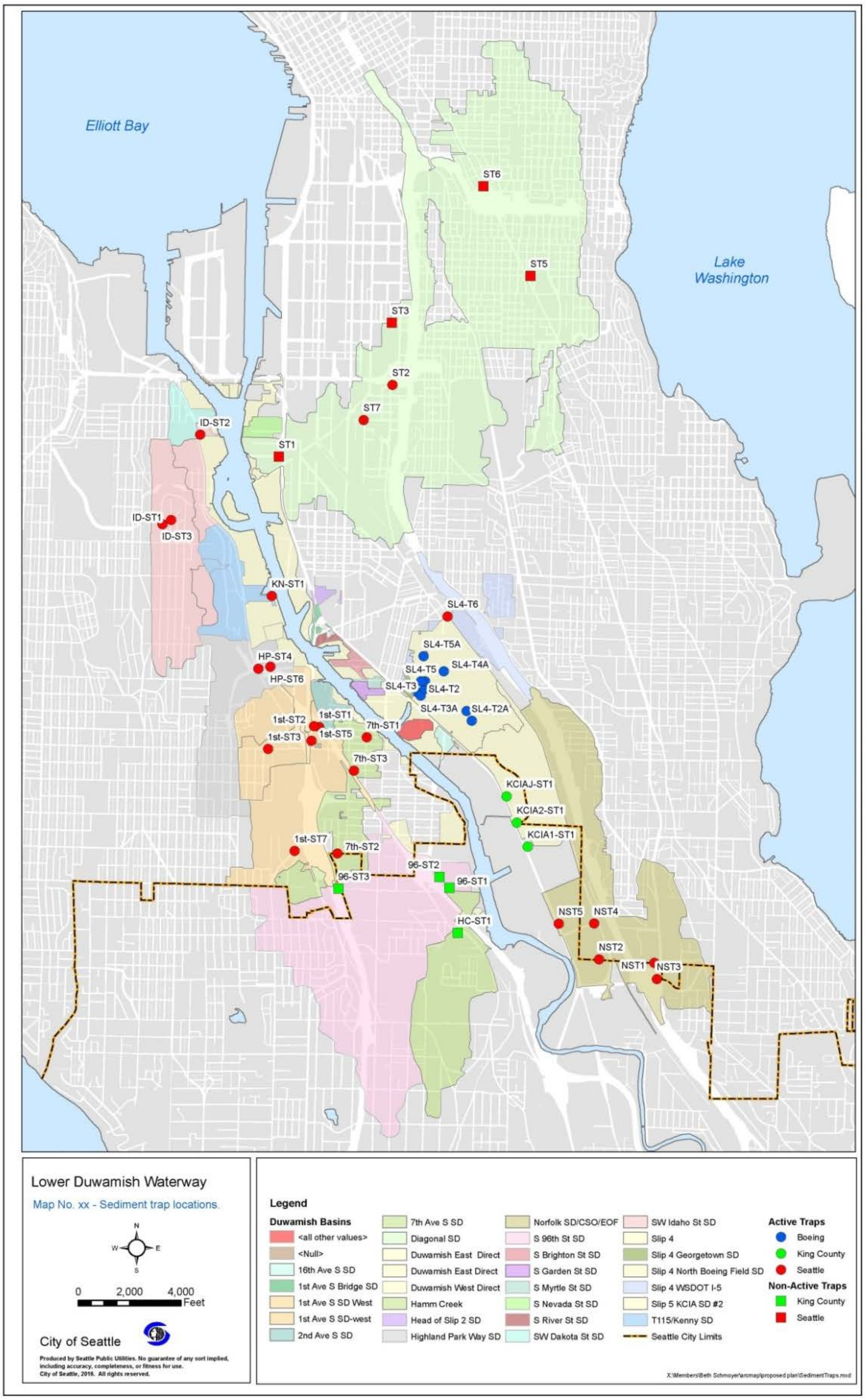

Figure 5. Current (2016) SPU sediment trap locations (Figure from City of Seattle 2016, pers. comm.)

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The standard analyte list for all of these different sample types (City of Seattle 2015) includes:

- PCBs as Aroclors
- Semi-volatile organic compounds
- Grain size
- Total organic carbon
- Total petroleum hydrocarbons – Diesel Range (NWTPH-Dx)
- Arsenic, copper, lead, mercury, and zinc; when metal platers are in a basin, SPU adds cadmium, chromium, and silver to the analyte list.

SPU's analytical results are independently validated and then entered into an EQuIS® database. As of December 2015, SPU had collected over 1,000 samples in the LDW. SPU's ArcMap system links directly to EQuIS® which allows these data to be quickly plotted and analyzed geographically.

Data are often plotted as "dots" on a map displaying the range of chemical concentrations using different size and color symbols. Although, there are no regulatory standards for storm drain solids, SPU and other members of the LDW SCWG typically compare sample results to the Washington State SMS and the Washington State MTCA Level A soil cleanup standards to provide a rough indication of storm drain solids quality. The SMS establish the SCO and CSL (Section 3.2.4). For most chemicals, including PCBs, SPU uses the CSL or its dry weight equivalent (the second lowest apparent effects threshold [2LAET]) to determine when additional source tracing is needed. The 2LAET for PCBs is 1,000 μg/Kg dw (See Section 3.2.4); in SPU's experience, this value is associated with larger PCB sources that merit follow-up investigations.

An illustration of a PCB inline solids "dot" map is provided as Figure 6. The City finds visualizing data this way helps identify areas or hotspots warranting more intensive investigations for specific sources. These follow-up investigations typically involve re-inspecting all the businesses and collecting multiple samples within the city-owned and private drainage systems to identify the source. SPU is currently conducting a pilot test, funded by Ecology, to determine whether specially trained detection dogs can aid in locating PCB sources at industrial sites in the LDW.

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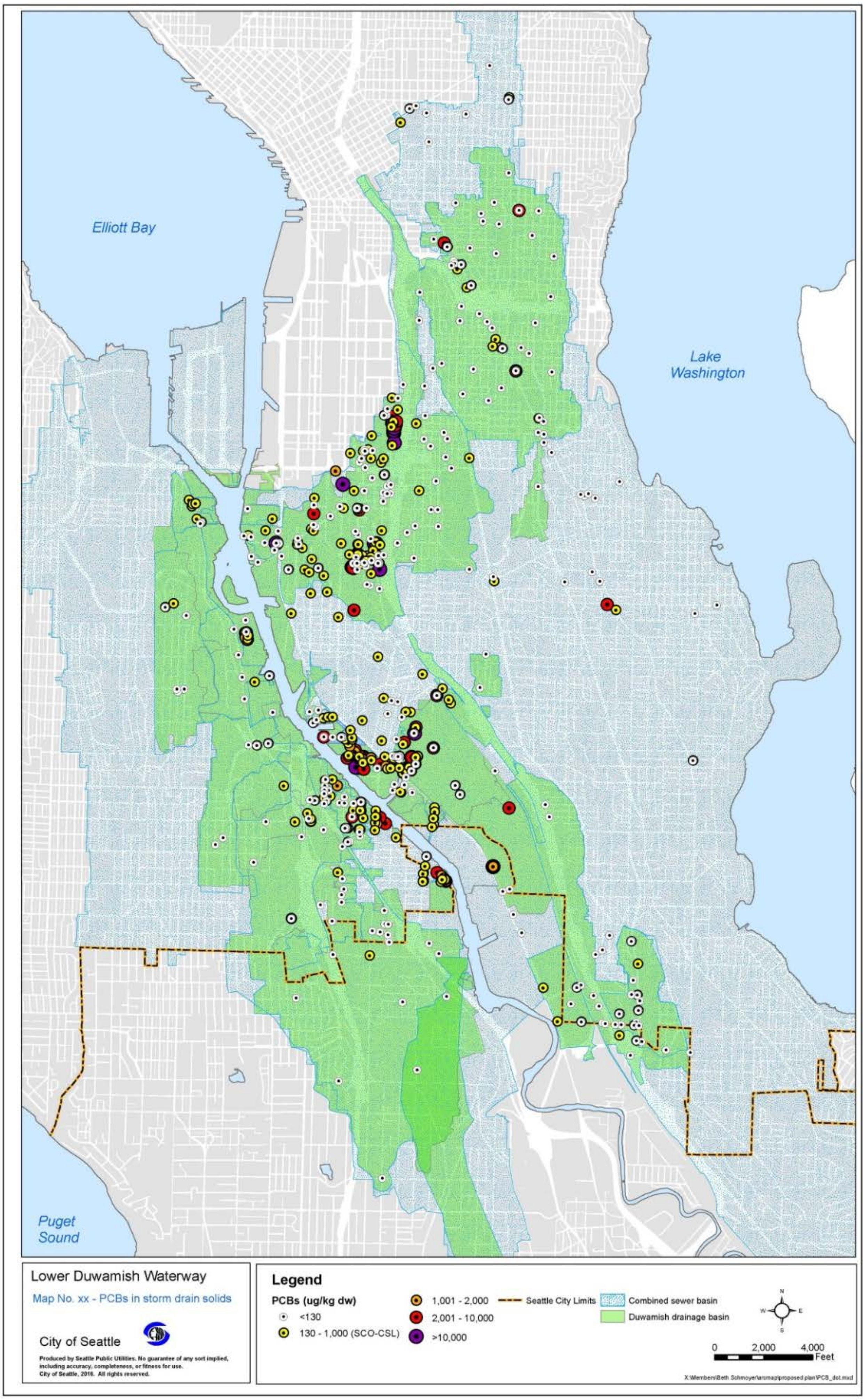

Figure 6. **Example dot map of sediment and inline solids concentrations (Figure from City of Seattle 2016, pers. comm.)**

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SPU also summarizes data in the form of a boxplot to enable comparisons between drainage systems to assess for relatively elevated levels of contaminants. An example boxplot for PCBs is presented in Figure 7 (City of Seattle 2015).

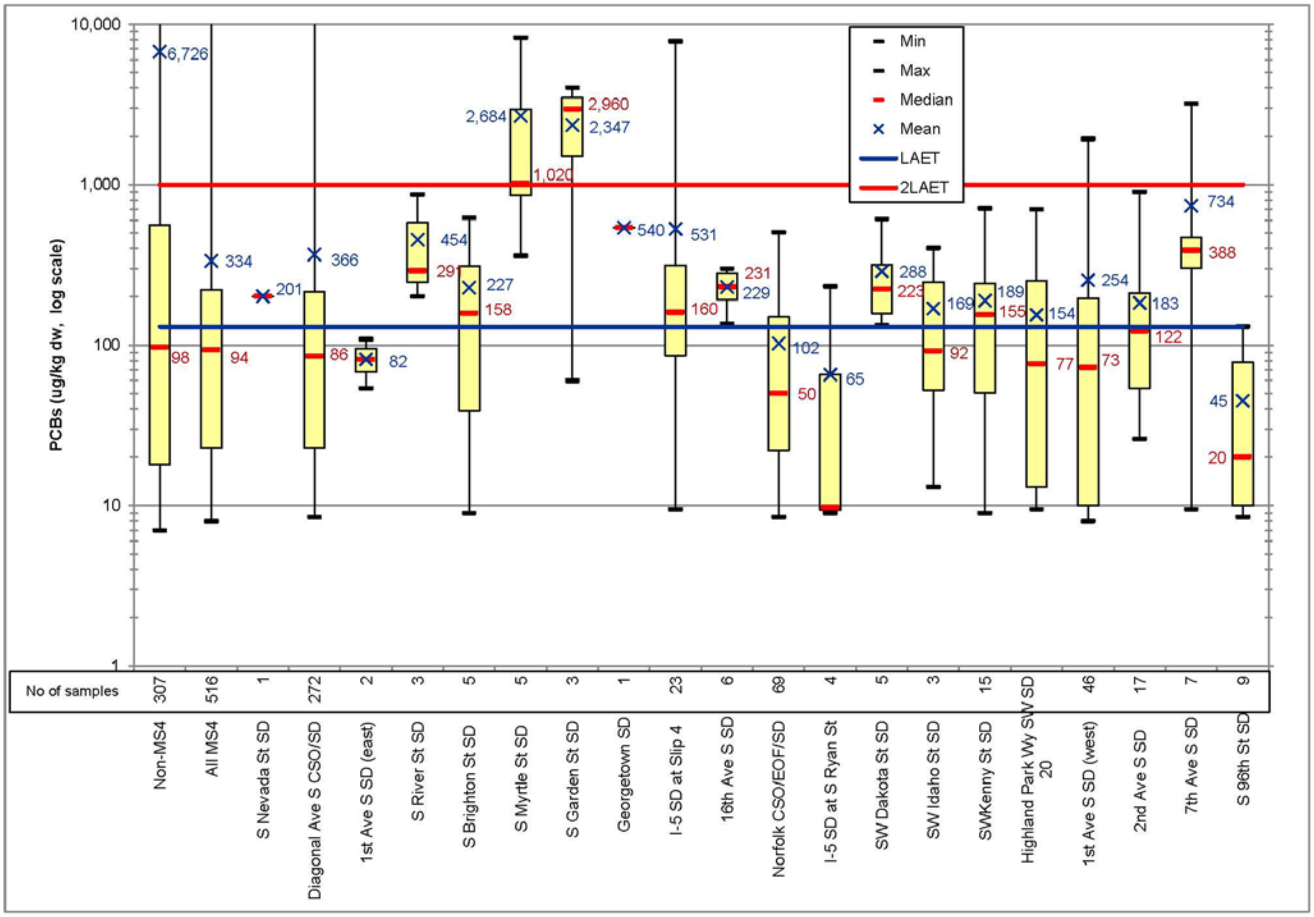

Figure 7. **Example box plot of PCB concentrations across LDW storm drain locations (Figure from City of Seattle 2016, pers. comm.)**

Business Inspection Program

Seattle's business inspection program supplements the source tracing program in the LDW by identifying pollution-generating activities at local businesses that may be impacting the City of Seattle MS4 and by collecting samples to confirm whether contaminants are entering the private and public drainage systems. Inspections address a variety of pollutants, including PCBs.

The inspection program is also an integral part of SPU's overall source control program in the LDW as it ensures the pollution prevention requirements specified in Seattle's Stormwater Code (SMC 22.800-808) and Source Control Manual are implemented. The Stormwater Code requires all responsible parties to implement and maintain source controls to prevent or minimize the amount of pollution leaving a site or property. It also establishes basic stormwater requirements for all real property in the City of Seattle and

identifies additional requirements for specific pollution-generating activities. It also gives SPU the authority to inspect businesses to evaluate, and when required, enforce compliance with the code.

As previously indicated, SPU has three to four business inspectors and conducts approximately 200 to 300 business inspections per year in the LDW. All of the approximately 1,200 businesses that have potential to discharge pollutants to the City of Seattle MS4 in the LDW have been inspected at least once, and many have been inspected multiple times. Businesses are ranked after each inspection cycle based on the severity of issues found and potential to pollute. High priority businesses are inspected every two years; medium every four years, and low every six years.

Summary of Findings

SPU's source tracing program has identified several PCB sources to storm drains which contribute to the LDW Superfund site. Two cases are described below.

Rainier Commons

Rainier Commons is a mixed use development of lofts, warehouse, and storage spaces which occupies the former Rainier Brewery Site at 3100 Airport Way South. While conducting routine sampling in 2004, SPU detected 17,500 µg/Kg PCBs in sediment from a catch basin on Airport Way South (RCB37 on Figure 8) (City of Seattle 2015). This catch basin receives runoff from a relatively small area along Airport Way S, and the adjacent Rainier Commons property. SPU subsequently found 17,000 to 23,000 µg/Kg PCBs in onsite catch basins RCBSTEV1 and RCBSTEV4 in the parking lot of Rainier Commons and found 2,200,000 µg/Kg PCBs in a trench drain located in a drive-through area on the property, all of which discharge to the city-owned drainage system on Airport Way South. The source of PCBs was later traced to exterior building paint, which contained up to 213,000,000 µg/Kg PCBs (NVL 2012).

In 2008, after negotiations between Rainier Commons, King County, and Ecology, SPU hired a contractor to clean the onsite catch basins and drainage system as well as the city-owned drainage lines on Airport Way South that were affected. Cleaning costs were shared by SPU and Rainier Commons.

Rainier Commons installed filter socks and material in their onsite drainage system to trap PCBs onsite. SPU continued to sample the catch basins and maintenance holes in the city-owned drainage system on Airport Way South. In 2012, 7,300 µg/Kg PCBs were found in the city-owned system and 8,200-12,400 µg/Kg PCBs were found in the onsite catch basins. SPU required Rainier Commons to jet and clean the on-site storm drains and city-owned lines on Airport Way South. Cleaning was completed in early 2013.

The Rainier Commons property became a TSCA site under EPA authority after property owners detected up to 2,300,000 µg/Kg PCBs in their exterior paint in 2005 (WDOH 2010). Subsequent testing in 2009 found 10,490,000 µg/Kg in paint chips from the building

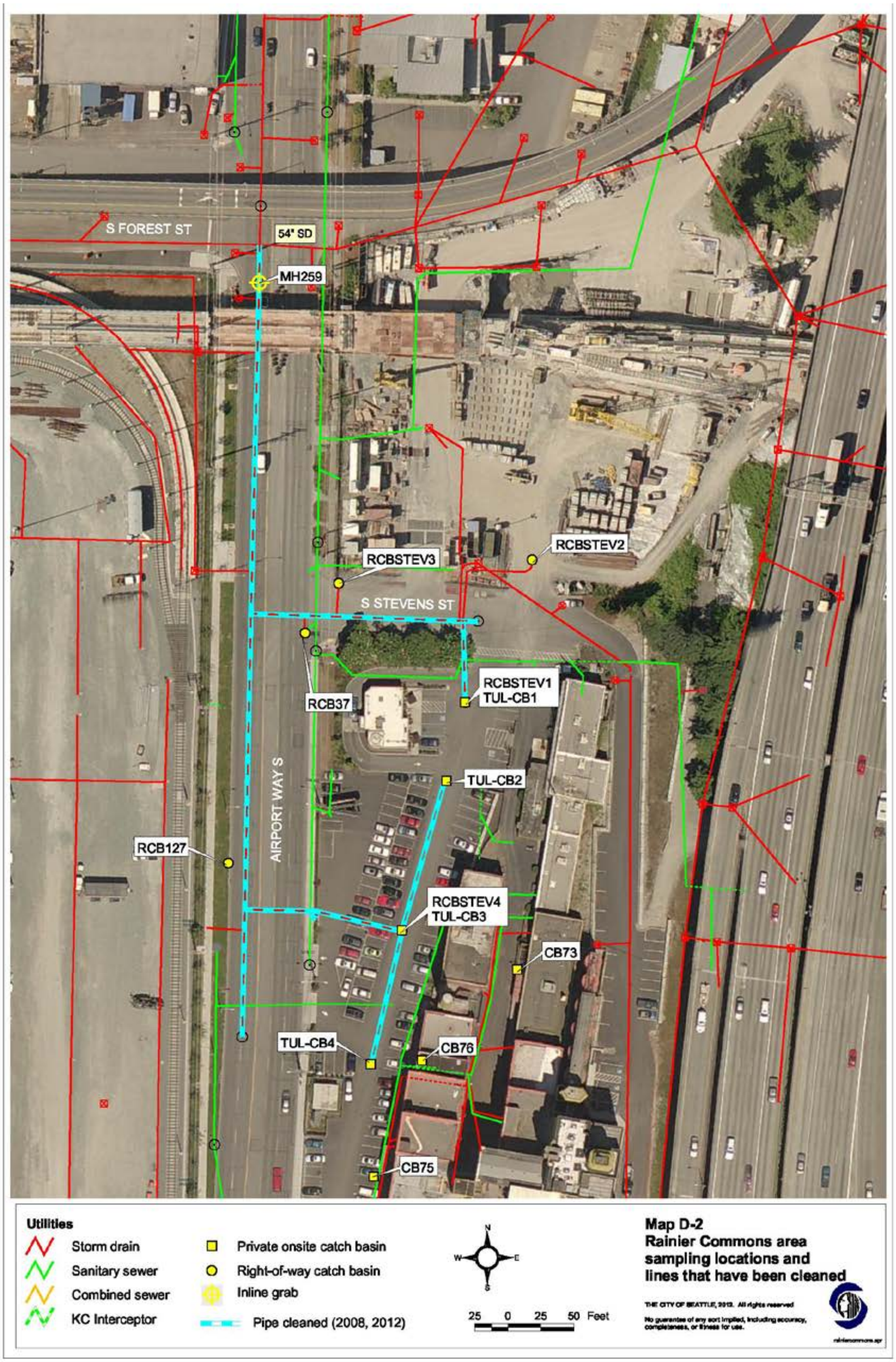

Figure 8. Catch basin and inline sediment sampling locations in the vicinity of Rainier Commons (Figure from City of Seattle 2015).

(WDOH 2010). Cleanup is being conducted in phases. The first phase, completed in 2014, removed exterior building paint from several of the worst buildings on the site. Additional phases will be conducted in future years to complete the cleanup.

Sternoff Metals

Sternoff Metals operated a scrap metal salvage yard along East Marginal Way South in Seattle for about 45 years (Figure 9) (SPU 2015). The business closed in 1986 and a number of other businesses have occupied the property since. Remedco, a soil remediation company, attempted to start a soil heat treating facility on the property; while the required permits were never obtained, debris and soils were accumulated on site. In 1999, the debris pile was sampled by Ecology and found to contain 69,000-120,000 µg/Kg PCBs. The material was removed and disposed of at a dangerous waste landfill; however, the sides and bottom of the excavation site still contained 9,000 to 77,000 µg/Kg PCBs.

In 2008, a community group collected soil samples from within the 8th Ave South ROW (Figure 9) to determine whether a stormwater bioretention system could be installed in this area. PCB concentrations in these soils were relatively low (4,400 to 5,900 µg/Kg) but above MTCA level A soil criteria (1,000 µg/Kg). The bioretention cell was moved farther west on 8th Ave S to a location where testing confirmed that soils were not contaminated.

These results initiated additional sampling by SPU within the 8th Ave South ROW and on the former Sternoff Metals property itself. Street dirt collected from shoulders adjacent to the former Sternoff Metals driveway contained 36,000 to 69,000 µg/Kg PCBs, while dust from the pavement on-site contained 1,340 µg/Kg PCBs. Samples collected from on-site soil piles contained only 182 to 530 µg/Kg PCBs. This investigation illustrates how past investigations and remedial actions removed on-site materials, but had not thoroughly investigated off-site migration pathways or delineated all PCB sources before finalizing remediation efforts. Thus, past cleanup actions were insufficient to prevent the tracking of PCB contaminated dirt and dust onto the right-of-way. As of February 2016, the Sternoff property remains on Ecology's list of known or suspected release sites with a rank of 5 (lowest priority).

Figure 9. PCBs in catch basin, inline sediments and soils in the vicinity of Sternoff Metals (Figure from City of Seattle 2015).

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4.1.2 City of Tacoma

The Commencement Bay Superfund Site spurred significant source tracing and control efforts for multiple contaminants, including PCBs. This effort has been led by both state and local government agencies. The City of Tacoma's contaminant source tracing program is highlighted in this report because of its long history, its use of stormwater monitoring, and recent examples of success that required extensive investigative methods.

4.1.2.1 Background

In 1983, the EPA designated 12 acres of Commencement Bay and adjacent nearshore tideflats in south Puget Sound as a Superfund Site. The EPA defined six distinct operable units (OU) for cleanup in the 1989 ROD (EPA 1989):

- Commencement Bay sediment remediation - tideflat sediments (OU 1)
- Various areas associated with the Asarco Smelter and Tacoma Tar Pits (OU 2-4, 6)
- Commencement Bay source control - tideflat uplands (OU 5)

OU 1 was broken into nine sediment problem areas including the Sitcum Waterway, St. Paul Waterway, Middle Waterway, head and mouth of the Hylebos Waterway, head and mouth of the Thea Foss Waterway, the Wheeler-Osgood Waterway, and one area associated with the Asarco Smelter. Following completion of cleanup, the EPA removed the St. Paul waterway from the OU in 1996.

The EPA and Ecology divided their responsibilities on all Commencement Bay OUs such that the EPA worked on sediment contamination and Ecology worked on upland source control. To take action on sediment remediation, the EPA entered a consent order in each sediment problem area with one or more potentially responsible parties[7]. The consent orders were legal agreements to design and implement remedial actions within the sediment problem areas. Many consent orders were entered into with private parties. However, the City of Tacoma entered a consent order in 1994 agreeing to design the remedial action for the Thea Foss and Wheeler Osgood Waterways (EPA 2000). Stormwater had been identified as one of the major contaminant sources to sediment (EPA 1997; City of Tacoma 2015, pers. comm.). The City of Tacoma designed and conducted 100% of the sediment cleanup in the Wheeler Osgood Waterway and 80% in the Thea Foss Waterway. Two companies (Puget Sound Energy and Pacificorp) remediated the remaining 20% of the Thea Foss Waterway sediments. The cleanup activities occurred between 2002 and 2006 under a second consent order. Fate and transport modeling predicted that contaminant concentrations, including PCBs, in the relatively clean sediments placed during remediation would increase over time due to ongoing discharges under status quo conditions. However, with source control actions, the goal was for sediment concentrations to equilibrate below sediment cleanup standards set by the EPA. In accordance with

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[7] The party(ies) involved may not be the only or even the principal parties responsible for contamination.

regulatory agreements, the City implemented a stormwater monitoring and source control strategy for municipal storm drains entering the Thea Foss/Wheeler Osgood waterways, hereafter referred to as the Foss Waterway (City of Tacoma 2015).

The Foss Waterway Watershed is one of nine watersheds in the City. This watershed covers approximately 5,864 acres and is comprised of drainage basins located in the south-central portion of Tacoma (City of Tacoma 2015). There are seven major stormwater outfalls, in addition to a number of smaller outfalls to the Foss Waterway that cover a drainage area of 5,744 acres (98%) within the watershed. Land use in the watershed is predominately residential, although most of the City's commercial businesses are also located in this watershed. Industrial land is concentrated in certain portions of the watershed.

The City of Tacoma developed a source control and long-term monitoring program following cleanup of the Foss Waterway. Their source control and long-term stormwater monitoring program focuses primarily on PAHs and phthalates, but also includes PCBs. The program began over 10 years ago and has resulted in opportunistic identification of PCB-contaminated materials in upland areas. The monitoring and source control strategy is described below.

4.1.2.2 Source Tracing Approach

The City of Tacoma's source control strategy has several elements: source control actions, long-term monitoring of Foss Waterway sediments, stormwater system water and suspended sediment, computer modeling to predict sediment concentrations in the waterways, and a decision matrix used to determine where and when additional source control is needed (City of Tacoma 2015). The City has integrated this program with activities required by their Phase I Municipal Stormwater NPDES permit.

PCBs were not the only contaminant of concern in the Foss Waterway. The 1988 RI/FS determined several contaminants were elevated in this waterway: zinc, lead, mercury, high molecular weight PAHs, low molecular weight PAHs, cadmium, copper, nickel, 2-methylphenol, 4-methylphenol, bis[2-ethylhexyl] phthalate, butyl benzene phthalate, and PCBs (EPA 2000). Non-aqueous phase liquid seeps were also found at the head of the Thea Foss Waterway. However, stormwater modeling predicted PAHs and phthalates would have the greatest contributions to waterway sediments after remediation. Thus, the City's monitoring and source control strategy has focused on these contaminants. PCBs, mercury and pesticides were also monitored as "legacy" contaminants whose sources were deemed largely controlled through regulatory bans or use restrictions.

Between August 2001 and August 2014, 565 source control actions were completed including construction projects, inspections, maintenance, controlling point sources to the storm system, managing underground storage tanks, site cleanup action or spill cleanup, regulatory fines/violations and public education (City of Tacoma 2015). Records of source control actions completed from 2001 through 2013 indicate that most were driven by the primary contaminants, PAHs and phthalates (City of Tacoma 2015). Additional source control actions conducted by the City under NPDES permit requirements have included

storm basin line cleaning, enhanced street sweeping, and pipe rehabilitation. The program element that has triggered PCB source control actions is their long-term stormwater monitoring program. Thus, this section will describe the approach used to monitor PCBs in stormwater and the source control investigations that followed. The City's 2014 Source Control Monitoring Report provides details for all recently completed source control actions (City of Tacoma 2015).

The City of Tacoma's long-term stormwater monitoring program was originally designed to annually[8] collect four baseflow and eight to ten storm event samples from one or more stations in seven stormwater outfall drainages[9]. These water samples are collected as flow-weighted composites using autosamplers. In addition, inline sediment traps[10] are deployed in six of the seven outfall drainages for one year (Figure 10). Suspended sediments are not collected in one of the seven stormwater outfall drainages due to tidal influence. After Water Year 2011, baseflow sampling was discontinued because the EPA and Ecology agreed that the prior ten years of data were adequate to characterize the baseflow quantity and quality in the basin (City of Tacoma 2015). PCBs in stormwater are only monitored using sediment traps, not by collection of water samples.

When the monitoring program began, stormwater and suspended sediment samples were analyzed for lead, mercury, zinc, PAHs, total PCBs as Aroclors, and phthalates. However, PCBs were not detected in water samples[11]. Given the lack of detections, the City stopped analyzing PCBs in water samples and continued with only suspended sediment sampling using sediment traps (City of Tacoma 2015, pers. comm.). All suspended sediment samples were and continue to be analyzed using the EPA's method (8270) for PCBs as Aroclors. The analyte list for water samples was expanded when the Ecology Phase I Municipal Stormwater NPDES permit was issued to the City because it required monitoring of specific parameters, not all of which were being monitored for purposes of the source control strategy (City of Tacoma 2015, pers. comm.).

The City of Tacoma collects samples at additional stations in each outfall basin for the purpose of evaluating and isolating sources. Up to 34 additional sediment trap stations are sampled each year for this purpose (City of Tacoma 2015). Stormwater sediment trap data are statistically analyzed for spatial trends by non-parametric Analysis of Variance (ANOVA) (by Kruskal-Wallis) and post-hoc testing (by Dunn Test). However, analyses have not demonstrated significant spatial differences for PCBs, in part because of intermittent detections (Figure 11). The City also qualitatively examines results over time for elevated concentrations that indicate ongoing sources. Where PCB concentrations are particularly

[8] Based on Water Year; starts in October and runs through September of the next year.
[9] There can be more than one stormwater subbasin per outfall drainage.
[10] Most outfalls are sampled with inline sediment traps which collect stormwater sediment, but some have sumps which collect baseflow and stormwater sediments and are sampled directly.
[11] The Aroclor method used by the City of Tacoma has higher detection limits than PCB congener methods; it is not uncommon to observe nondetects in water using this method because of the hydrophobic nature of PCBs.

elevated relative to other locations (there is no defined screening threshold), the City follows up with site-specific source control investigations. Two examples of source control investigations are summarized here. These investigations were conducted in two areas of the city based on elevated suspended sediment concentrations: one in an East Tacoma residential neighborhood and one in a commercial area of downtown Tacoma. These investigations involved iterative steps using sampling, research on possible sources, and sometimes business inspections, to progressively reduce the geographic area of interest and identify PCB sources. Additional details for these investigations are described below.

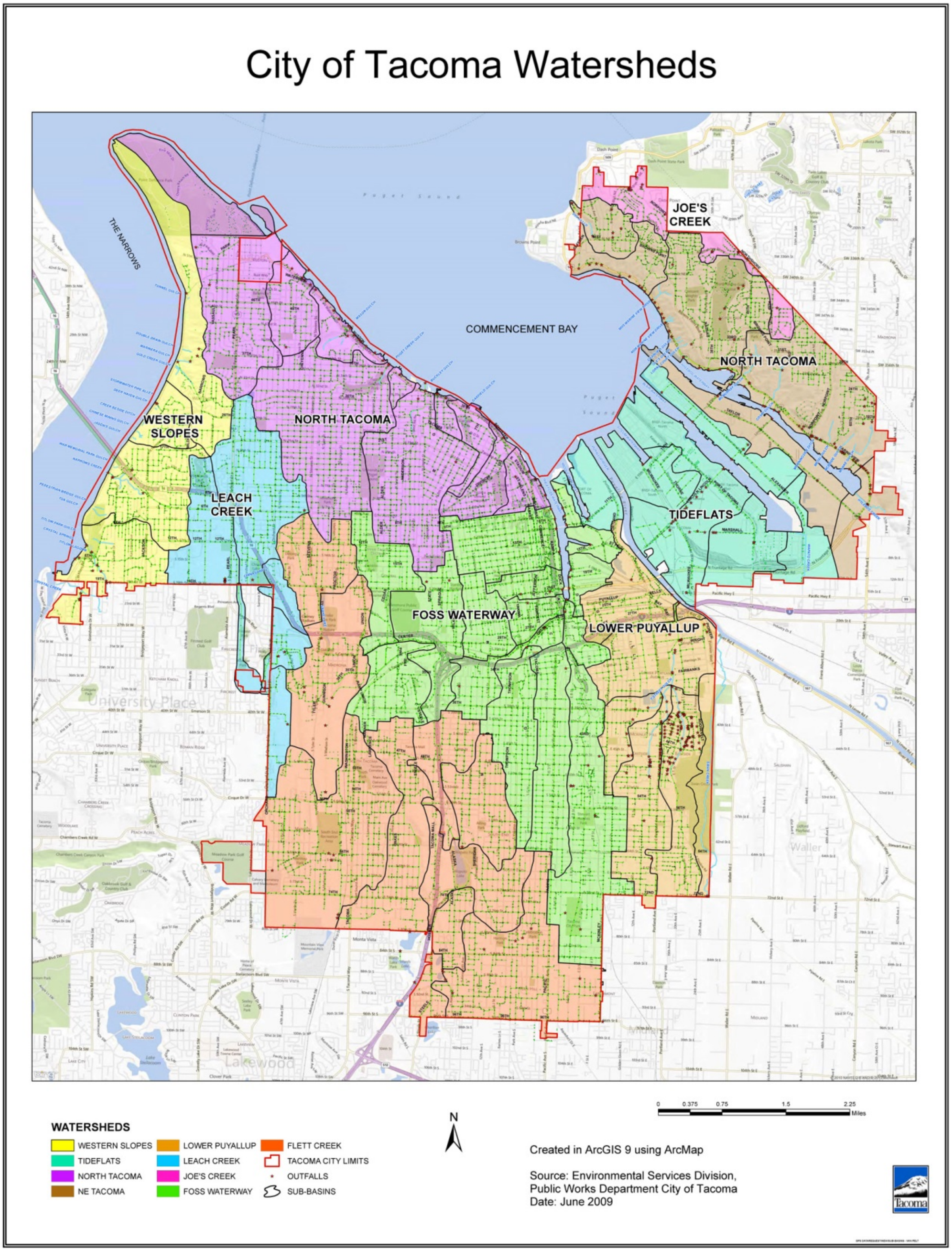

Figure 10. City of Tacoma outfall drainages (Figure from City of Tacoma 2012)

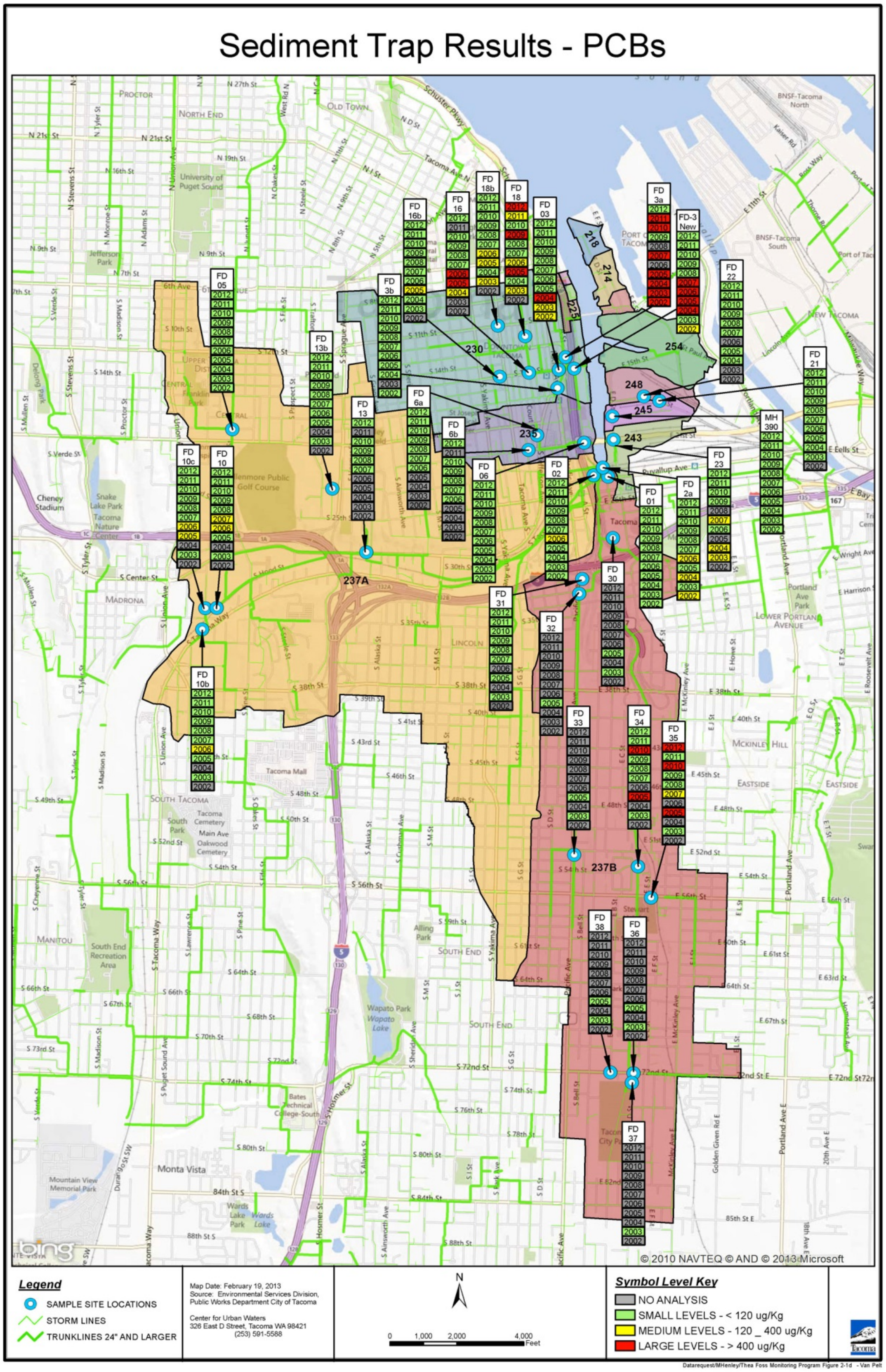

Figure 11. City of Tacoma sediment trap monitoring results (Figure from City of Tacoma 2013)

East Tacoma

The City of Tacoma observed intermittent PCB detections in sediment traps deployed in an upstream subbasin of the 237B basin south of downtown Tacoma. In 2010, PCB concentrations at this station were the highest measured since 2005 (>400 µg/Kg). In 2011, Tacoma performed a storm-line cleaning of several subbasins in the Foss Waterway, including the lines in the contaminated FD35 area. This cleaning was conducted as part of the NPDES source control activities, but also provided a tool to determine if PCBs at this station were originating from historical (from accumulation in the conveyance system) or ongoing sources. The following year, sediment trap PCB concentrations at this station were still elevated, indicating ongoing sources in the system. At this point, a source control investigation was initiated by the City of Tacoma in collaboration with the EPA and Ecology.

The first phase of the investigation involved collection of composite catch basin samples from upstream stormwater lines throughout the FD35 subbasin to identify areas with elevated PCB levels (City of Tacoma 2013a). This step narrowed the area of interest to one drainage segment in a residential neighborhood. The second phase involved collection of composite sediment samples from catch basins in the identified drainage segment. These results identified three streets with elevated PCB concentrations. During the third phase of the investigation, the City of Tacoma reviewed a variety of supplemental information to identify potential PCB sources in the identified area of interest. The following activities were conducted:

- Reviewed the drainage and topography of the contributing area;
- Looked for indications of PCB sources, such as transformers, peeling paint, and building materials;
- Reviewed City of Tacoma (www.govME.org) mapping for transformers, construction dates, commonality among builders, utilities, and aerial photos;
- Reviewed Sanborn maps[12], historic city directories, and library databases to determine past land use and historic businesses in the area;
- Searched Spills and Complaints Databases for historic spill information; and
- Contacted Tacoma Public Utilities regarding any historic transformer issues, including spills, in the project area.

This information, combined with previous sampling results, guided the design of further sampling.

Phase 3 included sample collection in catch basins, manholes, alleys, and undeveloped right-of-ways (City of Tacoma 2013a). A rapid laboratory analysis method[13] was used to

[12] Sanborn is an American publisher of fire insurance maps describing individual buildings, their uses and their proximity to other structures and utilities. At least portions of the Tacoma area were originally mapped as far back as 1885.

obtain screening level (1,000 μg/Kg) PCB concentrations in these samples. Also, potential items of interest identified by field crews were sampled opportunistically. Items included black tar, grout, and sediment from unusual side pipes[14] in catch basins, as well as asphalt, sediment from a newly identified catch basin, and solids from roadways. The results of this effort identified the stormwater conveyance system itself as a key PCB source(s) in contrast to sources outside the system (e.g., soils from roadways or private properties). However, the geographic locations with elevated PCB concentrations suggested a spatial discontinuity of sources. Research of historical construction projects in the area of interest discovered that all locations with elevated PCB concentrations were within a road improvement project area completed in 1975 (City of Tacoma 2013a). In the fourth and final phase of the investigation, the City sampled materials within the conveyance system focusing on features associated with this project.

During this last phase, additional catch basins, side pipe sediments, roadway cores, road sealant and associated soils were sampled (City of Tacoma 2013a). PCB concentrations measured in the side pipe sediments, road sealant and associated soils were elevated (See concentrations in Section 4.1.2.3; photos are in Appendix A) and confirmed suspicions that the road sealant used in the 1975 road improvement project was likely the primary PCB source and the side pipes were the key transport pathway to the stormwater system. Interviews with a former construction employee on the improvement project informed the City that the perforated side pipes were installed to assist with groundwater drainage. Because the side pipes likely drain only when the groundwater table is high, this explains the observed periodicity of the elevated PCBs in catch basins.

Downtown Tacoma

Elevated PCB[15] concentrations in sediment trap samples were observed over several years in downtown Tacoma (FD3A and FD18 – see Figure 11) and subsequently led to a source control investigation initiated in 2012[16] (City of Tacoma 2015). Similar to the East Tacoma investigation described above, composite sediment trap samples were collected across catch basins in different segments of the drainage system to narrow down areas of interest. Individual catch basin and product sampling was then conducted in segments with the highest PCB concentrations. Inspections were subsequently conducted at business properties draining to catch basins where elevated PCB levels had been detected. Caulking with elevated PCB levels was identified at two commercial properties: the Wells Fargo Tower and the Sound Physicians building (City of Tacoma 2015).

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[13] This was a micro-extraction method that had been previously compared to EPA 3534 extraction method to demonstrate quality control.

[14] During the source control investigation, staff had noted two-inch perforated pipes draining into catch basins.

[15] Elevated mercury concentrations were also present and also drove the source control investigation.

[16] Some previous actions were taken, such as a stormwater line cleaning in 2006, but did not substantially reduce PCBs measured in the monitored sediment traps.

Prior to completion of the business inspections, the City informed Ecology of the discovery of a potential PCB source at this and the East Tacoma neighborhood, through their NPDES General Condition G3 notification (City of Tacoma 2013b). The City conducted business inspections to identify possible sources and collected samples of materials inside and outside the buildings. At the Wells Fargo Tower and Sound Physicians building, the inspection did not identify any obvious visual evidence of spills, products or equipment that were suspected to be PCB sources either inside or outside the buildings. PCBs in samples of paint chips, soils, and roof tar were likewise low or nondetect. However, analysis of caulk samples collected from the exterior of the buildings and in sidewalks resulted in high PCB concentrations (up to 53,000,000 µg/Kg). The City of Tacoma concluded in the follow-up business inspection summary that building caulk materials were the source of PCBs to the stormwater system.

4.1.2.3 Summary of Findings

PCB concentrations detected in sediment traps generally decreased with distance from the identified sources. As shown in Figure 11[17], PCB concentrations in stormwater sediment traps monitored since 2002 ranged from nondetect to more than 400 µg/Kg, with a maximum near 2,000 µg/Kg (City of Tacoma 2015). Sediment trap samples from most outfall basins contained low PCB levels (<120 µg/Kg). Of the 33 sediment trap stations sampled since 2001, PCB concentrations were above 120 µg/Kg at 14 stations during at least one year. PCBs have been measured at elevated concentrations (>400 µg/Kg) at seven of the 33 stations (~21% of stations). Of these seven stations, only four had elevated concentrations for more than two years. Overall, even the highest PCB sediment trap concentrations were several times lower than the highest concentrations found in contaminated materials (e.g., building caulk, road sealant) from source control investigations (Table 4).

The highest PCB concentrations in catch basin sediments ranged from 16,000 µg/Kg in downtown Tacoma to 18,000 µg/Kg in East Tacoma (Table 4). Of the other materials analyzed, maximum PCB concentrations in surface soils (either ≤9,600 or 24,000 µg/Kg), asphalt and roadbed cores (≤1,600 µg/Kg), and paint chips (≤6,200 µg/Kg) were not considered high enough to be sources in either downtown or East Tacoma. The highest PCB concentrations in contaminated materials collected from the East Tacoma stormwater conveyance system were up to 260,000 µg/Kg (see Appendix A for concentration ranges by material type). PCB concentrations in caulk present in commercial downtown properties were orders of magnitude greater than in other sources; 17,000,000 µg/Kg in building caulk, and 38,000,000 µg/Kg in sidewalk caulk.

[17] The concentrations in this figure are color-coded as low, medium, and high categories with year of collection in descending order. These categories are set without regulatory basis, but rather in relation to the data distribution to allow for meaningful comparison between monitoring locations.

Table 4. Maximum PCB concentrations (µg/Kg) measured at Tacoma monitoring sites and from source control investigations.

Sample Type	East Tacoma	Downtown
Conveyance System Monitoring Sites		
Monitoring station sediment traps	5,200	3,400
Source Control Investigation Results		
Catch basin sediments	18,000	16,000
Catch basin sealant	96,000	NS
Catch basin tar	260,000	NS
Surface soils (including roof)	24,000	9,600
Asphalt and roadbed cores	1,600	NS
Side pipe sediments	91,000	NS
Building caulk	NS	17,000,000
Sidewalk/walkway caulk	NS	53,000,000
Paint chips	NS	6,200

Shaded cells were materials considered sources of PCBs to stormwater

NS – not sampled

Source control actions taken at contaminated properties are site-specific. In East Tacoma, the City has plans to delineate and remove contaminated materials from the roadway. This road construction project will be conducted in two phases between 2015 and 2016 (City of Tacoma 2015). In downtown Tacoma, the City is continuing to work with Ecology, the EPA and property management companies for Wells Fargo and Sound Physicians to address the discovered contaminated materials and prevent PCBs from entering the stormwater system. The City cleaned the system in early 2015 and will continue to monitor suspended sediments and catch basins in this outfall drainage. The City plans to continue cleaning the system to minimize PCB discharges to the Waterway.

The Foss Waterway sediment monitoring program data have shown no difference in PCB concentrations between 2007 and 2010. These data indicate that PCBs are equilibrating and do not pose a risk for recontamination of the waterway (City of Tacoma 2015). These results confirm initial model predictions that PCBs would not be a significant driver of recontamination to the Foss Waterway. Although many sources of PCBs and other contaminants were identified during the Commencement Bay investigation and cleanup, the number of easily located sources has dwindled. The City's stormwater monitoring and source control strategy for the drainage basin has opportunistically identified PCB sources since cleanup of the Waterway was completed. The program's recent successes (i.e., contaminated caulk sources in East Tacoma and downtown Tacoma) characterize the sporadic nature of where PCB sources can be located and how they are found.

4.1.3 Spokane River

Bioaccumulation of PCBs in Spokane River fish in reaches near the City of Spokane has driven development of source tracing programs in this region of Washington State. PCB source control in the Spokane area is inherently different than other regions discussed in this report due to some unique factors: the alternative process to a final TMDL[18] being used to meet water quality goals and the potentially large contribution of inadvertently produced PCBs. Source tracing efforts of the largest programs led by Spokane County, the City of Spokane, and Ecology's Urban Waters Project are highlighted below.

4.1.3.1 Background

The Spokane River flows from Lake Coeur d'Alene in North Idaho through the cities of Coeur d'Alene, Post Falls, Liberty Lake, Spokane Valley, and other urban areas within Spokane County before flowing through the City of Spokane to its confluence with the Columbia River. The Spokane River Basin drains over 6,000 square miles and is comprised of a mix of forest, agriculture, urban and range lands. The Lower Spokane, Little Spokane and Hangman Creek watersheds are mainly agricultural, while the urban areas are within Middle Spokane Watershed (City of Spokane and Spokane Valley) (Figure 12). The Spokane Valley Rathdrum Prairie (SVRP) Aquifer, lying below approximately 370 square miles of land, serves as the main drinking water source for the area (Boese et al. 2015). Due to its large size, the aquifer plays a role in stormwater treatment via dry well infiltration.

Several segments of the Spokane River were placed on Washington's 303d list in 1996 due to elevated PCB levels in fish. In response, Ecology conducted several PCB spatial characterization and loadings studies and issued the draft Spokane River water quality improvement plan (or TMDL) for PCBs in 2006 for public comment (Serdar et al. 2006). However, the TMDL was not finalized, in part, because more accurate data and consideration of changes in the water quality standards based on tribal fish consumption rates were needed. Additional data were collected by consultants (Parsons and Terragraphics 2007) and the information was incorporated into the Spokane River PCB Source Assessment Report, 2003-2007 released in 2011 (Ecology 2011b). This report was not a final TMDL, but focused on characterizing PCB loads from the major pathways – stormwater, municipal and industrial discharges, a tributary and upstream river waters from Idaho. Discharges from the City of Spokane were estimated to contribute the greatest total PCB load (44%). An additional 30% of the load was estimated to originate from upstream Idaho waters, while 20% was contributed by municipal and industrial sources and 6% from the Little Spokane River (Ecology 2011b). Although substantial uncertainties in flow volume estimates exist and these estimates need to be refined, stormwater was viewed as a significant contributor of PCBs to the Spokane River (Hobbs 2015).

[18] A plan of actions by responsible parties to establish waterbody-specific water quality goals to meet designated uses as defined by the CWA.

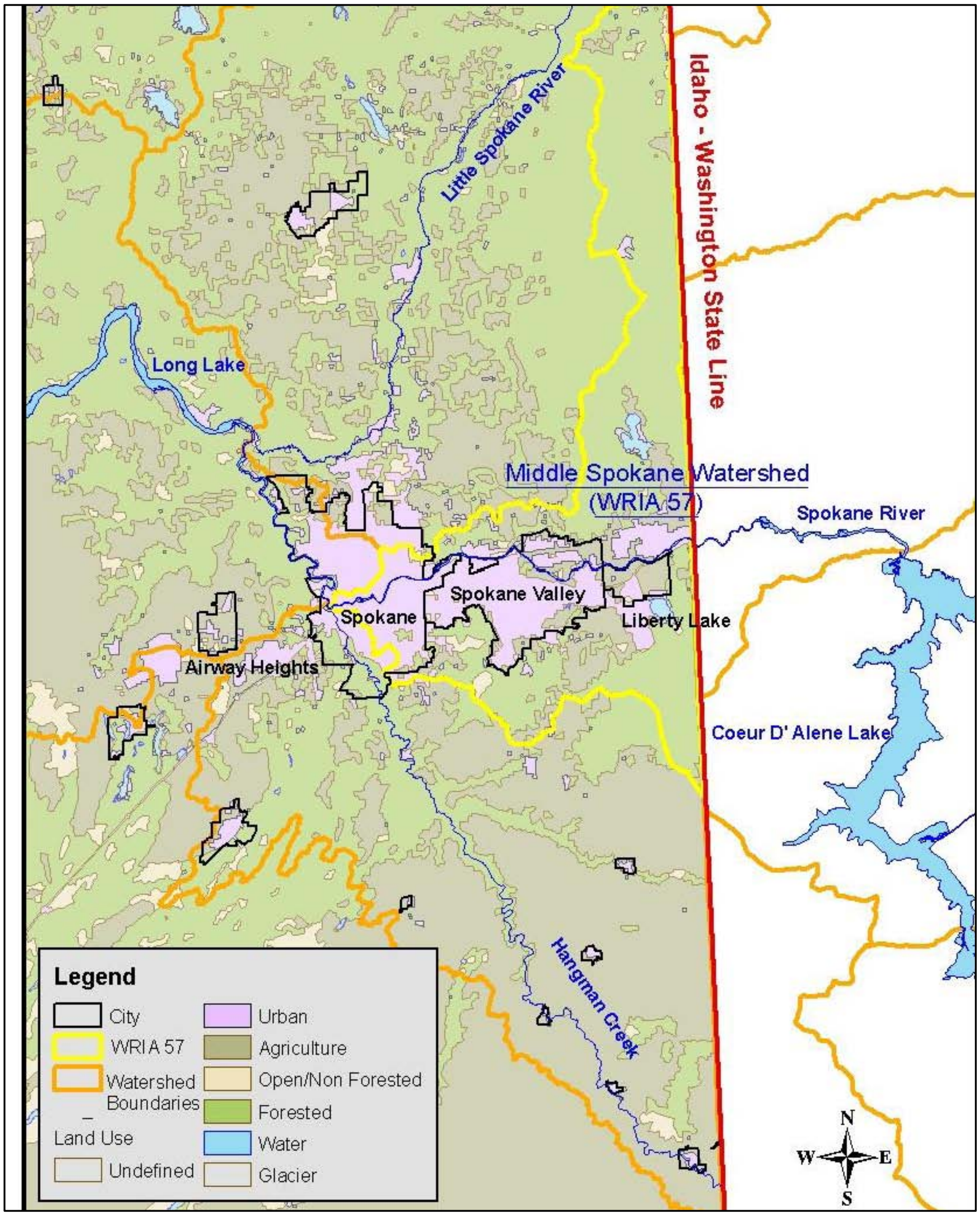

Figure 12. Spokane Basin land use. (WRIA is the Water Resource Information Area used by the state to identify watersheds) (Figure from Fernandez 2012a)

When the Spokane River PCB Source Assessment was released for public review, stakeholders, and local community members expressed interest in pursuing a direct-to-implementation approach. This approach was desirable because of local experience with lengthy TMDL processes in the past. The intent of this type of approach was to immediately identify and address PCB loadings to the Spokane River rather than spending years going through the time intensive TMDL process (Ecology 2012c). Ecology has adopted this approach, not finalizing a TMDL implementation plan, and instead working cooperatively with dischargers on source identification and reduction (Ecology website http://www.ecy.wa.gov/programs/wq/tmdl/spokaneriver/SpokPCBTMDL.html). As part

of this process, Ecology developed a Toxics Reduction Strategy to guide reduction and removal of PCBs and other pollutants in the Spokane River watershed (Ecology 2012d).

NPDES permits for Spokane dischargers do not include numeric discharge limits, but do require “measureable progress” for wastewater facilities and “reasonable progress” for stormwater dischargers in reducing PCB loadings to meet applicable state water quality standards. The wastewater NPDES permits also require participation in the Spokane River Regional Toxics Task Force (SRRTTF). The major dischargers, including the City and the County of Spokane, have developed source tracing programs under these permit drivers in collaboration with the SRRTTF. Created in 2012, the SRRTTF is comprised of NPDES dischargers, government agencies that regulate toxics (Ecology, Idaho Department of Environmental Quality[19], and EPA), Spokane and Coeur d’Alene tribes, and other interested industries, government agencies, environmental advocacies, and stakeholders (MOU 2015). The SRRTTF is charged with characterizing sources and identifying and implementing actions to make measurable progress toward meeting applicable water quality standards.

In addition to source tracing programs led by the City of Spokane and Spokane County, Ecology and the Spokane Regional Health District (under the Local Source Control program) also conduct PCB source tracing. These two agencies originally partnered under the Urban Waters Initiative. Passed by the state legislature in 2007, this initiative funded investigation and cleanup of three waterways in the state, one of which was the Spokane River. The Urban Waters Program provides $100,000 a year (two Ecology staff) to address PCBs and other contaminants in the Spokane River. The program funds public and business education programs, business inspections, and source tracing studies to assist in contaminant source reduction to the Spokane River. The Urban Waters Program team conducted business inspections and sampling studies to identify potential sources (Fernandez 2012b) and assisted in training City of Spokane staff in sampling methods (City of Spokane 2014). One of the more crucial components that made this effort successful was the level of effort put towards integrating knowledge and resources across local groups as well as across the state. This allowed them to manage a variety of concerns in a very complex bi-state community. Key elements included broad technical assistance from plan development to analytical interpretation regardless of agency or group, consistent technical education, set up for quick mobilization, utilization of the most effective regulation to collect data and conduct cleanup, and cross-region collaboration.

The Urban Waters Program team also collaborated with the City of Spokane to identify areas of potential concern for further source investigation. In addition to source tracing programs led by the City of Spokane and Spokane County, the Urban Waters source tracing program is described in the following sections.

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[19] Representatives of the State of Idaho are included in the SRRTTF because Spokane River waters listed by Washington State on the 303(d) list originate upstream in Idaho. However, Spokane River waters in Idaho do not violate the CWA and are not under a TMDL.

4.1.3.2 Source Tracing Approach

Agencies use various source tracing tools to locate PCB sources in the Spokane area including windshield surveys, sediment and/or water monitoring of stormwater basins and treatment plant influent/effluent, PCB fingerprinting, local business inspections, and testing of off-the-shelf products. The City and County of Spokane have integrated these tools into the management program activities required under their Phase II Municipal Stormwater and wastewater NPDES permits. This section describes the source tracing programs for the Urban Waters Initiative, City of Spokane, and Spokane County.

Urban Waters Program

The Urban Waters Program conducted the first source tracing studies for the Spokane River basin. Their work began in 2008 with a pilot study at Liberty Lake, a small lake near Spokane within a watershed that contains mostly urban residential land use (Fernandez 2012a). This project addressed multiple contaminants, including PCBs. Although there are no known industrial PCB sources nearby, the lake is on the 303d list for PCBs in fish (Fernandez 2012a). Ecology's Urban Waters Program selected this area to test sampling methods and business visit techniques before applying them in the more complex stormwater/wastewater systems of Spokane (Fernandez 2012a). Wastewater, stormwater and storm-drain sediments were sampled, mainly as grabs, and analyzed for PCB congeners by EPA Method 1668; business visits were also conducted. Ecology used the results of this pilot effort to refine the sampling and business visit methods for source tracing in the Spokane River, which was initiated in 2009 (Fernandez 2012b).

Ecology used the results of stormwater studies conducted during draft TMDL development (Parsons and Terragraphics 2007) to identify priority basins for source tracing: the Union, CSO 34, and Erie Basin's stormwater and CSO basins. Due to limited resources, they chose to immediately target in-pipe sampling to track sources upstream (Fernandez 2012b). Working in partnership with the Spokane Regional Health District (SRHD) under the Local Source Control Program, the Urban Waters Program used a combination of sampling and business visits to locate sources. SRHD conducted visits at small businesses that Ecology did not visit (Phillips 2015, pers. comm.).

The Program sampled wastewater for other contaminants, but for PCBs, they relied on the permit monitoring conducted by the City of Spokane. Stormwater and CSO sampling methods were limited to grab samples for water collected from manholes and storm-drain sediments (Fernandez 2012b). Grab samples were also collected from a limited number of street soils and drywells near potential sources. Between 2009 and 2011, the Program collected 57 samples (surface water, sediment) from a total of 11 stormwater and 3 CSO basins within the City of Spokane (Fernandez 2012b). These included four locations in Union Basin (1 at the River outfall), five locations in the CSO 34 and Erie Basins, and locations in ten other basins (Figure 13). Sediment and water samples were analyzed for PCB congeners by the low resolution EPA Method 8082 and a subset of water samples were analyzed for PCB congeners using the high-resolution method (EPA Method 1668).

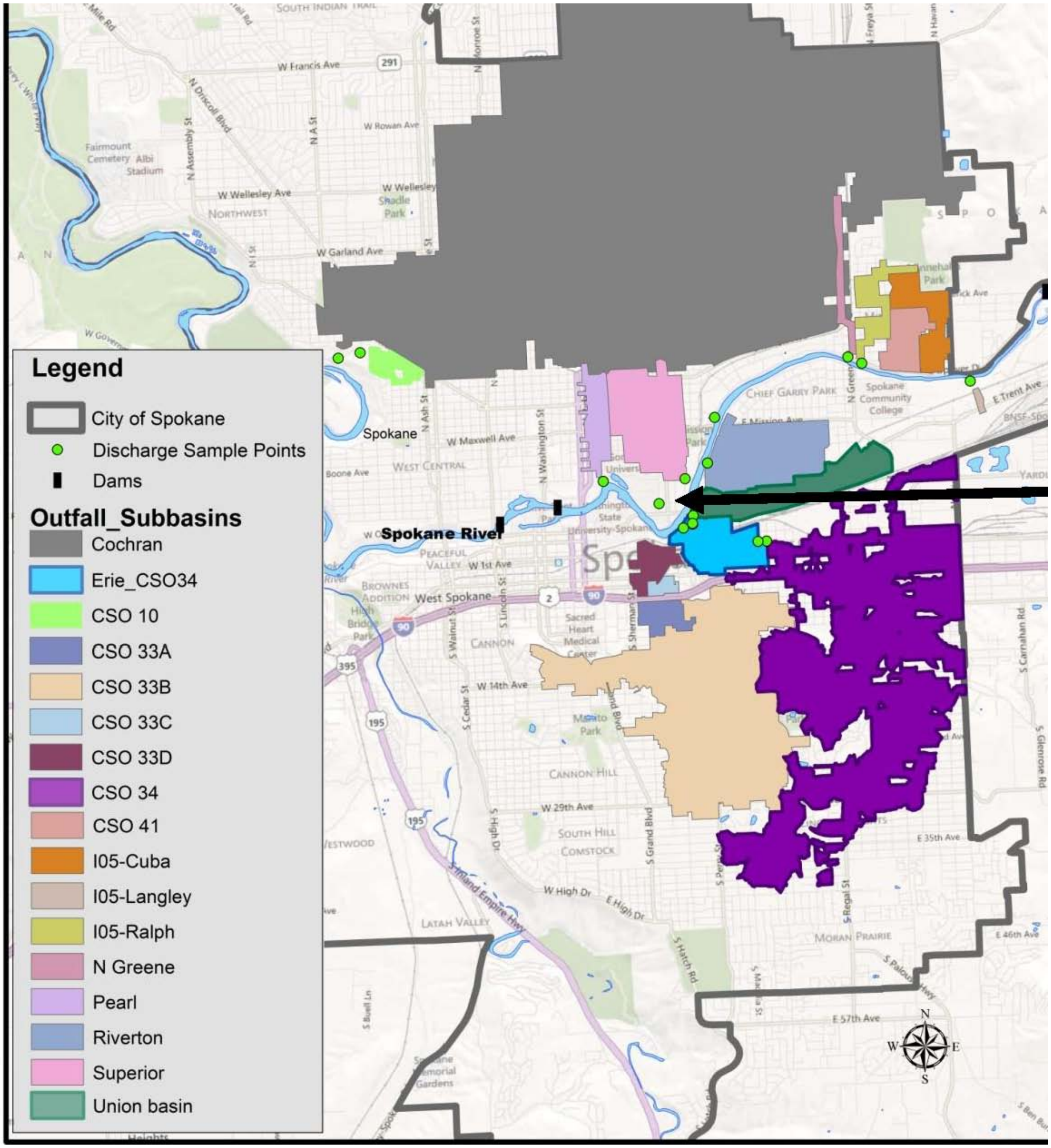

Figure 13. Urban Waters sampling locations 2009-2011 (Figure from Fernandez 2012b)

City of Spokane

The City of Spokane operates both a wastewater and stormwater sewer system servicing approximately 58.5 square miles. The wastewater conveyance includes both separated and combined systems. The wastewater and separated MS4 operate under different NPDES permits: The NPDES Waste Discharge Permit for the Riverside Park Water Reclamation Facility and the Eastern Washington Phase II Municipal Stormwater Permit for small MS4s.

The City of Spokane has developed an adaptive management plan to address PCB source control and load reduction. This plan addresses stormwater- and CSO-specific pathways for PCBs that enter the Spokane River and takes an adaptive approach by applying iterative steps of data collection, remediation actions and information analysis (City of Spokane 2014).

The City of Spokane's source tracing program began in 2010 (Phase I) with a focus on remedial maintenance[20], catch basin sediment sampling, and analysis of existing information (City of Spokane 2014). Priority areas of investigation were selected based on where the highest PCB concentrations had been detected during previous studies, as well as where land use practices were likely a contributing factor (City of Spokane 2012). Based on this analysis, the Union stormwater basin, a separated stormwater basin, was selected for analysis in 2010. In addition, to evaluate CSO discharges, a heavily industrialized portion of the CSO 34 basin was selected. Samples were collected from all catch basins (including drywells) in these two areas in 2010. Sediments from an average of ten catch basins within sub-areas were composited together totaling 41 samples (Figure 12). Samples were initially screened using Aroclor analysis (EPA Method 8082) to determine remedial maintenance needs. These samples were then analyzed again for 209 congeners by EPA Method 1668A for source tracing analysis purposes (City of Spokane 2012).

Following completion of the 2010 sampling and analysis, remedial maintenance was performed (City of Spokane 2012). Remedial maintenance consisted of pumping sediment out of each catch basin using vacuum trucks. The catch basins were then jet-cleaned to prevent any residual PCB contamination during future sampling events.

In 2011, the City of Spokane shifted their source tracing activities to an area upstream in the CSO 34 basin, where light industrial and other mixed land uses are found (City of Spokane 2013). Similar to 2010, sediments from an average of ten catch basins within sub-areas were composited together totaling 35 samples (Figure 14). In addition to these composite samples, individual samples were collected at 16 catch basins with the highest 2010 concentrations[21]. As in 2010, remedial maintenance was repeated after the 2011 sampling (City of Spokane 2012).

[20] Remedial maintenance refers to maintenance conducted for the purpose of removing chemical contamination from facilities and conveyance.

[21] Although 31 locations were identified for individual sampling, only 16 had enough accumulated catch basin sediment to allow sampling.

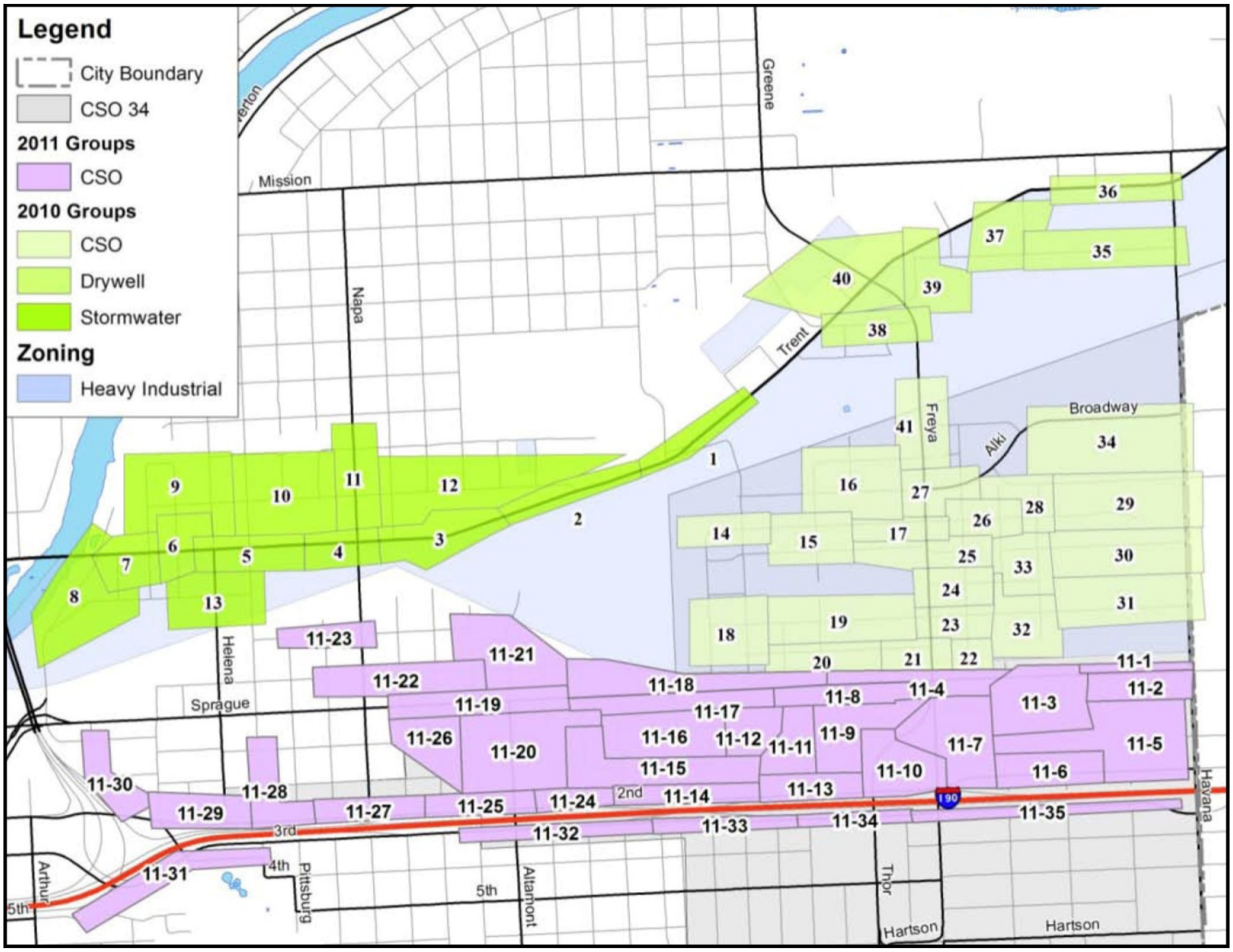

Figure 14. 2010 and 2011 sampling areas for catch basin sediment composites (Figure from City of Spokane 2012)

In 2012, resampling occurred at locations in the CSO 34 and Union basins where the highest PCB concentrations were detected in 2010. This effort was intended to determine if there were ongoing PCB sources (City of Spokane 2014). Because remedial maintenance had previously been performed, PCB concentrations were expected to be lower unless there were ongoing PCB sources to the system. Sediment samples were collected using the same methods as in 2010, matching composite and individual sampling correspondingly (City of Spokane 2014). Remedial maintenance was conducted after sampling as in previous years. Where 2010 data were available, the results showed decreases in PCB concentrations on the order of 16–59% depending on location, indicating remedial maintenance had lowered PCB concentrations, but active sources remained and were diffuse.

In addition to sediment sampling in the stormwater and CSO conveyance system, water sampling was initiated in 2012 in coordination with the Urban Waters Program (City of Spokane 2013). Automated composite water samplers were installed at two locations in the Union Basin where PCB concentrations in catch basin sediments were some of the highest. One site was at the Union Basin outfall, where the Urban Waters Program had also

sampled to maximize data comparability, and a second site was located upstream near the known PCB Cleanup Site called the City Parcel site, a former transformer repair and recycling facility. Remedial actions were previously completed at the City Parcel site; however, relatively high PCB concentrations (3,285 µg/Kg) were detected in the stormwater catch basins in the vicinity of this site in 2010 (City of Spokane 2013)[22]. The basin immediately downstream of the City Parcel site is a drywell with an overflow structure that connects to the storm sewer system. As a temporary remedial measure, the City inserted a plug into the overflow pipe, effectively disconnecting the City Parcel site's stormwater from the City system. Future sampling efforts will confirm if contamination from the City Parcel Site has been effectively prevented from entering the storm sewer system. Stormwater sampling has also been conducted in two additional stormwater basins and one CSO basin to provide a general system characterization (City of Spokane 2013). Stormwater basins and sample locations are shown in Figure 15.

In 2010, the City of Spokane also performed visual reconnaissance and research in the Union and heavily industrial section of CSO 34 basins to identify potential PCB sources to stormwater (City of Spokane 2012). Stormwater inspectors conducted "windshield surveys" (i.e., visual driving survey) to identify potential sources of PCBs to stormwater. Information gathered during evaluations included site pictures, business type, presence of paved or unpaved driving surfaces, stormwater flow direction, downstream inlets, and the potential for sediment transport onto the City ROW. Inspectors could not identify properties with obvious major PCB contributions to stormwater. The City concluded that PCB contributions were likely to originate from many smaller sources and widespread, low-level historical sources. The City researched and mapped known contaminated properties using information from Ecology's Integrated Site Information System (ISIS) and Facility/Site Database.

Details regarding all recently completed source control actions can be found in the City of Spokane's 2014 Annual Report and Adaptive Management Plan (City of Spokane 2014).

Product Testing

In 2010, the City of Spokane inspected the storm sewer system in the Union Basin for the presence of PCB-containing materials, along with legacy contamination in the pipes (City of Spokane 2012). The inspection focused on the storm sewer system downgradient of the City Parcel site. After cleaning was complete, a visual inspection was conducted which found no visual presence of sediment or products that could contain PCBs, such as crack sealer. Crack sealer is a commonly used product containing PCBs, and has also been used in other Washington cities, such as Tacoma. However, further sampling at this site, even after cleaning, has detected PCBs in both sediment and stormwater.

[22] Ecology also measured residual PCB contamination in subsurface soils at the City Parcel Site. In 2015, the agency proposed removing the contaminated soils (Ecology 2015b).

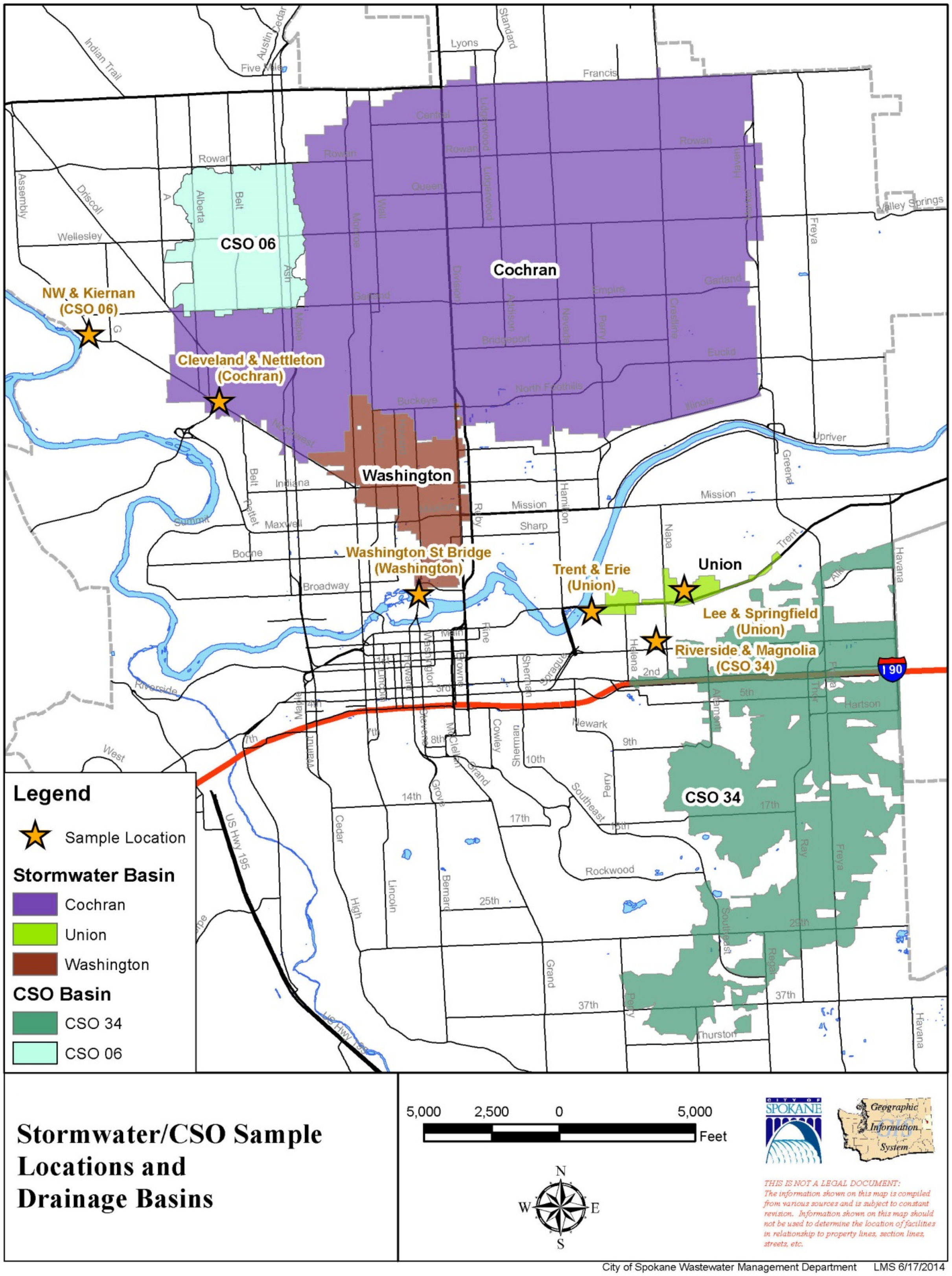

Figure 15. Stormwater sampling locations (Figure from City of Spokane 2013)

To help identify other potential PCB sources in stormwater, off-the-shelf products that could contribute PCBs to stormwater (e.g., motor oil, transmission fluid, and shredded tire scraps) were analyzed for PCBs in 2011. PCB concentrations in these materials ranged from 8.8 to 116 μg/Kg with synthetic motor oil containing the highest levels. In 2014, the City of Spokane received an Ecology grant to analyze other products that may serve as PCB sources to stormwater (City of Spokane 2015). In addition, the grant provided support for homologue pattern analysis to better discern the potential PCB sources. Over 40 different products were collected and analyzed for PCB congeners in 2014 (EPA Method 1668A) (City of Spokane 2015). Concentrations by product can be found in Appendix A. Most were products that might be used by municipalities, such as oils or road paints, but personal care products were also tested as potential PCB sources to the wastewater system. The results indicated that detectable levels of PCBs are found in many of the products tested, including personal care products, but most are present at relatively low concentrations (<1 μg/Kg). One brand of hydroseed (used for seeding new soils) was measured with 2,509 μg/Kg PCBs, the highest in any product tested (see Appendix A for a summary of results). However, follow-up testing of hydroseed, including this brand, resulted in concentrations below 5 μg/Kg (SRRTTF 2015). The City of Spokane plans to use the congener composition of the tested products to guide future source tracing efforts.

Spokane County

The largest wastewater treatment plant owned and operated by Spokane County is the Spokane County Regional Water Reclamation Facility (SCRWRF). This facility treats wastewater from approximately 37,000 acres in portions of unincorporated Spokane County, the cities of Spokane Valley and Millwood, as well as portions of Liberty Lake (Brown and Caldwell 2015). Two influent trunk lines, the North Valley Interceptor (NVI) and the Spokane Valley Interceptor (SVI), convey wastewater to the Facility via two pump stations. Typically, all of the wastewater in the NVI Pump Station (NVIPS) and SVI Pump Station (SVIPS) is pumped to the SCRWRF, but occasionally a small portion is conveyed to the City of Spokane's Riverside Park Water Reclamation Facility (Brown and Caldwell 2015).

Spokane County monitors SCRWRF influent and effluent waters for PCBs as required by their NPDES permit on a bimonthly and quarterly basis, respectively. For all influent and effluent sampling, automated composite samplers are used to collect time-weighted whole (unfiltered) water samples at hourly intervals for 24 hours (Spokane County 2015). Monitoring data indicates the treatment process removes 99% of the PCBs[23] from the influent (Brown and Caldwell 2015). In 2013, the County began a "track-down" (source tracing) sampling program within the wastewater conveyance system. Their source tracing model (Figure 16) involves sampling progressively upstream to narrow down geographic

[23] It is not specified in the reference if this reduction is based on concentration or load.

areas with elevated PCBs and use of fingerprinting[24] techniques to attempt to locate sources.

During the first year of track-down sampling, three manhole sampling locations were selected at the outlets of the five service area drainage basins: one location in the NVI line and two locations in the SVI line (Brown and Caldwell 2014) (Figure 17). Four samples were collected from the three locations. Due to traffic congestion and safety issues, the 24-hour composite sampling method was not used and instead grab samples were collected over a 40 minute period using a peristaltic pump and composited for laboratory analysis. All samples were analyzed for 209 PCB congeners (EPA Method 1668). Based on a comparison of the NVI and SVI influent concentrations to the track-down samples upstream, the results suggested a possible PCB source between the NVIPS and the outlet manhole station upstream. Of the three track-down locations, PCB concentrations at a manhole in the Dishman-Mica Interceptor (DMI) basin, a primarily residential area, were consistently higher than at the other two locations. Fingerprinting analysis of the data was conducted using homologues and Positive Matrix Factorization[25] (PMF) (Paatero and Tapper 1994) which concluded that both legacy and inadvertent production source types were contributing to the influent (Spokane County 2015).

[24] PCB fingerprinting refers to a method of identifying types of sources by comparing PCB congener or homologue patterns in samples to those of Aroclors or congeners in products with inadvertently produced PCBs.

[25] PMF is an advanced source apportionment tool that has been used to identify PCB sources in water, sediment, and air (Ding et al., 2013; Bzdusek et al., 2006a; Bzdusek et al., 2006b; Du et al., 2007; Du et al., 2008; Rodenburg et al., 2011; Qiu et al., 2012)

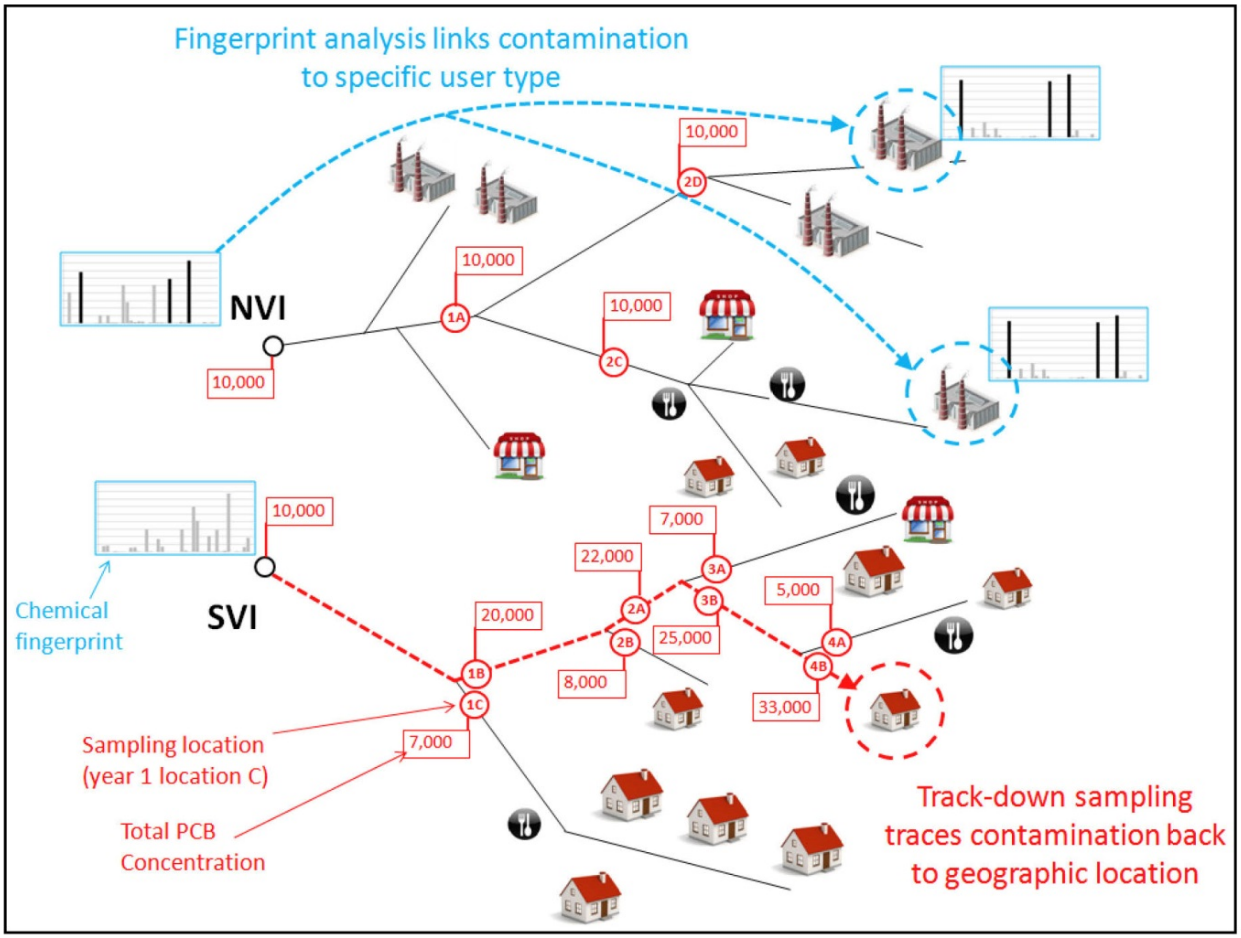

Figure 16. Source tracing approach model for Spokane County (Figure from Brown and Caldwell 2014)

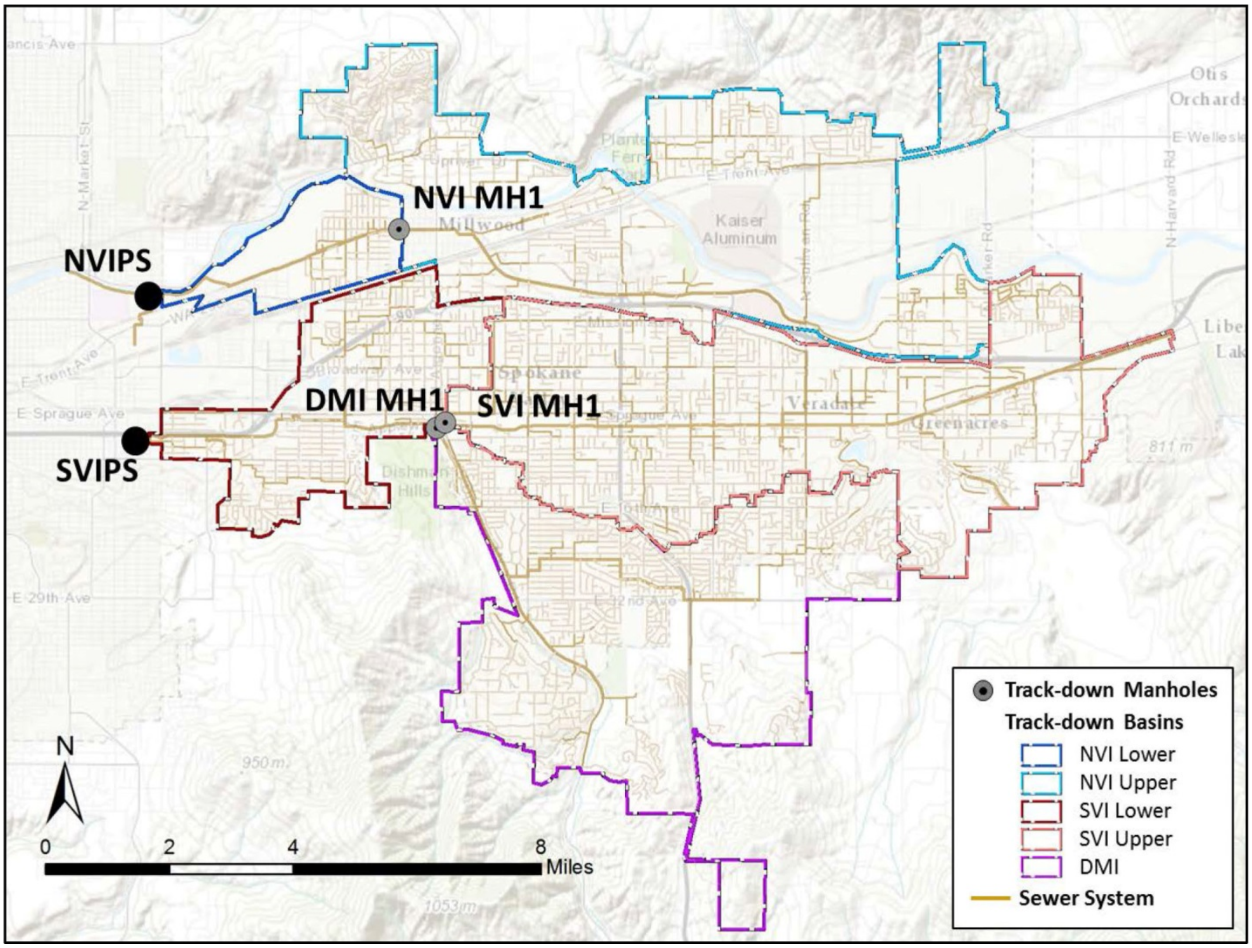

Figure 17. Spokane County 2013 sampling locations (Figure from Brown and Caldwell 2014)

In 2014, the County sampled at seven locations within the DMI basin (Brown and Caldwell 2015). Two were located at main branches in the system (coded MHA and MHB) and an additional five were selected to allow correlational analysis between sewage concentration and age of building development (Figure 18). These data were intended to inform whether older buildings with contaminated materials could be contributing legacy sources to the influent. Two samples were collected at each station using the sampling methods followed in 2013 for track-down samples.

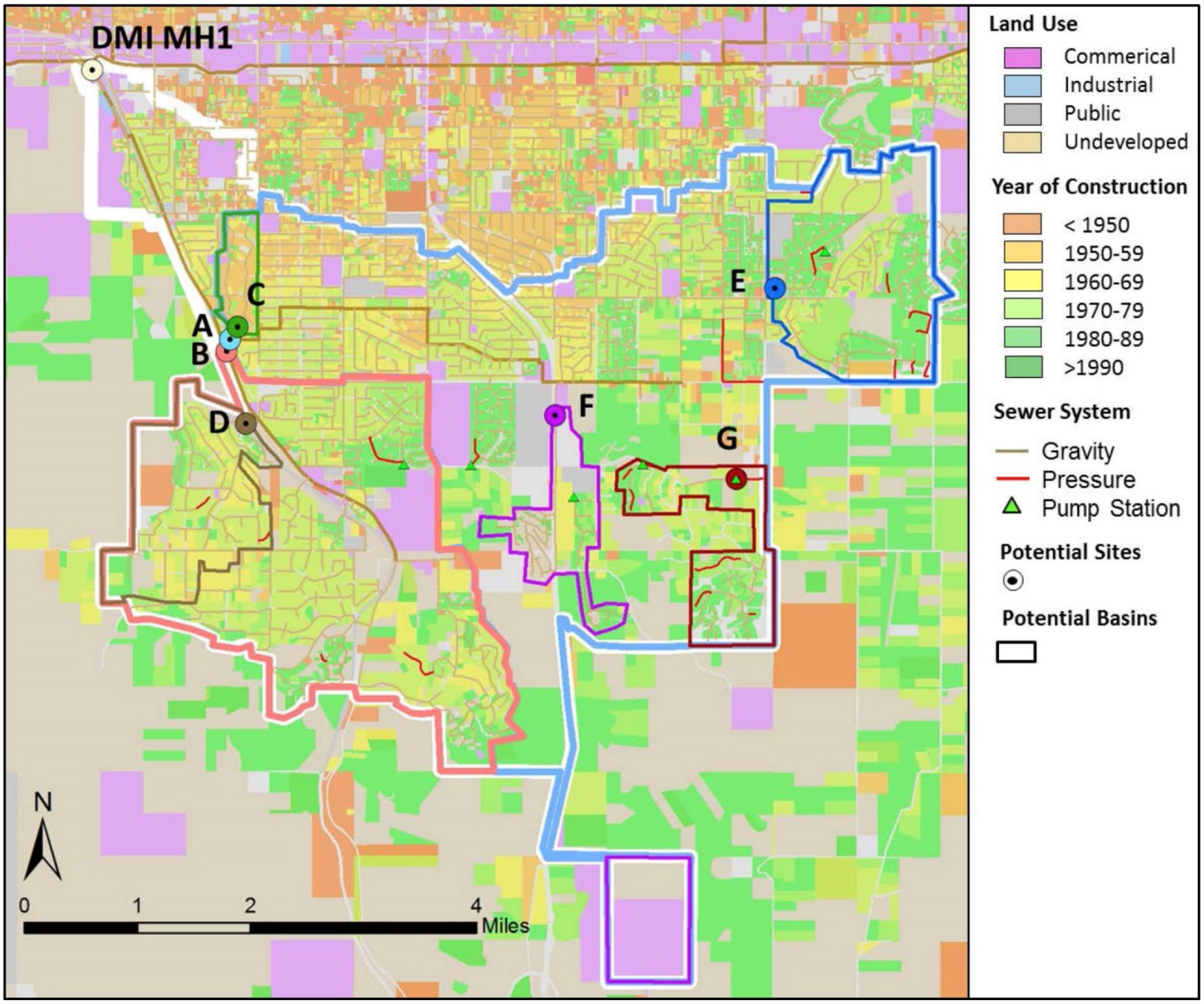

Figure 18. 2014 track-down sampling locations in five tributary subbasins (Figure from Brown and Caldwell 2014). A-D are in basin MHA; E-G are in basin MHB.

The small number of samples collected in 2014 (n=7) limited the ability to draw correlations or establish significant differences between locations (Brown and Caldwell 2015). However, lower PCB concentrations were measured in the basin with the higher proportion of new development. Also, PCB concentrations in one of the two basins were consistently higher than the other. None of the PCB concentrations measured at track-down locations were high enough to independently account for the elevated average concentration noted at the DMI manhole in 2013. Alternatively, the high concentration was surmised to more likely result from moderately elevated PCB concentrations from multiple sources. PCB concentrations found by the County's annual sampling events are presented in the following section (Section 4.1.3.3). PMF analysis of all samples indicated that legacy (i.e., Aroclor) sources were the primary contributors of PCBs, but contributions from current (inadvertently produced) sources were also present as indicated by the high PCB 11 congener component (produced in inks and pigments).

In 2015, the County shifted their focus to the NVI basin because this basin has a heavy industrial component (Brown and Caldwell 2015). Sampling locations were focused on heavy industrial and light industrial zones. Six locations were identified in these areas to characterize two subbasins – a lower and upper subbasin. The details and results of the 2015 sampling will be available in April 2016.

4.1.3.3 Summary of Findings

This section summarizes the PCB concentrations measured in wastewater, stormwater, and catch basin sediments by Spokane County, City of Spokane, and the Urban Waters Program.

Urban Waters Program

During the 2009 to 2011 sampling period, PCB concentrations in CSO waters of the Union and CSO 34 basins ranged from 7,000 to 39,000 pg/L (Table 5) (Fernandez 2012b). PCB concentrations in stormwater range from 8,000 to 745,000 pg/L and from 5.8 to 980 µg/Kg in catch basin sediments.

Table 5. PCB concentrations in CSO and stormwater systems from Urban Waters Program – Union and CSO 34 Basins

Location	CSO (pg/L)	Stormwater (pg/L)	Sediment (µg/Kg)
Union Basin outfall	NA	55,000 – 460,000 (n=7)	NS
Upstream Union lines	NA	14,000 – 745,000 (n=11)	5.8 – 980 (n=3)
CSO 34 weir	7,000 – 39,000 (n=5)	NS	NS
Erie Basin outfall	24,000 (n=1)	8,000 – 63,000 (n=3)	NS

NA = not applicable
NS = not sampled

In partnership with the City of Spokane, the Urban Water Program has identified two PCB sources to the Spokane River from their work through 2011 (Fernandez 2012b). One of these was the City Parcel, identified by Ecology soil samples collected from the property. Through business visits, the SRHD identified eight properties with potential, significant or unresolved contamination problems and referred them to Ecology for compliance inspection and follow-up. Some of these were due to potential contamination of stormwater by PCBs (Fernandez 2012b). Overall, SRHD and Ecology concluded that the business visits did not disclose identifiable point sources as anticipated. However, these visits did ensure proper management of hazardous materials and waste, thereby reducing the potential for non-point PCB sources (Fernandez 2012b; Phillips 2015, pers. comm.).

City of Spokane

PCB concentrations measured in storm system sediments between 2010 and 2012 varied greatly by location. The highest concentrations were detected in the Union and CSO 34 basins (Table 6). Concentrations in composite samples ranged from 25 to 1,709 µg/Kg (City of Spokane 2014). Individual grab samples from catch basins and dry wells contained PCB

concentrations ranging from 5.6 to 3,285 µg/Kg; the highest of these was at the City Parcel site where Spokane Transformer was historically located.

Table 6. PCB concentration ranges (µg/Kg) for individual and composite sediment samples from Union and CSO 34 Basins (2010-2012).

Location	Composite	Individual
City Parcel	NA	18 - 3,285
Union Basin	48 - 1,709	5.6 - 3,285
CSO 34 Basin	25 - 1,595	103 - 121

PCB concentrations in composite stormwater samples collected by the City of Spokane ranged from 695 to 136,000 pg/L (Table 7) (City of Spokane 2014). Concentrations in grab samples collected by Ecology at the Union Basin outfall were almost 10 times higher at their maximum, potentially reflecting the beneficial effects of remedial maintenance conducted by the City of Spokane. The highest individual and average stormwater PCB concentrations were measured in the Union basin.

Table 7. PCB concentrations (pg/L) in stormwater samples collected by Ecology and City of Spokane.

Sample Location	Date Range	Sample Size	Sample Type	Min	Max	Mean
Urban Waters (Ecology)						
Union Basin river outfall[a]	2009 -2011	6	Grab	53,300	460,000	160,516
City of Spokane						
Union Basin river outfall [b]	2012 -2013	8	Composite	13,563	48,438	34,383
Union Basin City Parcel Outfall[b]	2012 -2013	6	Composite	35,141	136,098	50,857
Other stormwater basins	2012 -2014	27	Composite	695	16,288	NA
CSO 34	2013	5	Composite	5,742	23,311	13,410
Other CSO basin	2013 -2014	4	Composite	8,460	15,862	11,409

[a]Union Basin pipe cleaning and City Parcel plug installed June 2010; remedial maintenance conducted July-Aug 2010.

[b]Union Basin remedial maintenance conducted 10/29/12 to 11/5/12

The redirection of contaminated City Parcel runoff from the stormwater system to the aquifer was intended to be a temporary mitigation measure. The City is currently designing a system of stormwater BMPs to treat stormwater throughout Union Basin (City of Spokane 2014). When this is completed, the City will disconnect the Union Basin outfall to eliminate this discharge to the Spokane River.

Also, the City of Spokane is planning to conduct a membrane filter pilot study for work needed to meet the dissolved oxygen TMDL[26] for phosphorus discharge by the end of 2020 (City of Spokane 2015, pers. comm.). There may be coincidental removal of PCBs from stormwater and CSOs similar to that measured by the County.

Spokane County

Influent wastewater concentrations over the 2012 to 2014 monitoring periods ranged from approximately 8,300 to 67,600 pg/L in the NVIPS, and 8,000 to 18,900 pg/L in the SVIPS (Table 8) (Brown and Caldwell 2015). Effluent concentrations ranged from 6 to 62 pg/L.

Table 8. Spokane County 2012-2014 influent and effluent PCB concentrations (pg/L).

Location	# of Samples	Average	Standard Deviation	Minimum	Maximum
NVIPS (influent)	14	17,580	14,960	8,370	67,630
SVIPS (influent)	14	13,240	3,480	8,060	18,920
Effluent	9	30	20	6	62

PCB concentrations in wastewater at the three track-down stations sampled in 2013 ranged from 1,590 to 18,100 pg/L with the highest average concentration detected at the DMI MH1 (Table 9) (Brown and Caldwell 2014). Concentrations in samples collected within the DMI basin ranged from 590 to 34,400 pg/L in 2014 (Table 10) (Brown and Caldwell 2014).

Table 9. Spokane County 2013 track-down sample PCB concentrations (pg/L).

	# of Samples	Average	Standard Deviation	Minimum	Maximum
NVI MH1	4	12,630	3,630	9,220	17,400
SVI MH1	4	15,430	1,590	14,000	17,700
DMI MH1	4	20,380	1,700	18,100	21,900

Table 10. Spokane County 2014 track-down sample PCB concentrations in the DMI basin (pg/L).

Location	Sample 1	Sample 2	Average
DMI MHA	33,000	19,700	26,300
DMI MHB	14,000	12,600	13,300
DMI MHC	8,120	20,800	14,500

[26] There is a dissolved oxygen TMDL for the Spokane River.

Location	Sample 1	Sample 2	Average
DMI MHD	53,800	14,900	34,400
DMI MHE	8,160	11,100	9,600
DMI MHF	5,340	590	2,970
DMI MHG	3,640	28,600	16,100

Homologue analysis of the influent and effluent samples reflected solids removal through the wastewater treatment process (Figure 19) (Brown and Caldwell 2015). Heavier chlorinated homologues (Penta-, Hexa-, and Heptachlorobiphenyls), which are less soluble and prefer adsorption to particles, were more prominent in the influent than the effluent. The lighter chlorinated homologues (Dichloro-, Tri-, and Tetrachlorobiphenyls) are more soluble and, thus, less efficiently removed by the solids removal in the treatment process.

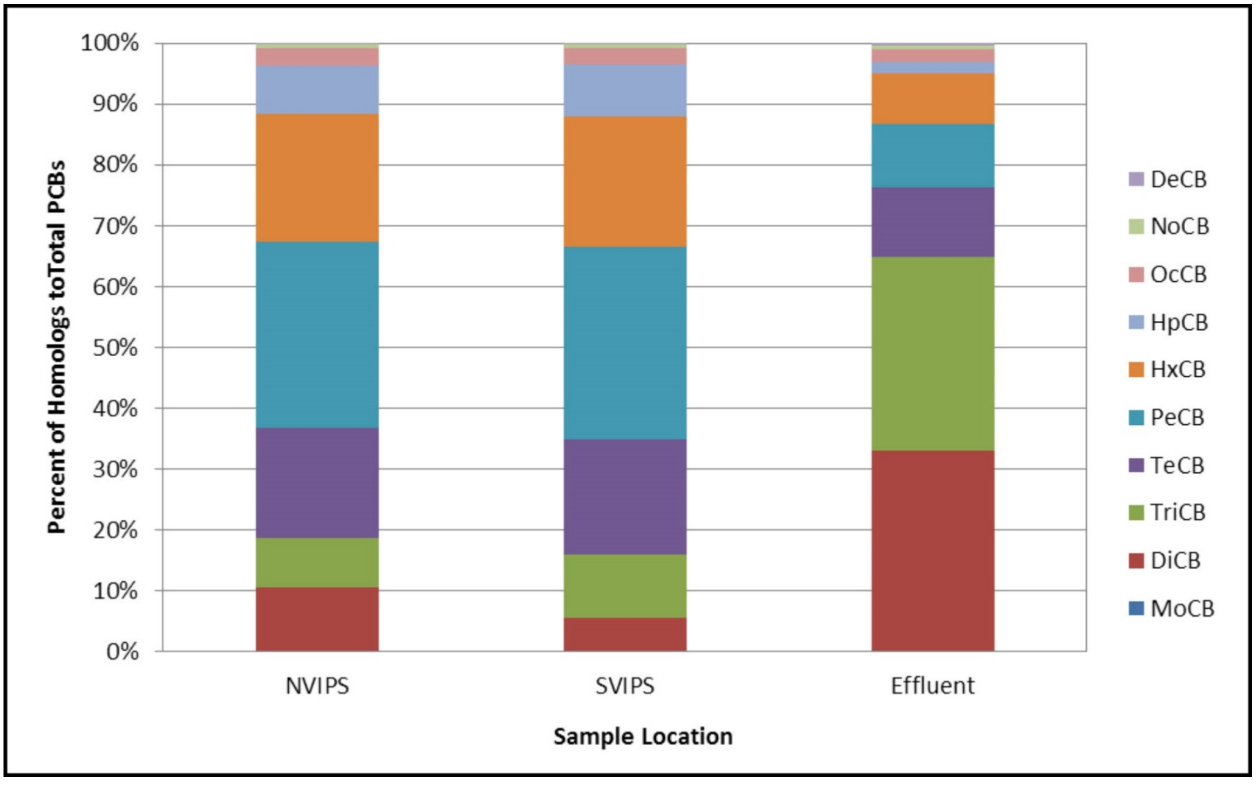

Figure 19. Homologue pattern in influent (NVIPS and SVIPS) compared to effluent samples. (Figure from Brown and Caldwell 2015)

4.1.4 City of Portland

PCB source tracing in the Lower Willamette River area of Portland was initiated by the listing of Portland Harbor as a Superfund Site. Although in the Pacific Northwest region, some of the state laws, rules, and collaborative agreements the City of Portland has formed are unique to Portland and Oregon. The general approach the City has used and some specific examples of their source tracing efforts are presented below.

4.1.4.1 Background

The investigation of widespread in-river sediment contamination in Portland Harbor and the lower Willamette River was initiated in 1997 by the Oregon Department of Environmental Quality (ODEQ) and the EPA. Data from this investigation led to the listing of Portland Harbor Superfund Site in 2000. Similar to the LDW Superfund Site discussed above in Section 4.1.1, the Portland Harbor site includes ten miles of river with decades of historic contamination from PCBs, PAHs, 1,1,1-trichloro2,2-di(4-chlorophenyl)ethane (DDT), and metals. Note that PCBs are only a contaminant of concern at a portion of sites. The predominant land use/zoning classifications within the site are parks and open space (58% of total drainage area) and industrial (31% of total drainage – including light and heavy industrial). Combined, the remaining land use categories comprise approximately 11% of the site. Approximately 51% of the basin drains through 36 city outfalls; the remaining 49% of the area drains through non-city outfalls (City of Portland 2013).

Portland's source control program is structured through a 2003 intergovernmental agreement between the City of Portland and ODEQ (DEQ 2003). The intent of this agreement was to foster a collaborative relationship and to recognize, in many cases, that source control would need to be implemented by parties other than the City of Portland. There is mutual recognition that the City of Portland's stormwater system outfalls can be a pathway for contamination from identifiable upland sources to reach the river and its sediments.

4.1.4.2 Source Tracing Approach

The primary purpose of the City of Portland's source tracing program is to identify significant contaminant sources to the municipal storm system. High priority sites were addressed by ODEQ's environmental cleanup program and lower priority sites were addressed by other city or ODEQ water quality programs. ODEQ's cleanup program assumes responsibility for investigating and implementing source control at the high priority sites to reduce contaminant loading to the river. This is articulated in the EPA/ODEQ Portland Harbor Joint Source Control Strategy (ODEQ and EPA 2005). To further illustrate the collaborative relationship between the City and ODEQ, the City of Portland provided technical input on the ODEQ guidance for evaluating the stormwater pathway at upland sites. Additionally, the City administers the ODEQ industrial stormwater permits and city permit managers have significant knowledge of activities and drainage at permitted and inspected sites in the Harbor. This information has been invaluable in both developing source tracing efforts and during ODEQ cleanup program investigations at specific properties.

The source tracing program began in 2000 with a historical data review and detailed basin delineations. These paper investigations included information on:

- Drainage basin and conveyance system maps
- Current land uses and zoning maps
- Sediment concentrations in the vicinity of the outfalls

- Databases of state and federal cleanup programs, including
  - The EPA's toxic release inventory and hazardous waste generator list
  - State fire marshal records of hazardous waste storage, usage, and spills
- City records of specific properties in the basin, including
  - Industrial and commercial properties in the basin, types of permits, and whether site activities had exposure to stormwater
  - Industrial stormwater permits and sampling results
- Polk directory information on historical businesses in the basin
- State and federal cleanup decisions and actions.

The program was initiated by prioritizing investigations on stormwater basins with the highest likelihood of including significant sources of PCBs or other contaminants of concern to river sediments. The City of Portland found that existing water quality programs were not necessarily designed to identify sites with sources related to legacy operations. The City's mapping, basin delineations, and industrial history has been instrumental in identifying potential pathways to these stormwater outfalls including:

- Surface runoff
- Non-stormwater discharges to the stormwater system
- Wastewater
- Illicit connections
- Contaminated groundwater infiltration (for COCs other than PCBs)

With the land use, drainage and historical information compiled and mapped, targeted areas and drainage pipes for source tracing were identified for sampling by inline or catch basin solids (City of Portland 2013). Over the course of this effort, the City used a variety of inline solids sampling techniques (catch basin, manhole and in-pipe grab, sediment trap), including a unique inline sediment sampling trap developed and patented by the City of Portland (Patent No. US8857280 B2).

As an initial screening of inline solids data, the City of Portland uses a rough screening threshold of 100 µg/Kg total PCBs as Aroclors (City of Portland 2015, pers. comm.). Typically, when concentrations in the municipal system were detected at or above this level, significantly higher concentrations were detected at the associated upland property. For instance, total PCB concentrations in downstream inline solids in Basin 19 ranged from 214 to 231 µg/Kg, while inline solids concentrations on a nearby contributing property were as high as 2,360 µg/Kg (see Basin 19 example below for further discussion).

The City of Portland completed source tracing activities in the municipal stormwater conveyance systems in Portland Harbor by 2013. The usual first step in the City's source tracing approach was to prioritize outfalls that had the highest river sediment PCB concentrations. The City would then conduct sampling (e.g., stormwater solids) at a location that represented the entire drainage to a given outfall (i.e., outfall basin) or at key

branches within the basin. The City would subsequently evaluate the results and then continue to work up the system as needed, by adding inline solids and/or stormwater sampling to refine their understanding of where the contributing source was located. Once the City believed it identified the source, additional information about the property (e.g., current and historical operations and inline solids data adjacent to the site) was compiled by the City and referred to the ODEQ's environmental cleanup program for investigation and remediation (Figure 20). This was done in part because ODEQ retains solid and hazardous waste authority throughout Oregon, which is different from Washington State where Ecology retains hazardous (dangerous) waste jurisdiction, but has delegated solid waste jurisdiction to counties and cities.

To demonstrate how this approach was implemented, the section below describes the sequential sampling conducted in Basin 19 to identify multiple PCB sources for referral and subsequent evaluation under ODEQ's cleanup program. The City of Portland's intergovernmental agreement with ODEQ provides the City of Portland with the opportunity to review and comment on all PCB cleanup work plans and reports at sites discharging to the municipal storm system. This review process allows the City to understand how each cleanup plan will ensure that the stormwater system doesn't continue to serve as a transport pathway to the river sediments. The review process also provides ODEQ with additional site-specific information relevant to source investigations at the site. Figure 20 illustrates how the City's basin characterizations, the ODEQ source control evaluations, and the Portland Harbor Remedial Investigation interrelate and how decisions regarding oversight are made.

The City of Portland's goal has been to identify significant PCB sources to the stormwater system to: (1) ensure they are addressed at the source; (2) reduce the need for regional stormwater treatment; and (3) ensure recontamination does not occur after the in-river sediment remedy is implemented. To date, the City has been coordinating with ODEQ on approximately 50 sites that are in the ODEQ cleanup program (not all sites include PCBs) and that discharge stormwater to the river via the municipal stormwater conveyance system. The City referred 12 new properties to the ODEQ cleanup program as a result of its PCB source tracing efforts.

Portland Stormwater Basin 19

One Willamette River stormwater subbasin which was subject to intensive source tracing and control efforts over many years is "Basin 19" (City of Portland 2010a). Basin 19 is about 490 acres in size; 70% of this area is forested and the remainder is zoned industrial. Source investigations began in Basin 19 because river sediment PCB (and other contaminant) concentrations in the vicinity of the outfall exceeded risk-based screening levels for both the protection of biological communities and bioaccumulation to tissues and associated human health risks.

The targeted source investigations in Basin 19 began in 2003 with inline solids sampling at key branches within the conveyance system (Figure 21). Grab samples from manholes[27] were collected and analyzed for PCBs and other contaminants of concern at locations where in-river sediment concentrations in the vicinity of the outfall were elevated. Based on both the solids results from the municipal conveyance system and property investigations conducted by the City of Portland and ODEQ, the City collected additional solids samples adjacent to properties to evaluate property contributions from 2006 to 2008. The remainder of this section describes the subsequent investigations to identify which parcels were found to be PCB sources to the stormwater basin. The City of Portland was able to refer these parcels into the ODEQ cleanup program for evaluation, to clean legacy contaminated solids from stormwater lines if the onsite source was found to no longer have a pathway, or to abandon the storm lines if they were no longer needed (Figure 19; City of Portland 2010a). The City's overall goal is to ensure that all parcels requiring remedial action get referred to ODEQ for on-site investigation. The remaining parcels are to be addressed through state and municipal programs, including stormwater permits, redevelopment code requirements and BMPs.

The 2003 inline solids investigation in Basin 19 included eight sampling sites (Figure 21). The highest PCB concentrations were from the upstream side of manhole AAP918 (231 µg/Kg) and at manhole AAP932 (242 µg/Kg) (City of Portland 2010a). However, detection limits were elevated at the other six locations (up to 1,030 µg/Kg) and PCBs were nondetect (Figure 21). Because of the high detection limits, the City of Portland worked with its laboratory to institute new sample cleanup procedures to minimize matrix interference and achieve lower detection limits. The grab sample from AAP932 was from a stormwater line that serves four different Environmental Cleanup Site Information (ECSI) properties. Mt Hood Chemical Corporation is the only one currently active in the ODEQ cleanup program (a groundwater remediation site, ECSI number 81), and a stormwater evaluation is underway. The City of Portland requested that this private stormline be cleaned out as part of the ODEQ cleanup program implementation.

[27] Sampling in manholes included grab samples from pipes originating from private property.

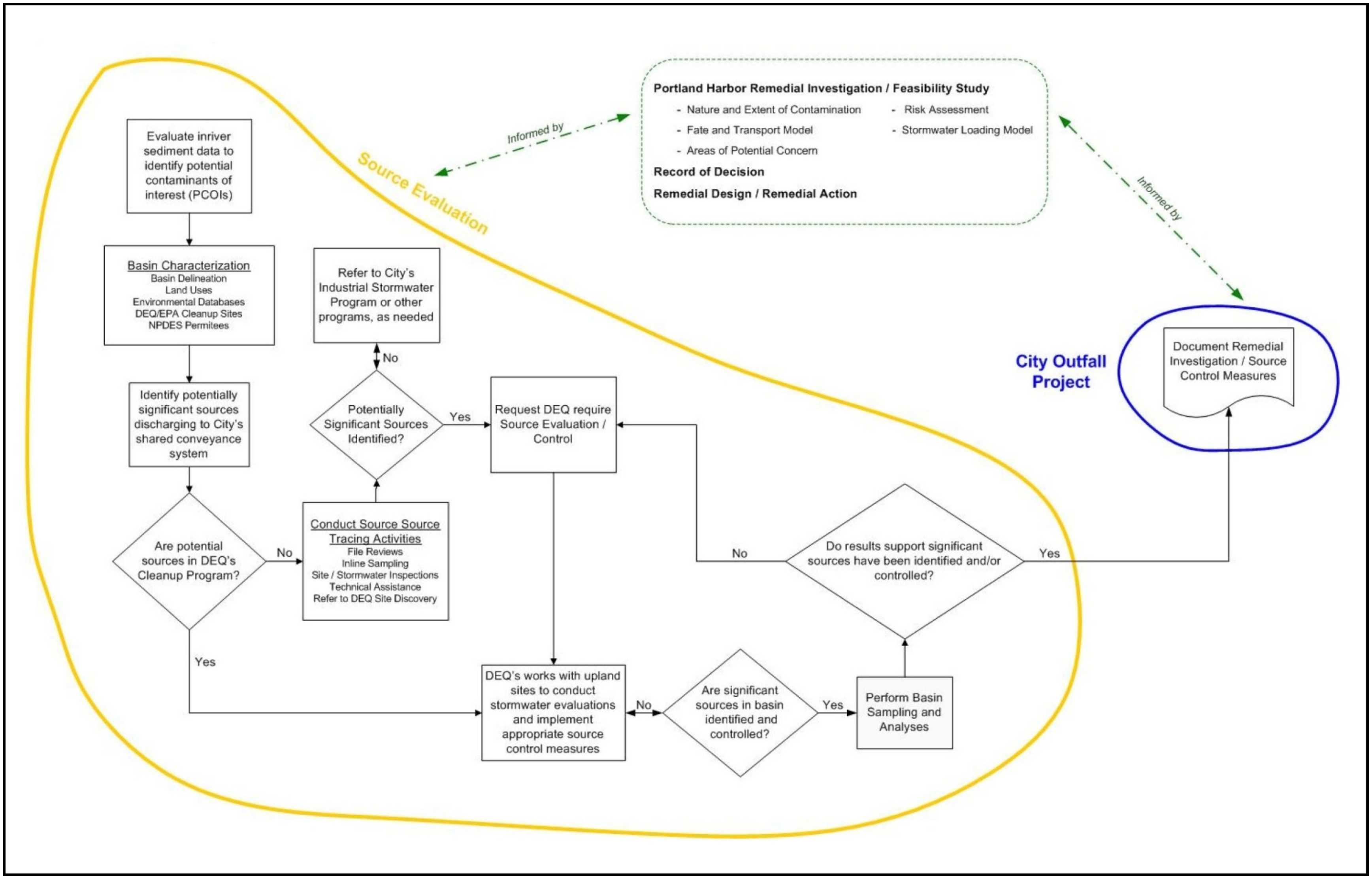

Figure 20. Portland outfall-basin evaluation process (Figure from City of Portland 2010b)

Further source tracing was initiated after this 2003 effort and included a 2006 stormwater investigation of the Pacific Gas and Electric (PGE) Forest Park property. This site had been remediated in 2000 after soil concentrations up to 930,000 µg/Kg PCBs were measured (PGE 2001). ODEQ had issued a no further action letter in 2001. However, no stormwater evaluation had been conducted during this earlier remediation action. Thus, in 2006, as part of an agreement to purchase this property as a public trailhead, the City investigated the configuration of the stormwater lines adjacent to the Forest Park site and whether these lines contained legacy contaminants. The City collected and analyzed manhole, catch basin and excavated pipe[28] solids from several lines in the vicinity of the site, and conducted camera surveys. Manhole and catch basin solids from this area contained PCB concentrations ranging from nondetect (<10 µg/Kg) to 137 µg/Kg indicating historical sources of PCBs to the lines (Figure 21 and Scheffler 2007). PCB concentrations in excavated line solids were higher (187–771 µg/Kg). Abandonment of these lines prevented migration of these legacy contaminants to the river. These samples also identified the Brazil & Co. property and its stormwater lines as a potential PCB source.

PCB concentrations in the two municipal system solids samples adjacent to the Brazil & Co. property were 679 and 771 µg/Kg. After the Brazil & Co. site entered the ODEQ Cleanup program (ODEQ 2014), on-site soils were removed in 2015 containing up to 6,680 µg/Kg PCBs (Terra Hydr 2015).

In 2007, the City of Portland initiated further inline sediment sampling in Basin 19 at, and downstream of, the former Calbag Metals site. This metals recycling facility closed in 2003 and some source control measures had been conducted in 2005, including line cleaning and site repaving. Sediment traps were deployed in 2007 at both a manhole representing the entire basin, and in the lateral connection from the former Calbag Metals site. The total PCB concentration in the basin sediment trap was 214 µg/Kg, while that in the Calbag Metals sediment trap was 630 µg/Kg; these results suggested that despite some stormwater controls, this property was an ongoing PCB source. A sediment trap was deployed in the Calbag property lateral again in 2008 and revealed an even higher PCB concentration (2,360 µg/Kg). These data confirmed that this property was an ongoing PCB source despite the prior remedial actions. ODEQ reopened the investigation at the Calbag site in 2010 based on the City's source investigation findings (ODEQ 2014). Subsequent investigations detected PCBs in on-site catch basins at 182 to 3,460 µg/Kg (Creekside 2010).

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[28] Soils above abandoned lines were excavated and a hole was cut in the pipe to grab sample any solids present.

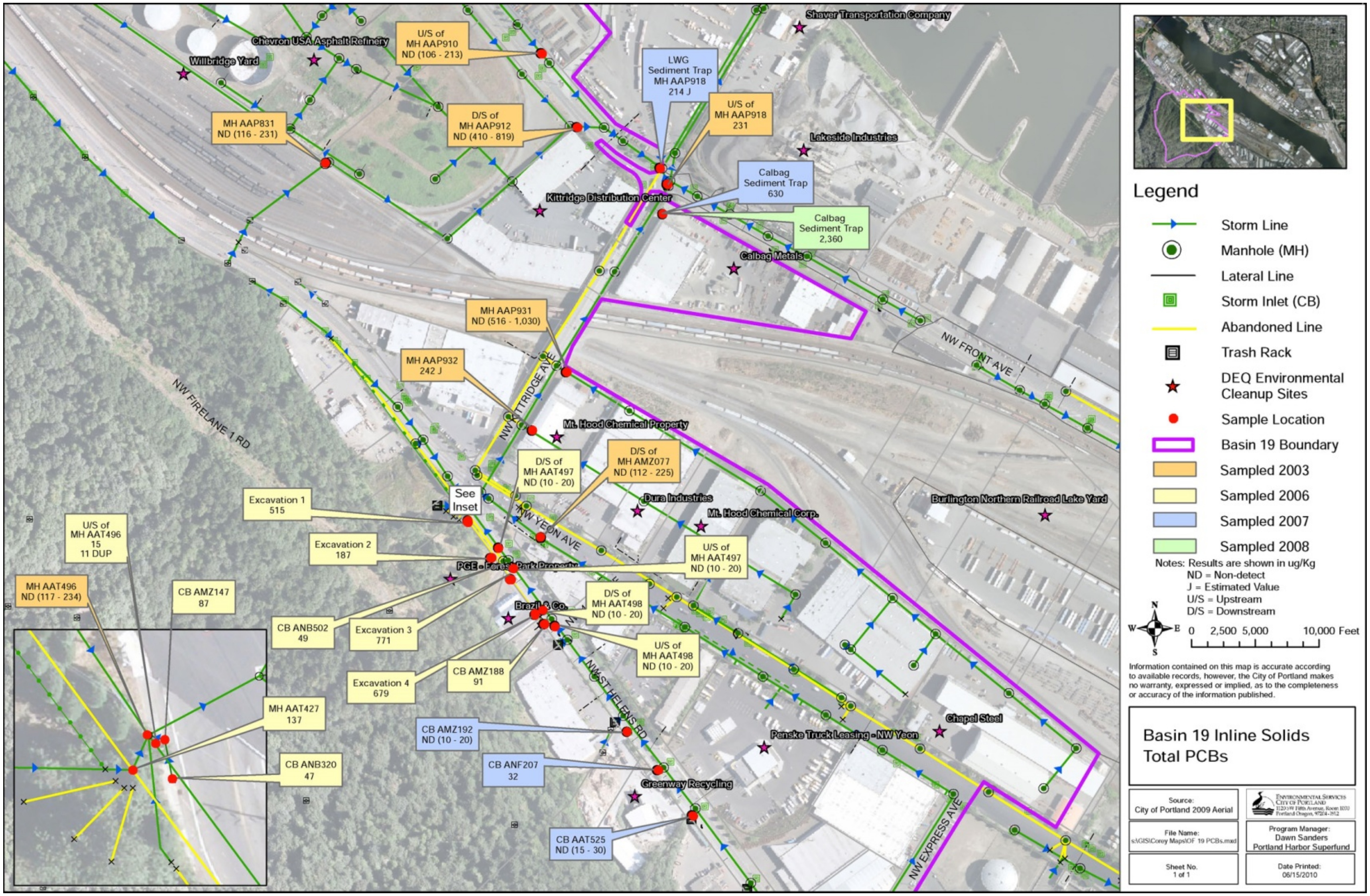

Figure 21. Sediment trap, manhole, excavated pipe and catch basin solids sampling locations and PCB concentrations from Basin 19 source tracing investigations (Figure from City of Portland 2010a)

Potential PCB source evaluations were also initiated through other municipal programs. For example, as part of property transfer investigations, the adjacent parcel to the west of the PGE-Forest Park site (Anderson Portland Properties) was also identified as a PCB source during a Phase 2 Site Assessment by METRO (the owner of regional parks) and the City, which detected soil PCB concentrations as high as 308,000 µg/Kg (Schwartz 2014; ODEQ 2014). An inline solids sample collected from the lateral of this site found a PCB concentration of 467 µg/Kg indicating the site was a significant source to Basin 19 (City of Portland 2011). Comprehensive evaluation and remediation of this site under ODEQ oversight was completed in 2014 and concentrations in excavated soils were as high as 1,750,000 µg/Kg PCBs (Wohlers Env. Services 2011; ODEQ ECSI database Site #1026).

Another example is the Greenway Recycling site in the upper portion of Basin 19 (City of Portland 2010a). In response to complaints of erosion from the site, the City of Portland sampled catch basin solids in the adjacent NW St. Helens Rd stormwater line in 2007. PCBs were detected in one catch basin at 32 µg/kg, indicating the Greenway site was not a significant PCB source via overland flow (Figure 21). However, the City requires submittal of site soil data as part of a future redevelopment permit for potentially contaminated sites. These soil data revealed 560 µg/Kg PCBs in soils near an onsite catch basin (City of Portland 2010a). The redeveloper proposed to remove some soil, disconnect the catch basin, pave over the contaminated soil and add additional stormwater treatment. The City approved this redevelopment permit because it prevented any legacy contaminants from entering the municipal system. Based on the site redevelopment work, Greenway Recycling was issued a no further action letter by ODEQ in 2009 (ODEQ 2014).

4.1.4.3 Summary of Findings

The City of Portland collected a number of inline PCB samples throughout Basin 19 between 2003 and 2008 (City of Portland 2010a). Storm solids collected in 2003 from the municipal conveyance system and at upland sites already in the ODEQ cleanup program led the City to focus source tracing on the eastern branch. These efforts led to the identification and referral of several sites for more rigorous evaluation of the stormwater pathway through the ODEQ's cleanup program. Potential PCB sources were also evaluated as part of other municipal efforts, such as redevelopment and property transfers. Table 11 illustrates the range of PCB concentrations measured in sediment trap, manhole, catch basin and excavated in-pipe solids, and on-site soil samples collected near or on potential source properties in Basin 19.

The City of Portland found PCB concentrations of inline solids were higher near potential PCB source areas (> 100 µg/Kg) compared to storm lines in other areas (<100 µg/Kg). PCB concentrations of inline solids were higher near potential PCB source areas than in storm lines sampled downstream. Detected PCB concentrations in on-site soils and catch basins were much higher than off-site inline solids. PCBs in inline solids from locations adjacent to identified sources ranged from 137 to 515 µg/Kg, whereas contaminated site soils ranged from nondetect up to 1,750,000 µg/Kg PCBs and catch basin and sediment trap solids contained 182 to 3,460 µg/Kg PCBs. On-site soils have been measured with orders of magnitude higher PCB concentrations than onsite inline solids.

Table 11. Minimum and maximum PCB concentrations (as total Aroclors) in inline solids and soils from potential source areas in Portland Harbor's Basin 19.

Sample type	Minimum Concentrations (µg/Kg)	Maximum Concentrations (µg/Kg)
Calbag Metals		
Downstream City inline Solids	214	231
On-site solids		
Catch basins	182	3,460
Sediment trap	630	2,360
Anderson Portland Properties		
Downstream City inline solids	137	137
On-site storm line solids	467	467
On-site soils	ND	1,750,000
PGE Forest Park		
Adjacent City inline solids	187	515
On-site soils	ND	930,000
Brazil & Co.		
Adjacent City inline solids	679	771
On-site soils	ND	6,680

ND – nondetect

4.2 Established Programs outside the Northwest

This section summarizes the background, source tracing approaches, and findings of two other large programs in the United States where PCB source tracing has been conducted: the Delaware River Basin and San Francisco Bay. In both regions, PCB TMDLs associated with bioaccumulation in fish were the drivers for development of PCB source tracing programs.

4.2.1 Delaware River Basin

PCB monitoring in the Delaware River Basin was prompted by several factors: fish consumption advisories for PCBs established in the 1980s, a 1998 decision to list the Delaware River and Estuary as impaired under the CWA, and 2003 and 2006 TMDLs (for different areas)(EPA 2003). The TMDLs also required development of Pollutant Minimization Plans (PMPs), which generally consist of PCB source tracing, PCB reduction strategies, monitoring for PCB reductions, and remediation when necessary.

4.2.1.1 Background

The Delaware River Basin includes over 13,500 square miles and borders the states of New York, New Jersey, Pennsylvania, and Delaware (DRBC 2013). Land use in the drainage basin

is varied and includes forested, agricultural, urban, and residential areas (DRBC 2013). In addition to recreational uses, surface and groundwaters in the Delaware River Basin are used as a drinking water source by over 15 million people (USGS 2014; DRB Source Water Collaborative 2015). The water resources in this area are also important for energy, industry, and fishing. The river also supports the Delaware River Port Complex, which is the largest freshwater port in the world (DRBC 2013).

The DRBC was created in the 1960s to address regional management of the Delaware River Basin and consists of state and federal representatives from the region. The group includes governors from each state in the Delaware River Basin, and their alternate commissioners, as well as the North Atlantic Division Engineer from the U.S. Army Corps of Engineers (DRBC 2015a).

The Delaware Estuary is designated as the most downstream 133 miles of the Delaware River (EPA 2003). Fish consumption advisories apply in all three bordering states: New Jersey, Pennsylvania, and Delaware. In 1998, the estuary was placed on the 303d list due to high PCB concentrations in fish (Cavallo 2015). The advisories and 303d listing prompted the four states and two EPA Regions (2 and 3) to designate the DRBC as the lead agency to develop multistep TMDLs for PCBs in the Delaware Estuary starting in 2003.

In the 1960s, the Delaware River was divided into six water quality management zones (Figure 22):

- Zone 1: upstream of River Mile (RM) 133.4 (outside the estuary)
- Zone 2: RM 133.4 to 108.4
- Zone 3: from RM 108.4 to RM 95.0
- Zone 4: from RM 95.0 to 78.8
- Zone 5: from RM 78.8 to the head of Delaware Bay (Liston Point)
- Zone 6: from Liston Point to the mouth of the Bay (Cape Henlopen to Cape May)

In the estuary (Zones 2-6), the three most upstream zones are bordered by New Jersey and Pennsylvania, while the two most downstream zones are bordered by New Jersey and Delaware. The TMDL for Zones 2-5 was developed in 2003 and the TMDL for Zone 6 was established in 2006. Zone 6 has a separate TMDL due to additional requirements for the shellfish harvesting that occurs in this zone (EPA 2003).

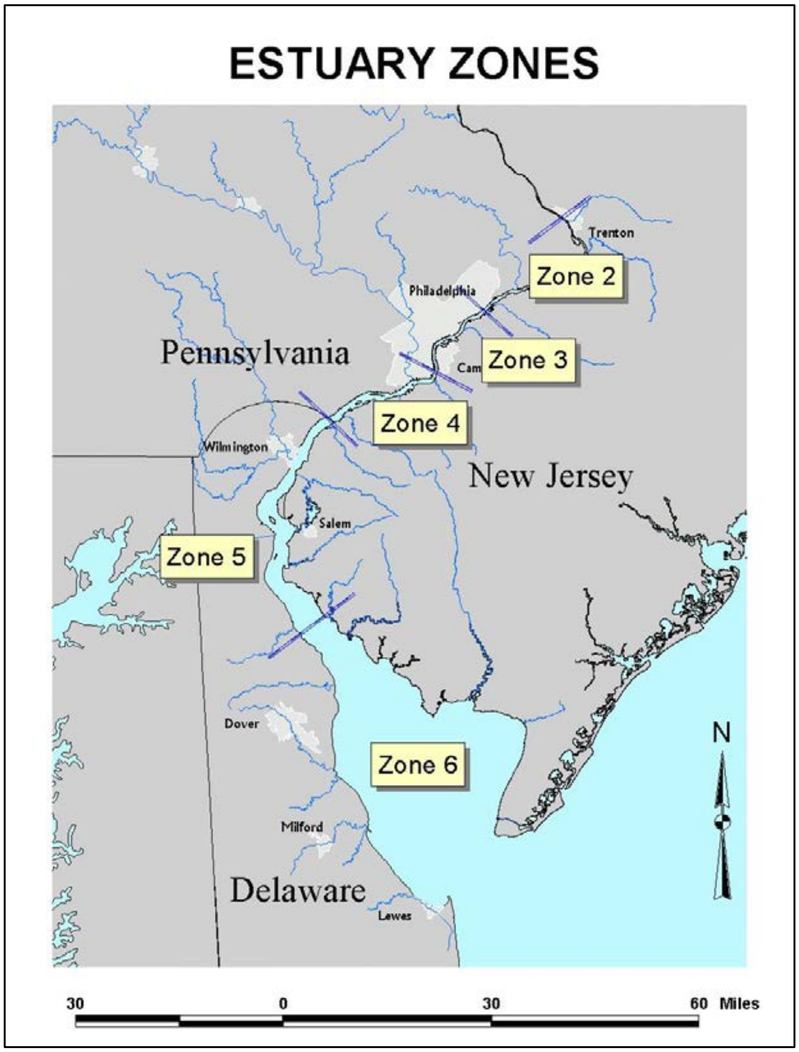

Figure 22. Water quality zones of the Delaware River (Figure from EPA 2003).

The DRBC was tasked with developing the two TMDLs and coordinating efforts between the EPA, the states, and the regulated parties (Cavallo 2015; DRBC 2015b). The other groups involved in TMDL development include the DRBC's Toxics Advisory Committee of scientific experts, and the TMDL Implementation Advisory Committee (IAC). The IAC was formed by the DRBC and helped develop load reduction strategies focusing on non-point sources. The group includes representatives from each affected state, municipal and industrial dischargers, environmental and other related organizations, and is advised by Regions 2 and 3 of the EPA (DRBC 2015b). Funding for TMDL development was provided, in part, by the EPA, the states, and the Commission's general funds (DRBC 2015, pers. comm.).

The TMDLs for the Delaware River Estuary were developed using water quality criteria, designated uses for each zone, monitoring of dischargers/ambient conditions, and a water quality model (EPA 2003; Suk and Fikslin 2011). Initially, the TMDL water quality targets were established separately for each water quality management zone and ranged from 7.9

to 64 pg/L total PCBs (EPA 2003). However, in 2013, the water quality criteria were updated across the entire estuary to 16.1 pg/L total PCBs (DRBC 2015b). When the TMDLs were first established, each zone exceeded TMDL targets by about two or more orders of magnitude (EPA 2003).

Instead of numeric PCB limits for each point source discharger[29], monitoring using Method 1668A and individual PMPs were required (DRBC 2015c). EPA originally planned to include PMPs in NPDES permits as they were reissued or renewed, but permits are only renewed every five years, prompting the need for more immediate PMP development. Thus, the DRBC adopted the PMP requirements for all dischargers through rule-making in 2005 (Fikslin 2012).

Each PMP is unique to the discharger, but generally consists of documenting known and potential PCB sources on the property (e.g., old transformers), required biannual PCB monitoring (end-of-pipe), PCB source tracing, PCB reduction strategies, source prioritization, and remediation when necessary (DRBC 2006). Baseline loads are estimated and anticipated reductions are also reported. Dischargers submit annual reports to describe actions taken, and subsequent changes in PCB loads (DRBC 2006). PCB reduction strategies and remediation can include stormwater controls, improved solids removal from wastewater facilities, and removal of historical PCB contamination (e.g., transformers, sediment in stormwater systems and/or other contaminated materials) (DRBC 2006; Kricun 2012). As of January 2015, 85 of 94 point source dischargers in the Delaware River Estuary had implemented PMPs (Cavallo 2015). The first phase of the TMDLs focused on reducing loads from point source dischargers. The next phase will require non-point source load reduction focusing on contaminated sites and tributaries (DRBC 2015, pers. comm.).

PCBs in effluents are monitored by point source dischargers as congeners using a modified version of EPA Method 1668A (Fikslin 2012). This method provides relatively low detection limits and the ability to analyze homologue or congener patterns for improved source tracing. At a minimum, effluent samples are collected once every two years, but as part of the TMDL implementation process, monitoring now includes collection of several dry and wet season samples per year if the discharger has continuous flow (DRBC 2006; DRBC 2015d). Samples can be collected as 24-hour time-weighted composites or as single grab samples (DRBC 2015d). Dischargers submit sampling event concentrations and flow data to DRBC, which can be used to track discharger load reductions and calculate loading rates. These loading rates are used in the Basin-wide water quality model to estimate loads (Suk and Fikslin 2011). The DRBC also maintains a Microsoft Access® database containing all PCB monitoring results that is accessible to all permittees (Cavallo 2014).

[29] Point sources are considered industrial and municipal discharges such as stormwater outfalls, treatment plant outfalls, CSOs, and MS4s (EPA 2003).

4.2.1.2 Source Tracing Approach

Source tracing activities can include water column, sediment and/or soil sampling for first-cut or iterative "trackback" sampling, windshield surveys for small municipal utilities, and mapping sites with known PCB contamination (DRBC 2006; Amidon 2012). While DRBC requires EPA Method 1668A (PCB congeners) for effluent sampling, other analytical methods have been used for source tracing samples where PCB concentrations are higher and can be detected with less sensitive analytical methods (Kricun 2012; Amidon 2012).

The Camden County Municipal Utilities Authority (CCMUA) provides a comprehensive example of PMP and source tracing implementation in the Delaware River Basin. As the third largest discharger of PCBs to the Delaware Estuary, according to the DRBC, the CCMUA has undertaken many efforts to reduce PCB discharges, including a multi-phase source tracing program starting in 2003 (Aquatic Sciences Consulting 2014). A complementary, but separate, source tracing pilot study was also conducted in the CCMUA service area, which was led by New Jersey Department of Environmental Protection (NJDEP) in collaboration with CCMUA and DRBC (Belton et al. 2008). These two efforts are discussed separately below.

CCMUA Source Tracing

During TMDL development, the DRBC identified the CCMUA as a major PCB discharger to the Delaware Estuary (Kricun 2012). The CCMUA is located in southern New Jersey and provides secondary wastewater treatment for over 500,000 customers. Eighty million gallons of wastewater are treated per day, and then discharged to the Delaware Estuary. The CCMUA service area also includes some combined sewer systems with uncontrolled CSOs to the Delaware Estuary (Belton et al. 2008).

The CCMUA has addressed the following components included in their PMP (Kricun 2012; Aquatic Sciences Consulting 2014):

- An inventory of items that might contain PCBs within the treatment plant:
    - Since the treatment plant was built after the ban on PCBs, the inventory found no major PCB sources (e.g., transformers) within the plant.
- Optimizing treatment plant operations to enhance PCB removal:
    - To accomplish this, the plant changed treatment processes to increase solids removal by 20%, to reduce PCBs in effluent.
- Adding solids removal to CSOs:
    - Netting systems were added at all CSOs to keep all solids larger than a quarter inch in diameter from entering the estuary during overflow events, thereby reducing PCBs in overflows.
- PCB transformer Inventory Survey:
    - Through an EPA grant, the CCMUA conducted a survey on PCB transformers in Camden City. Using an established business database, 280 businesses were identified as having the electrical consumption and standard industrial

classification suspected to coincide with operating a PCB transformer. A survey was conducted with these businesses, identifying one owning PCB transformers. However, additional businesses that owned PCB transformers were identified through windshield surveys, and confirmed through source tracing efforts.

- Source tracing for PCBs in the sewer system:
    - Phase 1: Whole water samples were collected at each of three main interceptor lines using both autosamplers and passive in-situ continuous extraction samplers (PISCES[30]). Water samples were analyzed for PCB congeners (EPA Method 1668A) and indicated most of the PCBs were coming from the sewer line leading from Camden City (Aquatic Sciences Consulting 2014; Kricun 2016, pers. comm.).
    - Phase 2: Camden City was divided into 10 sectors and whole water samples were collected from sewer system manholes to further pinpoint specific areas of PCB contamination (Kricun 2007; Kricun 2016, pers. comm.). These samples were analyzed for Aroclors (EPA Method 8082), because PCB concentrations were expected to be high (Kricun 2007; Kricun 2012). Since this area of the system includes combined sewers, both dry and wet weather samples were collected to assess stormwater inputs. The sewer lines leading from South Central Camden and the South Camden waterfront were identified as having the highest PCB concentrations (Aquatic Sciences Consulting 2014). Concentrations were highest during wet weather suggesting the majority of the PCBs were not entering the system through active industry discharges, but instead through runoff from contaminated sites (Kricun 2016, pers. comm.).
    - Phase 3: NJDEP requires permits for significant indirect users (SIUs) which are industries that discharge particularly large volumes to the sewer system or have discharges with known pollutants. The SIUs in this part of Camden City were reviewed to identify candidate industries for source tracing sampling (Kricun 2016, pers. comm.). Samples were then collected upstream and downstream of each candidate industry. In the South Central Camden sector, sampling occurred after a moderate rain event in September 2010 and included whole water grab samples and sediment samples from combined sewer manholes and storm drains (Aquatic Sciences Consulting 2014). In the South Camden waterfront sector, solids were collected in May 2011 from combined sewer manholes, storm drains, and at the street-level. Water samples were analyzed for PCB congeners (EPA Method 1668A) and

[30] PISCES are semipermeable membranes filled with hexane in a protective housing. During deployment, dissolved/soluble hydrophobic chemicals can pass from the water column through the semipermeable membrane into the hexane. Temperature can affect the accumulation rate, so concentrations of the contaminants in the water column are estimated based on the hexane sample concentrations and temperature data.

solids were analyzed for PCBs using an enzyme-linked immunosorbent assay (ELISA)[31], with a subset of samples also analyzed for PCB congeners (EPA Method 1668A) (Aquatic Sciences Consulting 2014). Parcels contributing PCBs to the sewer system were identified when PCB concentrations were substantially higher in the downstream samples, or when solids concentrations were greater than New Jersey's non-residential direct contact soil cleanup criteria of 1,000 µg/Kg total PCBs (Botts and Schmitt 2011). Homologue patterns were also used to identify sites with the same PCB source, and, when possible, identifying possible sources by matching the homologue patterns of Aroclor contaminated sites to those in downstream combined sewer or storm drain samples (Aquatic Sciences Consulting 2014).

NJDEP Pilot Study

The pilot study conducted by NJDEP compared results from different sampling and analytical methods, and identified general property types as potential PCB sources. A report by Belton et al. (2008) provided the information summarized in this subsection, unless otherwise cited.

Similar to the CCMUA effort, the first source tracing phase identified which basin within the CCMUA service area should be prioritized for further source tracing. Seven sampling locations were selected based on the potential for PCB contamination using maps of the CCMUA sewer systems and permitted discharges, as well as a database of sites with known PCB contamination. At each location in the sewer system, samples were collected during the dry season (July 2003) using three methods: whole water grab samples, whole water 24-hour composite samples, and samples collected continuously over two weeks by PISCES. All samples were analyzed for PCB congeners using a modified EPA Method 1668A.

Results from the three sampling methods were compared to assess which might provide the most cost-effective, but also representative, estimate of PCB concentrations. Instantaneous grab samples are quick to collect and provide a snapshot of concentrations, but the longer timespan associated with the PISCES and composite samples could provide better estimates of average or typical concentrations at a given site. However, PISCES results exclude PCBs bound to particulates. The pilot study found that samples collected with PISCES contained a greater proportion of lower chlorinated PCBs than either of the water samples. This is likely due to the exclusion of the higher chlorinated congeners, which are typically bound to particulates. While all three sampling techniques provided sufficient information for PCB source tracing, the 24-hour composite samples were considered the most representative of total PCB concentrations at each location.

[31] ELISA kits can be used for quick screening of general PCB concentrations as Aroclor 1254, with a detection limit of 50 µg/Kg.

Congener patterns from 24-hour composite samples were compared between sites to better understand potential differences in sources. Some sites had a higher proportion of lower-chlorinated congeners than others. This suggests they may have received inputs from more recent or on-going PCB sources due to the fact that lower-chlorinated congeners tend to degrade or volatilize more rapidly. Sites with a greater proportion of higher-chlorinated congeners may indicate the presence of older, more degraded PCB sources. A homologue pattern analysis revealed site-specific patterns, indicating potentially different PCB sources.

PCB concentrations and estimated loads at each site were then compared to identify priority subbasins for more detailed source tracing. The subbasin receiving wastewater from the industrialized south-central area of Camden City was identified as having the highest wastewater PCB concentrations and contributing the largest PCB load to the treatment plant. Loading analysis estimated the Camden City subbasin was contributing over 70% of the PCB load to the treatment plant.

The second phase of the source tracing effort included a more comprehensive search in several state and federal regulatory databases for areas of known PCB contamination within the south-central Camden City subbasin. After identifying additional sites of interest (n=98 sites), targeted street soil samples were collected during very dry conditions (March 2006) and analyzed for PCBs using an ELISA. A subset of samples, testing positive for PCBs, were also analyzed for PCB congeners using a modified EPA Method 1668A.

For each sample, ELISA results were comparable to the PCB congener results except at higher concentrations (>1,000 μg/Kg) where the ELISA greatly underestimated PCB levels. Despite these discrepancies, samples with relatively elevated PCB concentrations could still be identified using ELISA. Belton et al. (2008) suggest the results support the utility of ELISA kits for source tracing purposes.

Homologue patterns were compared with known Aroclor patterns for the subset of samples analyzed for PCB congeners. Samples collected near metal scrapping areas had homologue patterns closely resembling those of Aroclor 1248, whereas homologue patterns from other soil samples more closely resembled Aroclors 1254 and 1260.

All street soil sample results were categorized by potential PCB sources in the area (e.g., industry types or sites of known contamination). The categories often associated with the highest soil PCB concentrations were sites with known PCB contamination and metal scrapping areas.

To explore metal scrapping facilities further, street dust sampling and analysis was conducted in an area with a high density of these facilities. The results of this effort indicated that transport of automotive shredder residue corresponds to increased PCBs in street dust. Belton et al. (2008) includes an appendix with various actions that could be taken by metal scrappers to reduce PCB contamination, but acknowledges that CCMUA has little regulatory power. These facilities do not directly discharge to the system, but may

indirectly contribute PCBs through stormwater runoff, and the CCMUA needs regulatory support from NJDEP to control these sources (Belton et al. 2008).

Camden County Source Tracing Summary

Overall, the PCB source tracing efforts conducted by CCMUA and NJDEP were effective in identifying the south-central area of Camden City as contributing the greatest amount of PCBs to the combined system. There are several reasons why PCB concentrations and loads may be higher in this subbasin. The subbasin receives flow from older industrial areas and includes many parcels with known PCB contamination (Belton et al. 2008; Kricun 2016, pers. comm.). Additionally, much of this subbasin has combined sewers; thus, stormwater runoff from these industrial areas also drains to the sewer system (Belton et al. 2008). A previous study of New Jersey air deposition found substantially higher PCB deposition rates near Camden City than in outlying areas. Therefore, air deposition may also contribute PCBs to stormwater and thus to the combined sewer system (Reinfelder et al. 2004). Stormwater as a source of PCBs was further supported by the CCMUA source tracing findings of elevated PCB concentrations in the combined system during wet weather relative to dry weather concentrations (Kricun 2016, pers. comm.). The NJDEP pilot study identified specific industries and property types within Camden City that were sources of PCBs to the combined system (i.e., metal scrapping, sites with known contamination), while the CCMUA study identified specific parcels requiring further action (Kricun 2016, pers. comm.; Botts and Schmitt 2011).

4.2.1.3 Summary of Findings

The DRBC's PMP program has resulted in decreased PCB loadings for some of the major contributors. From 2005 to 2013, the top 10 PCB dischargers have collectively reduced loadings by 71% (Cavallo 2015; DRBC 2015c). This includes the CCMUA, described above, with a 62% decrease in overall PCB loadings. Due to a decrease in finfish PCB tissue concentrations in 2013, the consumption advisory for part of the Delaware River was softened to allow one eight ounce meal per year for the general adult population, instead of recommending no consumption (Cavallo 2015).

Some of the major PCB sources discovered through source tracing efforts have been sites with known PCB contamination, old transformers, and automotive shredder residues from metal scrapping (Belton et al. 2008; DRBC 2015, pers. comm.). However, stormwater runoff is a common pathway for these sources rather than point source discharges (Kricun 2016, pers. comm.). Implementing PMPs at sites with known PCB contamination resulted in some of the largest, and most cost-effective, PCB loading reductions (DRBC 2015, pers. comm.). Because major point sources of PCBs were found in the Delaware River Basin, PCB loadings have been reduced without the need to target the more dispersed, incidentally-produced PCBs from consumer products.

CCMUA Source Tracing

The CCMUA source tracing effort identified several PCB hotspots, but three major PCB sources were prioritized. One was a Superfund site with known PCB contamination (Aquatic Sciences Consulting 2014). Many lines of evidence suggested improved

stormwater controls were needed on site: groundwater results for PCBs (provided by EPA), the relatively high PCB concentrations in an offsite storm drain (6,600 µg/Kg in sediment), as well as elevated PCB concentrations in whole water samples collected from downstream combined sewer manholes (3.4 µg/L versus <0.1 µg/L) (Kricun 2016, pers. comm.; Aquatic Sciences Consulting 2014). At CCMUA's request, the EPA agreed to contain the stormwater generated onsite (Kricun 2016, pers. comm.).

The other two prioritized sites were active industries. Water concentrations in offsite storm drains were 12,000 and 65,000 ng/L PCBs compared to the upstream combined sewer concentration of 0.1 µg/L (Kricun 2016, pers. comm.; Aquatic Sciences Consulting 2014). In collaboration with local and federal regulatory agencies, legal agreements (e.g., consent orders) are being negotiated with these industries (Kricun 2016, pers. comm.).

As an additional remediation tool, in compliance with their PMP, the CCMUA has asked the City of Camden to routinely flush sediment from their combined sewer lines. This sends the contaminated material to the treatment plant, where the improved solids capture helps reduce the PCB load before release to the Delaware Estuary. This action also prevents the sediment from entering the Delaware Estuary during CSO events (Kricun 2016, pers. comm.).

NJDEP Pilot Study

The source tracing pilot study led by the NJDEP included both combined sewer water samples (Phase 1) and street soil samples (Phase 2), as described in Section 4.2.1.2 (Belton et al. 2008). In Phase 1, the maximum total PCB (based on congeners) concentration in water samples was 798,081 pg/L, while concentrations in other samples ranged from 32,763 to 173,466 pg/L. These results, combined with flow data, identified the industrial, southern area of Camden City as the major PCB source to the system. Table 12 lists average concentrations in street soils near different source types from Phase 2. These data indicate how sites with known contamination and metal scrapping were identified as the major sources of PCBs to the combined sewer system in this phase (Belton et al. 2008).

Table 12. Average PCB concentrations (based on ELISA) in street soil samples near combined sewer drains in southern Camden City (adapted from Belton et al. 2008).

Potential PCB Sources	Average PCB Concentrations (µg/Kg)[1]	Number of Samples
Sites with known contamination	1,600	5
Metal scrap – junkyards	1,410	10
Metal scrap – shredders	500	3
Metal scrap – smelters	470	4
Paper and pulping	420	1
Transportation	420	8
Gas plant – pipeline	400	3
Drum cleaning – reconditioning	380	10
Manufacturing – metal	350	3
Manufacturing – general	260	15
Waste management	240	5
Electrical transmission (substations)	160	7
Aggregates	50 ND	4
Landfill	50 ND	2
Background (parks, cemeteries)	50 ND	18

ND = nondetect;
[1]This study found the ELISA underestimated PCB concentrations when concentrations were >1,000 µg/Kg. The actual PCB congener concentrations may be higher than the ELISA results presented here.

4.2.2 San Francisco Bay

The San Francisco Bay area PCB source tracing programs are driven by a TMDL due to elevated PCB concentrations in fish. San Francisco Bay (the Bay) is the second largest estuary in the United States with an estimated population of 7 million in the surrounding area (CA Bay Area Census 2010). PCB source tracing has been conducted by numerous local and regional governments, state government, several consortia of municipalities and utilities, nonprofit organizations and private industry. Because urban stormwater was identified as a major PCB pathway to the Bay, a substantial effort has been committed to source tracing in stormwater systems across municipalities in the region. This section focuses on source tracing approaches used in stormwater systems that have led to source identifications.

4.2.2.1 Background

Over 48 million acres of land drain into the Bay primarily via the Sacramento and San Joaquin Rivers, the largest rivers in California (EPA http://www2.epa.gov/sfbay-delta/about-watershed#watershedareas). Being a large metropolitan area, land use in the watersheds are varied and range from industrial, urban residential and commercial to open space and agricultural lands. The majority of municipal stormwater and wastewater is

conveyed in separated systems with the exception of the City and County of San Francisco which have combined systems.

In 1994, California issued a fish consumption advisory for the Bay based on several pollutants including PCBs. The CWA section 303d impairments due to PCBs and other contaminants were identified in the Bay in 1998 by the California Water Resources Control Board (Water Board) (CA EPA 2010). Following CWA requirements, California developed a PCB TMDL in 2007 that was approved by EPA in 2010.

Many years of research and monitoring were required to develop the PCB TMDL. Sampling investigations and modeling were used to quantify PCB loading estimates from each pathway to the Bay, determine the natural attenuation rate, characterize the spatial distribution of PCBs, and begin the process of source identification. All surface waters in the Bay are covered by this TMDL (approximately 290,000 acres) (CA RWQCB 2008). State and local government agencies led investigations during TMDL development with substantial sampling and modeling assistance from the nonprofit SFEI. For example, a study to quantify water and sediment concentrations in two key tributary watersheds was conducted by SFEI in the late 1990s (Leatherbarrow et al. 2002). Because of an earlier mercury TMDL for the Bay (also based on bioaccumulation in fish), the parties involved conducted characterization studies for both mercury and PCBs and other contaminants of interest (e.g., pesticides and PAHs). Initial load estimations identified stormwater as the largest and most controllable pathway for PCBs (Davis et al. 2000; Davis et al. 2007).

In the early 2000s, sediment studies in the greater San Francisco area urban stormwater conveyance system were conducted by a stormwater consortium to identify areas contributing the most sediment (and associated contaminants) to stormwater entering the Bay (KLI and EOA 2001; KLI and EOA 2002). Sediment data from 164 sites demonstrated that the highest PCB load was derived from industrial and commercial/residential urban land uses (KLI and EOA 2002). The PCB data from these studies allowed investigators to prioritize high contributing areas in the conveyance system for follow-up source tracing projects. For example, despite its relatively small size (approx. 1000 acres), the Ettie Street Pump Station watershed was identified with some of the highest in sediment PCBs concentrations in the entire Bay (Gunther et al. 2001; Yee and McKee 2010). PCB concentrations in this basin were nine times higher than in the watershed with the second highest sediment concentrations, Glen Echo. Source investigation efforts in the Ettie Street basin were successful and ultimately served as a model for current PCB source control efforts under the TMDL. The details of this investigation are presented in the next section.

Pathway investigations during TMDL development concluded that stormwater was the primary PCB loading pathway to the Bay (Table 17 of the PCB TMDL). These data indicated that and a 90% load reduction is required to meet the TMDL load allocation. The TMDL therefore emphasizes actions to reduce PCBs in the stormwater pathway. All data used for the TMDL development were PCB congener-based (CA RWQCB 2008).

Since prior to TMDL approval in 2010, the Water Board has lead its implementation through the Municipal Regional Stormwater Permit (for stormwater dischargers) and the

Watershed Permit (for wastewater dischargers) for municipal and industrial discharges of PCBs. Municipal stormwater permittees are required to take actions to reduce controllable PCB sources in runoff. The stormwater permit requires a phased approach using pilot studies to evaluate the most effective stormwater management methods followed in later years (and successive permits) with focused implementation. The goals of the first pilot studies were to:

- Evaluate management of PCBs in construction materials, such as caulk, that can be released to the environment during demolition and renovation,
- Identify and abate areas with high PCB concentrations,
- Evaluate enhanced sediment removal and management practices for stormwater conveyances, such as city street sweeping, and pump station cleaning,
- Evaluate on-site stormwater treatment retrofits, and
- Evaluate diversion of dry weather flows and first flush runoff for treatment (e.g., at a wastewater treatment plant).

Some aspects of the Watershed Permit also address PCBs. The following actions are specifically required by the permit:

- Identify and manage controllable sources of PCBs,
- Use best management practices to maintain optimum performance for solids removal; use updated analytical methods to test for PCBs, and
- Undertake a program to reduce the health risks for people who eat San Francisco Bay fish contaminated with PCBs and mercury.

An association of San Francisco Bay area stormwater management agencies, Bay Area Stormwater Management Agencies Association (BASMAA), received a $5 million EPA grant that funds a project called Clean Watersheds for a Clean Bay (CW4CB). This project is being conducted by BASMAA in partnership with county municipal stormwater management programs and the California Department of Public Health. The total project budget is $7 million, with the remaining $2 million coming from county stormwater municipalities, wastewater treatment agencies and industrial dischargers. The CW4CB project is conducting pilot studies to address the TMDL-mandated stormwater permit requirements, including source identification and abatement. These source identification studies are described in more detail below. The CW4CB project is also conducting public outreach to educate citizens about health risks associated with consuming contaminated Bay fish, which is a requirement in the wastewater permit. This latter public education program is called the San Francisco Bay Project.

An additional element of the Bay PCB source tracing work is the Regional Monitoring Program (RMP) which conducts long-term monitoring of water, sediments and fish to track changes in PCB concentrations over time and measure human and ecological exposure. The RMP is implemented by the SFEI and led by a steering committee of municipal and industrial dischargers and regulatory agencies. The RMP began in 1993, prior to initiation of the TMDL, as a San Francisco Bay pollutant monitoring program mandated by the

San Francisco Regional Water Quality Control Board (Regional Water Board) for implementation by dischargers and included in their NPDES discharge permits (SFEI 2015). Therefore, its annual budget of $~4 million from permittees, covers monitoring of many contaminants, not just PCBs, and other aspects of the program including program management and an extensive online data and information management system[32]. As part of the RMP Program, SFEI also conducts extensive monitoring within the tidal waters of the Bay and funds special studies with a $1 million annual budget. These studies have reached into the tributary watersheds of the Bay, and have assisted in source identification and load quantification.

4.2.2.2 Source tracing approach

This section describes the PCB source tracing approaches used in the Ettie Street Pump Station basin, the CW4CB project, and the RMP.

Ettie Street Pump Station Source Investigation

Following the initial sediment characterization in 2000 that identified the Ettie Street Pump Station with one of the highest PCB sediment concentrations in the region, the City of Oakland conducted follow up studies in 2001. The City conducted studies in two distinct phases, in July and November 2001 (Salop et al. 2002). All sampling was completed near the middle-to-end of the typical several-month dry period in California's summer and early fall. This timing duplicated the conditions in 2000 and was expected to maximize the retention of fine sediments in the channels and storm drain system. In Phase I, sample locations were selected in three of the five drainage lines leading to the pump station. Two lines closest to the pump station were eliminated due to their relatively short length and lack of depositional sediments. Depositional areas were limited, but weirs were identified as the best locations for sampling. Although composite samples were desired, it was not feasible to collect composites due to access issues and limited depositional areas. Five discrete samples were collected in the three selected drainage lines and analyzed for PCB congeners along with mercury. Percent fines were also measured. It was estimated that the majority of the PCB load was associated with the fine fraction. PCB concentrations were examined as total PCBs and as normalized to percent fines (the fines-normalized data are not presented in this document). PCB concentrations greater than 1,000 µg/Kg were detected in one of the five sampling locations (32nd and Hannah Streets).

During Phase II of this effort, the City of Oakland identified more than 54 inlets to this catchment which prohibited individual sampling of inlets. However, composite samples were collected across multiple inlets; in industrial areas, samples were composited from inlets from two intersections and in commercial and residential areas, samples were composited from inlets from three to four intersections. In total, 39 inlets were sampled

[32] SFEI is the Regional Data Center for the San Francisco Bay-Delta and northern montane regions. Water quality data from the RMP are freely downloadable and visualized via their CD3 data tool (http://www.sfei.org/rmp/data#sthash.ltyrHUTE.dpbs). SFEI maintains quality control protocols consistent with state-level database business rules.

and nine composite samples were collected and analyzed. Elevated PCB concentrations (>1,000 µg/Kg) were detected in two of the nine samples collected near 30th St.

The PCB congener profiles for samples collected in both 2000 and 2001 were evaluated to identify correlations between locations and highlight any differences in PCB sources. Congener patterns in the pump station sediments were similar between years (resembling Aroclors 1254 and 1260) and similar to samples with the highest concentrations collected near 30th St. However, the congener pattern in the Phase I sample with the highest PCB concentrations (from 32nd and Hannah) was generally different, closer to Aroclor 1248, and suspected to be from an ongoing source. City of Oakland staff also considered the uncertainty that the location with the highest concentrations may not be contributing the highest load to the pump station and subsequently to the Bay. To answer this question, the City constructed a model based on multiple linear regression analysis of contributions from the Phase II sampling stations to the pump station (Salop et al. 2002). PCB data from stations with significant correlations with the pump station were kept in the model, others were excluded. The results of this analysis indicated that locations that comprised the Phase II composite sample with the highest PCB concentrations did not contribute significantly to the Ettie Street Pump Station sediment concentrations. The analysis suggested instead that a nearby location with lower PCB concentrations was contributing a higher load and therefore should be a higher priority for follow-up work. Lastly, sediment concentrations from Phase I and II were compared to the screening concentration of 8.6 µg/Kg[33] to characterize levels of concern. Nearly all samples were above the screening value. These source investigations indicated that multiple PCB sources existed in the Ettie Street Pump Station basin.

The City of Oakland conducted a subsequent source identification and abatement study from 2004 to 2006 with funds from the Water Board (Kleinfelder 2006a). This study included: (1) review of documents and a windshield reconnaissance of the area to identify properties of concern, (2) facility inspections to evaluate the selected properties of concern (See Appendix B), (3) collection and analysis of sediment samples from the public right-of-way and private properties, and (4) abatement of PCBs in the public ROW and prevention of further releases/runoff by encouraging private property owners to cleanup and dispose of PCB-contaminated materials. Documents reviewed to identify properties of concern included aerial photographs; City business tax lists; PG&E (i.e., utility) and Coast Guard databases; California Department of Toxic Substances Control (DTSC) files; Alameda County Department of Environmental Health files; lists of businesses that use, store or generate hazardous materials/waste in the City of Oakland; information on illegal dumping sites under surveillance by the City of Oakland; and review of an environmental database

[33] This is the screening value for coarse sediments. Sediment screening values were developed by the Regional Water Board for San Francisco Bay sediments: 8.6 µg/Kg for coarse sediments (<40% fines) and 21.6 µg/Kg for fine sediments (40-100% fines). The derivation method is described in Gandesbery et al. (1998) but is not based on toxicity. Rather, it is a reference indicating if a concentration would be considered elevated relative to ambient Bay sediments.

report for the watershed indicating locations with records of PCB spills, PCB wastes, and/or soil/groundwater investigations and cleanups. Properties were selected for inspection based on the document review and area reconnaissance.

Over a five month period in 2004, the City of Oakland inspected 123 properties (by walking and driving surveys) and recorded relevant information for each property on a checklist. Inspected properties were categorized as low, medium or high priority based on the site history of PCB spills or uses, and site characteristics or management practices that increased the likelihood of on-site pollutants migrating to stormwater. Based on inspection results, the City selected sites in the public ROW for follow-up soil sampling (Kleinfelder 2005). These data were used to evaluate the effectiveness of the low/medium/high site prioritization. PCB concentrations above soil screening levels defined by the Regional Water Board (residential Environmental Screening Level [ESL]) and the state (CA Human Health screening level [CHHSL]) were detected at both the sites characterized as high priority, in addition to the sites characterized as medium to low priority. However, the highest PCB concentrations were largely detected at the high priority sites. After review of ROW sampling results, 23 locations on 19 private properties were selected for additional sample collection (Kleinfelder 2006b). Property access for sample collection was coordinated through the City's Certified Unified Program Agency (CUPA) authority, an agency that enforces state hazardous waste standards under the California Environmental Protection Agency (http://www.calepa.ca.gov).

In addition to soil samples collected from private property and ROW for the grant, the City of Oakland performed a supplemental study to evaluate PCB concentrations in the ROW using a randomized site selection process (Kleinfelder 2006c). Data from the randomized approach was compared with those from the prioritized sampling. The randomized site selection method resulted in identification of 18 ROW sites for sampling. Results from all sets of sample data strongly suggested that private properties were the source of PCBs in the ROW. The private property concentrations were statistically higher than the prioritized right-of-way concentrations, and the prioritized ROW concentrations were higher than the randomized ROW sample concentrations. The City pursued abatement of the private property and prioritized ROW locations. This abatement is described in the next section.

CW4CB Project

Of the $7 million total funds for the CW4CB project, $2.6 million is allotted for PCB load reduction. As described above, pilot studies are planned in the CW4CB project with the objective of comparing approaches for reducing PCBs and other contaminants in stormwater runoff to the Bay (BASMAA 2012). The project began in July 2010.

The three pilot studies in this project are designed to:

- Identify source properties for referral to regulatory agencies that can enforce abatement (Task 3),
- Evaluate various operation and maintenance enhancement activities for pollutant reduction (Task 4), and

- Evaluate effectiveness of urban stormwater runoff treatment structures (Task 5).

These studies cover Tasks 3-5 in the grant proposal (BASMAA 2009). For the purpose of this report, only the scope and approach for Task 3 ($1.1 million allotment) will be described because it encompasses source tracing techniques. Although other contaminants are being considered in this task, the presence of PCBs will be the focus (BASMAA 2009). Source tracing in Task 3 is modelled after the City of Oakland's Ettie Street Pump Station subwatershed investigations described above. Thus, this suggests the Ettie Street Pump Station investigations are generally considered successful and an adequate model for additional source tracing work.

Task 3 was scoped to identify five subwatersheds that were previously documented as high priority with respect to PCB contributions from stormwater to the Bay. The project team plans to conduct a records review, driving/walking survey, site inspections, and sediment/soil sampling to identify sources that would be referred to The Regional Water Board for abatement follow up. As of September 2012, the records review, driving/walking survey and site inspections had been completed with sampling scheduled for Fall 2012 (BASMAA 2012). The grant proposal indicates that the records review will include interviews of local and state agency staff and review of several sources of information such as local and state databases, relevant agency files, and other records as appropriate (available business records, land use records, Sanborn Fire Insurance Maps, aerial photographs, etc.). The objective of the records review is to identify potential PCB/mercury source properties and areas where contaminated sediment may have accumulated, including within the stormwater conveyance system. Areas identified as being potentially contaminated will be assigned a preliminary priority ranking.

The driving/walking survey will be conducted across the entire area of each project subwatershed to identify high priority properties for site inspections. The survey will further identify potential source areas and determine if runoff from these locations is likely to convey soils/sediments with PCBs or mercury to municipal stormwater conveyances. Based on criteria developed during the Ettie Street project, potential high priority sites may include a previously identified PCB spill site, sites with potential for soils/sediments to erode and migrate off-site, or sites with outdoor storage yards and storage tanks or poor housekeeping.

Site inspections will be conducted using the checklist developed for the Ettie Street project with some adaptations as appropriate. Inspected sites will then be ranked for further investigation using criteria developed during the Ettie Street project, adapted for this project as appropriate.

As with the Ettie Street project, sampling will occur on both the public ROW and private properties in areas suggested by the review, survey and inspection steps. An estimated 70 soil/sediment samples are scoped for collection from each of the five project subwatersheds (350 samples total), which is comparable in scale to the Ettie Street project. Samples will be analyzed for PCBs, total mercury, total organic carbon and particle size distribution. Ten percent of these samples will also be analyzed for dioxins, PBDEs, legacy

chlorinated pesticides, and PAHs. An example of a specific workplan for one of the five subwatershed projects is available online for the Leo Avenue Watershed in San Jose (EOA 2011) (http://www.scvurppp-w2k.com/pdfs/1011/PCB_ID_Pilot_Project_Leo_Ave_San_Jose_2011.pdf)

At the time of this report, the CW4CB grant project remains ongoing and the original schedule has been extended to September, 2017 (EOA 2016). Soil/sediment samples have been collected and analyzed from public ROW (Phase I) and private properties (Phase II) (~100 samples total). Data review has resulted in seven properties referred to the Regional Water Board as of April, 2016. Preliminary results were unavailable so it is unknown how many of these were potential PCB source sites.

Regional Monitoring Program

SFEI monitors contaminant concentrations, including PCBs, in water, sediment, sport fish, and bird eggs in the Bay under their RMP status and trends program. Surface water is sampled every four years and sediment is monitored biennially (alternating between wet season and dry season sampling) (http://www.sfei.org/rmp). Since 2002, monitoring samples have been analyzed for PCB congeners by EPA Method 1668 (McKee 2015a, pers. comm.). The historic study design for water and sediment chemistry was changed in 2002 from a discharge-focused, fixed station design to a randomized study design which retained a subset of the historic fixed stations. Sport fish were monitored triennially from 1997 to 2009. In 2014, the schedule changed to a five year frequency for fish and a ten year frequency for water. Sport fish samples are analyzed as composites of fillet tissue. The periodic monitoring of benthic taxonomy and water and sediment toxicity enhance the chemistry monitoring data. Also, triennial bird egg tissue monitoring was added in 2008 to follow bioaccumulation of PCBs in wildlife and small fish tissue monitoring was conducted in 2009 for the first time.

In addition to the status and trends program, the RMP conducts special studies to assist in answering current questions on contaminants. For example, studies have included estimates of pollutant loadings (McKee et al. 2012; David et al. 2012), spatial characterization of contaminant concentrations in urban stormwater (Yee and McKee 2010; McKee et al. 2012), and, with grant funding, estimates of PCB mass in caulk on existing buildings (see Appendix A for concentrations) (Klosterhaus et al. 2014).

SFEI developed the PCB Strategy to guide the RMP and ensure that the program produces information that managers need to find remedies for PCB reduction in the Bay. Because the RMP addresses multiple contaminants, the PCB Strategy provides direction specific to the objectives for PCBs. Studies under this PCB Strategy began in 2010.

4.2.2.3 Summary of Findings

This section describes abatement activities and PCB results for the various stages of the Ettie Street Pump Station source investigations and major findings of the RMP.

Ettie Street Pump Station

The Ettie Street basin source investigations were driven by results of the 2000 Bay area characterization (KLI and EOA 2002) that detected elevated total PCB sediment concentrations at the pump station (3,263 µg/Kg) relative to other areas in the region. Total PCBs measured in the subsequent Phase I sediment characterization of the Ettie Street basin ranged from 25 – 1,004 µg/Kg (Table 13; Figure 23). PCB concentrations measured during Phase II in samples collected along the conveyance branch with the highest Phase I concentrations, ranged from <100 µg/Kg to approximately 2,500 µg/Kg. Linear regression modeling of all the Ettie Street basin sediment data indicated that the drainage with the second highest PCB concentration (EP2-6) likely contributed more of the load to the pump station, not the drainage with the highest concentration (EP2-7). Thus, it was recommended that further investigations focus on this drainage.

Table 13. Maximum PCB concentrations from early Ettie Street basin conveyance sediments.

Investigation	Sediment Range (µg/Kg)
Ettie Street Pump Station	3,263 (n=1)
Phase I – Ettie St. conveyance	25 – 1,004 (n=5)
Phase II – Focused branch	<100 – ~2,500 (n=9)

Data from Salop et al. (2002)

The inspections conducted during the City of Oakland's source identification and abatement study immediately resulted in discovery of a 55-gallon barrel labeled as containing PCBs, along with other unlabeled barrels. The barrels were located in the yard of an active asbestos abatement business (Salop et al. 2006).

Based on the inspection and previous data reviews, sites were categorized into low, medium and high priority (Table 14). PCB concentrations ranging from 23 to 31,000 µg/Kg were detected in soils at public ROW high priority sites. The property with the maximum PCB concentration was adjacent to the property where the PCB-labelled barrel was discovered. Of the 41 samples collected from 37 high priority sites, 25 exceeded the Regional Water Board residential ESL of 220 µg/Kg and 33 exceeded the CHHSL of 89 µg/Kg. Thirteen of 25 samples collected from private property exceeded the industrial soil ESL of 740 µg/Kg. The a maximum PCB concentration 93,000 µg/Kg was measured at a marble cutting facility located on property previously involved with disposal of PCB-containing waste.

Table 14. Concentration ranges for soils sampled at Ettie Street Basin right-of-way and private property sites

Investigation	Concentration Range (µg/Kg)
Right-of-way high priority	23 – 31,328 (n=37)
Right-of-way medium priority	28 – 750 (n=8)
Right-of-way low priority	9 – 993 (n=8)
Private property	40 – 93,411 (n=23)
Random right-of-way sampling	17 – 2,287 (n=18)

Data from Kleinfelder 2006a and c

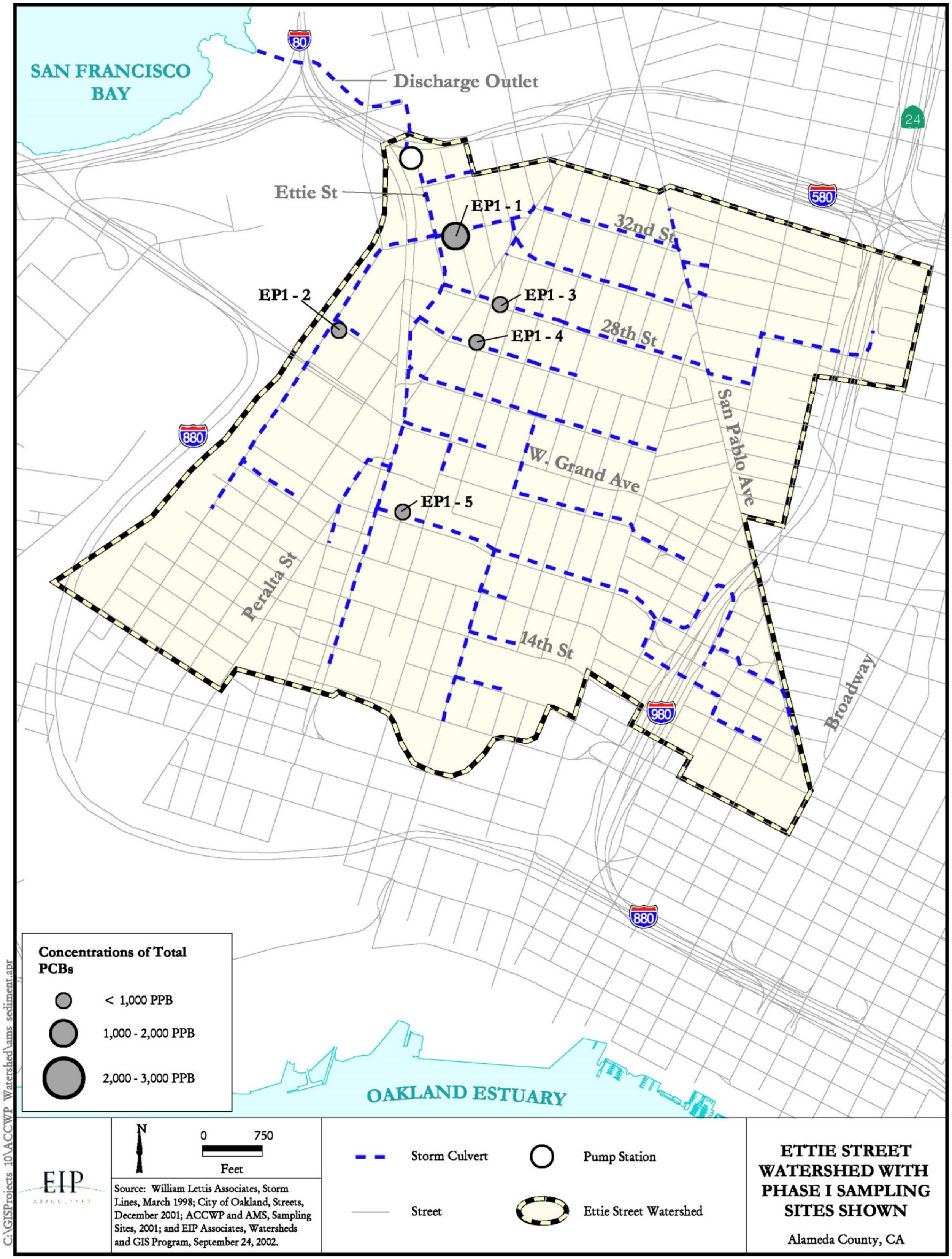

Figure 23. Ettie Street Watershed Phase I sampling locations (Figure from Salop et al. 2002)

ROW sampling results confirmed that high priority sites had higher PCB concentrations than either the medium or low category sites, although there was no statistical difference between them. The average measured PCB concentration was approximately four times higher for high priority than medium priority sites. Average PCB concentrations in low and medium categories were similar (Salop et al. 2006). PCB concentrations in the randomized ROW soil samples ranged from 17 to 2,287 μg/Kg. As discussed earlier, comparison of all ROW and private property sample results showed that private property sites were likely contaminating ROW sites.

As mentioned earlier, abatement activities were conducted in both ROW and private property locations prioritized during the data collection phase (City of Oakland Case Study). Sites where soil PCB concentrations exceeded the residential ESL (220 μg/Kg) were proposed for abatement (Kleinfelder 2006a). However, the DTSC requires abatement of any private property with PCB concentrations over 1,000 μg/Kg. Thus, DTSC oversaw abatement activities at nine private properties. At the other 13 properties, where PCB levels were between 220 and 1,000 μg/Kg, abatement was overseen by the Regional Water Board and local agencies (Kleinfelder 2006a). Therefore, abatement of private properties was conducted by regulatory authorities and independently of the City of Oakland grant project.

Screening level exceedances were used to prioritize 11 ROW sites for abatement. This list was narrowed to two areas based on abatement method feasibility and site proximity to the pump station and residences. Higher than anticipated sampling costs limited the number of areas that could be abated to two, which were both illegal dump sites. Debris and dry sediment removal was conducted prior to power washing of paved streets, gutters, and sidewalks. An estimated 8 g of PCBs were removed from the ROW in the two abated areas (Kleinfelder 2006a). Sampling results from the storm drain and ROW one year post-abatement showed decreased concentrations ranging from 27-94% of pre-abatement levels. The results suggested that decreases were larger where private property abatement had also occurred (Kleinfelder 2007).

Regional Monitoring Program

Comparison of 2002-2003 to 2007-2012 sediment monitoring data suggests that PCB concentrations in the Bay may be declining; however, further sampling is needed to demonstrate this as a significant trend (SFEI 2014). Although mussel monitoring data show a significant decrease in PCB concentrations since 1980, sport fish data (only available since 1997) suggest that PCB concentrations are not declining (Davis et al. 2014). SFEI publishes monitoring data reports regularly and current and historical reports can be found on their website (see Appendix C for web links).

Collectively, RMP special studies and monitoring data have led to several key findings (Davis et al. 2014). Some examples (SFEI 2014) are:

- RMP monitoring data helped prioritize four of 24 stormwater basins sampled for source investigations based on suspended sediment PCB concentrations (>400 µg/Kg).
- RMP fish tissue monitoring data has helped identify contaminated sites in margins of the Bay (i.e., not in the open Bay).
- Small tributaries are the pathway of largest PCB loadings to the Bay.
- Stormwater loadings are primarily associated with large storm events and suspended sediment.
- Older urban and industrial land uses is linked to the highest PCB concentrations.

SFEI summarized storm collection facility sediments and streetside soils data across the Bay Area; PCB concentrations ranged from nondetect to 93,000 µg/Kg (Table 15, Figure 24) (Yee and McKee 2010). An SFEI survey of storm drain and creek/river stormflow water in 17 watersheds found PCB concentrations ranged from 700 to 468,000 pg/L (McKee et al. 2012). McKee et al. (2012) found the stations with the highest water PCB concentrations also had the lowest suspended solids concentrations suggesting that these locations would be more cost-effective than the others to target for source control.

Table 15. Ranges of PCB Concentrations in sediments/soils and stormwater found in Bay Areas surveys.

Sample type	Concentration Range	Units
Storm facility and streetside soils	ND-93,000	µg/Kg
Stormwater	700-468,000	pg/L

Special studies too numerous to summarize have been conducted over the years by SFEI. The study of PCBs in building caulk was particularly relevant to source tracing. This study found 40% of caulk samples (n=25) exceeded 50 mg/Kg PCBs and detectable results ranged from 1 to 220,000 mg/Kg (Klosterhaus et al. 2014). The authors estimated that 10,500 kg of PCBs were present in internal and external caulking of existing buildings in the Bay Area. A portable XRF (a field chlorine detector) was tested as a screening tool and the authors concluded it is useful to screen caulk at concentrations >10,000 mg/Kg. A searchable library of publications is available at their website for further information (http://www.sfei.org/biblio/author/212%3Fsort%3Dyear%26order%3Dasc).

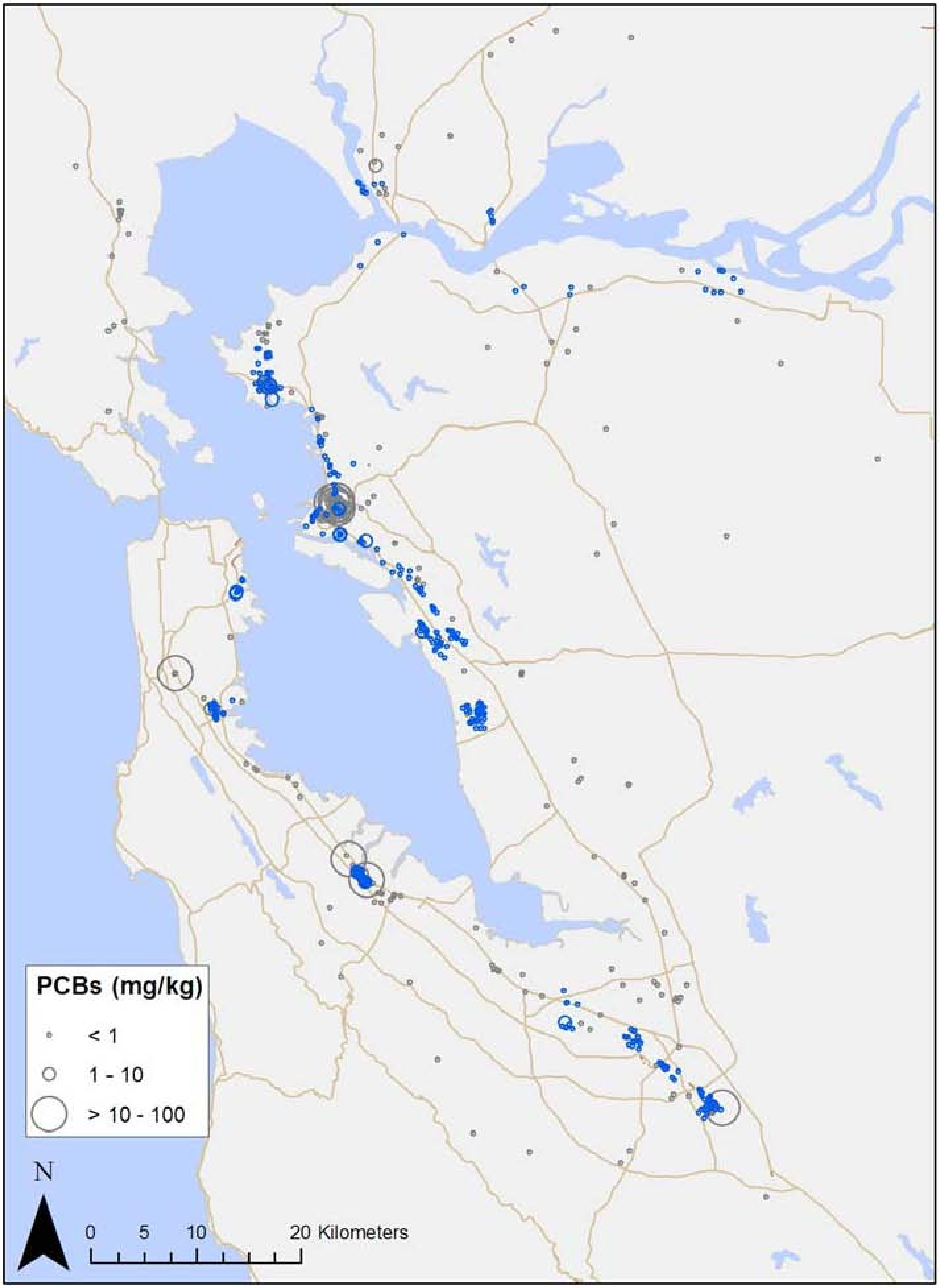

Figure 24. PCB concentrations in storm facility collection systems and streetside soils in the Bay Area (Figure from Yee and McKee 2010).

4.3 Summary of Programs

Each source tracing program summarized above is unique in the combination of elements selected as tools to locate where PCBs (and other contaminants) enter separated or combined stormwater conveyance systems. At least two of the following tools were/are used in various combinations in each program (Table 16):

- Status and trends monitoring in receiving waters
- Long-term monitoring of water and/or solids in system
- Initial spatial survey of PCBs
- Track-down inline sampling (stormwater and CSOs)
    - Sediment traps
    - Catch basin sediments
    - Grab or composite water sampling
- Influent and effluent wastewater sampling
- Historical records review (e.g., chemistry and land use data, property use history, cleanup site locations)
- Business visits and inspections (can include sampling)
- Visual surveys
- Pipe cleaning (to identify ongoing sources)
- Street level soils sampling
- Fingerprinting by homologue analysis or PMF
- Product testing
- Analysis of contaminated materials in building and road structures or in the conveyance system.

Table 15 summarizes the source tracing tools, sample materials tested and common PCB analyses used by the parties in this report. Note that the "Other" agencies only include parties mentioned in this report.

Several of these tools involve prioritization of geographic areas based on environmental concentrations. Sometimes prioritization is done using a pre-established screening threshold concentration (e.g., the Regional Water Board's thresholds for San Francisco Bay sediments) or one developed from a data distribution (e.g., as done by City of Tacoma). Regulatory screening thresholds are not usually applicable to environmental samples collected in source tracing investigations. However, sometimes state or federal criteria or cleanup levels are used as a screening guide. Permit-specified discharge limits and state or federal soil cleanup levels may legally apply in some situations.

Although the source tracing programs reviewed here have used a variety of approaches to locate sources, all have started with some type of spatial prioritization of drainage areas. This step has been achieved with different tools depending on the program. Typically, a

review of existing PCB data from either receiving waters or discharges is conducted and supplemented with a historical records review (e.g., land use, industry activity, parcel ownership). Without historical data, an initial spatial survey may be required. Further characterization of identified high priority drainage areas often follows using a finer scale survey (to reduce spatial scale) or progresses directly into a source investigation. Source investigations have generally used trackback (or trackdown) sampling that moves upstream to isolate sources (used by Cities of Tacoma, Oakland and Portland, and CCMUA) and/or business inspections or windshield surveys (Cities of Seattle and Oakland, and Urban Waters Program in Spokane and CCMUA) paired with confirmatory street level sediment/soils sampling. For most of the source tracing examples described, business inspections or windshield surveys alone did not result in a high success rate for source identification (SRHD in Spokane, Cities of Oakland and Seattle). Historical reviews of information such as land use, environmental chemistry data, and/or property ownership can provide a starting point for potential sources, but is more effective when partnered with sampling. In areas with numerous known PCB cleanup sites, a review of historical records can be successful in quickly identifying significant sources such as in the Delaware River Basin (see CCMUA example; DRBC 2015, pers. comm.).

Agencies have successfully used line cleaning to test whether PCBs that have accumulated in the stormwater conveyance system over time are being released either slowly or periodically (depending on system flow rates). While line cleaning is relatively expensive and may not be feasible, it can be used for multiple purposes (e.g., under an NPDES permit action), and may be opportunistically implemented. If follow-up testing shows recontamination of the lines, an ongoing PCB source is indicated. This source may ultimately be located outside the conveyance system (e.g., building caulk, paint) or within the conveyance system due to contaminated construction materials. For example, the City of Tacoma found that road sealant within the conveyance system of the East Tacoma neighborhood was contributing PCBs to stormwater.

Receiving water monitoring (of water, sediments or tissue) is a valuable tool that provides a baseline to measure future changes. These data also assist in identification of the most contaminated areas needing drainage characterization and potential source tracing, and allow for future estimation of source pathway loads. The timing of source pathway load estimation may depend on site-specific regulatory drivers: establishing a TMDL starts with load quantification and allocation, whereas Superfund, RCRA, and in Washington State, MTCA drivers focus first on defining the level of contamination and a cleanup goal. Regardless of the regulatory driver, an initial coarse estimation of source pathway loads provides key information that efficiently focuses source tracing resources. At TMDL sites, receiving water monitoring is most often funded and/or conducted by regulatory agencies, whereas at cleanup sites, regulatory agencies may require this monitoring be conducted by Potentially Responsible Parties.

Table 16. PCB source tracing tools used and sample types and analyses tested by region.

	Region	**LDW**				**Spokane**				**Tacoma**		**Portland**		**Delaware River Basin**			**San Francisco Bay**		
	Regulatory Driver	CERCLA/MTCA				CWA violations				CERCLA/MTCA		CERCLA[2]		TMDL			TMDL		
	Tool/Agency	SPU	Ecology	NBF parties	Other	City	County Wastewater	SRHD[1]	Ecology	City	Other	City	Other	DRBC	CCMUA	Other	City of Oakland	SFEI	Other
Tool	Receiving waterbody monitoring				X				X	X			X	X		X		X	
	Pathway loadings estimation								X		X			X	X[3]			X	
	System mapping and monitoring	X		X		X	X			X		X					X		
	Spatial surveys (for system/pathway prioritization)	X				X						X			X		X	X	
	Trackdown sampling									X					X		X		
	Business inspections/reconnaissance	X	X					X		X		X			X		X		
	Historical records review		X			X		X	X	X		X			X		X		
	Line cleaning			X		X				X									
	Street level sampling	X		X		X				X		X			X		X		
	Homologue/congener data analysis						X								X		X		
	Product testing					X			X										
Method	**Typical PCB Analysis**																		
	Aroclor	X		X		X			X	X		X					X		
	Homologue or congener					X	X		X					X[4]	X		X	X	
Materials	**Materials Tested**																		
	In line solids (trap, catch basin)	X				X				X		X			X		X	X	
	Water						X								X			X	
	Soils	X		X		X			X	X		X			X		X	X	
	Conveyance system materials			X						X									
	Building/construction materials	X		X						X								X	

Notes: This table only covers source tracing programs discussed in this report and other parties that have been mentioned. PCB source tracing activities for other programs are not included.
Shaded – Methods and Materials used by other parties are not summarized in this table.
Blank - not used by agency in examples described.
[1] As a partner with Ecology, SCRHD activities were limited to business visits, no sampling or remedial activities.
[2] State of Oregon cleanup laws also apply and are similar to Washington State's MTCA. They are specified in Oregon revised statutes Chapters 465 and 466.
[3] The NPDES permit requires regular reporting of PCB loads.
[4] DRBC requires congener data for permit discharges.
CERCLA – Comprehensive Environmental Response Compensation and Liability Act
MTCA – Washington's Model Toxics Control Act
CWA – Clean Water Act
NBF – North Boeing Field
SPU – Seattle Public Utilities
SRHD – Spokane Regional Health District

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Product testing has been conducted in the Spokane Region because of the potential importance of inadvertently-produced PCBs in off-the-shelf products. Congener analysis results indicated that inks and pigments are an important PCB source to the County wastewater system. Also, challenges in identifying classic PCB sources to stormwater systems, such as former electric utility properties and cleanup sites, are resulting in the need for creative thought in exploring more diffuse PCB sources. Inadvertently-produced PCBs in products are believed to contribute total PCB concentrations much lower than the Aroclors historically added to paints and caulks (parts per trillion/billion versus parts per million/thousand).

There are benefits and drawbacks to sampling whole water versus accumulated or suspended (by trap or filter) solids in stormwater and wastewater systems. Sampling and analysis of suspended or accumulated solids instead of water is common in the PCB source tracing programs reviewed in this report. Some reasons for this are that PCBs bind strongly to solids, solids can be sampled more inexpensively than water, and PCB concentrations on solids are often detectable using the less expensive Aroclor analytical method. However, accumulated solids data may be influenced by historic sources, specific grain size accumulated, and local dilution by clean sediment. Sediment traps can also result in particle size bias. In separated wastewater systems, whole water samples are often collected for analysis. Because solids removal is inherent to wastewater treatment, water concentrations are more relevant for examining PCB load reductions in wastewater discharges. Composite sampling for water (manually or by autosampler) can obtain a more representative sample than instantaneous grab measurements, although it is challenging to obtain a composite sample representative of an entire storm due to their unpredictability. PCB concentrations in whole water are typically so low they are not detectable, except by congener methods. This type of sampling can require greater sample volumes, more equipment and laboratory funding than solids sampling, but provides a more accurate picture of the quantity of PCBs reaching a receiving water body. Thus, the selection of water or solids sampling should consider the project objectives (e.g., screening survey, loadings estimate), budget, sampling expertise and available equipment, expected detection levels and the tradeoffs of each sampling method.

As demonstrated by the Cities of Spokane and Oakland, there can be value in analyzing solids for PCB congeners or homologues, although this is more costly. Some agencies have found homologue or congener data useful for providing more information about the possible derivation of the PCB sources (e.g., Spokane County, Cities of Spokane and Oakland, SFEI). Homologue data allow a minimum level of pattern analysis to identify the types of PCBs present – specific Aroclors or simply light versus heavy PCBs. Congener data provide even more information and allow more precise pattern matching for Aroclors, analysis of Aroclor weathering (i.e., dechlorination), and indicators of specific congener dominance. Advanced statistical analyses, such as PMF, can indicate if multiple sources may be present and whether byproduct PCBs, such as PCB 11, may meaningfully contribute as a PCB source. Based on PMF analysis, Spokane County learned that inks and pigments are significant contributors to their wastewater influent and even more dominant in the effluent. Some agencies balance the costs and benefits of congener analysis by using

Aroclor analysis as a screening tool, and congener analysis for detailed source tracing (e.g., City of Spokane). Alternatively, a subset of samples can be analyzed for congeners.

Additional PCB screening methods have been tested on occasion and may prove helpful in certain situations. For example, ELISA testing of street soils by CCMUA confirmed that this method, although it underestimates concentrations above 1,000 µg/Kg, can still effectively identify elevated PCB concentrations. SFEI concluded that the XRF field detector was useful for screening caulk because it can detect relatively low PCB concentrations (below 10,000 mg/Kg) avoiding these caulk samples from being sent for laboratory analysis.

In most of the geographic regions covered, the stormwater runoff pathway typically contributes the greatest loads in the local area (i.e., upstream sources may also be important). Separated stormwater and combined system source tracing appear to be the most challenging, likely due to the wide variety of possible sources in stormwater and the lack of sophisticated and centralized stormwater treatment. Source tracing in separated wastewater systems benefits from established wastewater systems allowing for convenient influent monitoring and a minimum PCB reduction through existing treatment technologies. For example, Spokane County is able to reduce their influent PCB concentrations by 99% with their existing treatment technology. In addition, the source tracing example in a combined system in the Delaware River Basin demonstrated that the largest sources are often contributed by the stormwater portion of the combined system.

While the source tracing programs described here identify contaminated properties, the ultimate identity of PCB sources is sometimes unknown; however, several specific PCB sources have been identified. Very high concentrations of PCBs have been found in building and sidewalk caulk (in Tacoma), airport runway caulk and building paint (in Seattle), storage barrels of PCB oil (in Oakland), steam plant flume residue (in Seattle) and road sealant (in Tacoma). Contaminated soils were often found either on properties newly identified by source tracing (in Portland) or on and around properties that had previously been remediated (in Spokane, Seattle, and Portland). These latter situations demonstrate that historic remediation at cleanup sites does not eliminate the need for reconsideration during PCB source tracing. Ongoing industries may also be active sources of PCBs; metal shredding facilities are associated with PCB contamination in Seattle and New Jersey. Two illegal dump sites were identified as PCB sources in Oakland. Likely smaller but potentially important contributors to wastewater and stormwater discharges include inadvertently produced PCBs in products.

5.0 LABORATORY ANALYTICAL METHODS FOR PCBS

PCBs can be analyzed by a variety of laboratory methods. These methods cover three different levels of identification: Aroclors, homologues, and congeners. When PCBs were legally manufactured, they were produced by Monsanto in the U.S. as PCB mixtures called Aroclors. Two-hundred and nine individual PCB congeners can theoretically be present in a sample, each differing by level of chlorination and position of the chlorine molecules. PCBs are most commonly analyzed as Aroclors or as individual congeners. An additional method has also been developed that analyzes PCB congeners grouped by chlorination level, or PCB homologues. This section describes and compares these three methods.

Aroclors are analyzed using a gas chromatography method (EPA Method 8082A, EPA 2007)[34]. An analyst uses patterns in the chromatograph of the sample extract to identify the presence of specific Aroclors. Once the Aroclors are identified, the chromatograph is compared to Aroclor standards to determine the concentration of each detected Aroclor. Only the detected Aroclor concentrations are typically summed to calculate total PCBs.

The Aroclor method is relatively inexpensive, especially compared to the PCB congener method; however, there are several drawbacks to this analysis. The detection limits for Aroclors are relatively high, often above risk-based thresholds (Ecology 2014b; Narquis et al. 2007).The method relies on analyst interpretation of the chromatogram compared to Aroclor standards, which is a subjective process. This can be further complicated by pattern disruption due to the presence of multiple Aroclors, weathered Aroclors, other chlorinated compounds (such as chlorinated pesticides), or PCBs from sources other than Aroclor mixtures. When testing Aroclor products (e.g. transformer oil) or relatively high PCB concentrations, the Aroclor method may be preferable to high resolution methods, which are specialized for low range PCB concentrations. Congener detection limits are in sediments are generally 0.005 μg/Kg compared to 0.5 μg/Kg for Aroclors (Ecology 2014b).

PCB congeners are analyzed using a high-resolution gas chromatography/mass spectrometer method (EPA Method 1668C, EPA 2010). This method is able to detect and quantify individual PCBs, with the exception of some co-eluting congeners, which are quantified together. Only detected congener concentrations are typically summed to calculate total PCBs, but summing subsets of congeners is also common[35].

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[34] This method can also be used to identify and quantify a subset of PCB congeners, as done in San Francisco (Section 4.2.2). As written, the method can analyze for 19 congeners, but may be modified to include a larger congener subset. The method is not designed to identify relatively low concentrations (ppt) of coplanar PCBs.

[35] One common PCB congener subset is based on a list of 12 most toxic PCB congeners as identified by the World Health Organization (Narquis et al. 2007). SFEI developed a list of 40 congeners used as a standardized total PCB sum for TMDL monitoring. The 40 congeners were selected based on several factors including their toxicity, bioaccumulation in fish, and abundance in San Francisco Bay samples (Davis et al. 2014).

There are several benefits to the PCB congener method. The detection limits are orders of magnitude lower than the other two methods; therefore, PCBs measured with this method can be quantified at very low concentrations (e.g., parts per quadrillion). Also, by quantifying individual congeners, congener profiles can be used to assist in source identification or to consider differences in toxicity between congeners. PCB congener data can be used to calculate toxicity equivalents based on the relative toxicity of detected congeners (Ecology 2014b; Narquis et al. 2007).

The primary drawbacks to the PCB congener method are the need for specialized equipment and costs, which can be about four to five times higher than for Aroclor analysis (Ecology 2014b). Furthermore, since many PCBs are ubiquitous, and detection limits are relatively low, PCB congeners are often detected in method and equipment blanks. The PCB concentrations in blanks are usually well below environmental PCB concentrations, but in some instances, can be within the range of ambient water quality criteria (e.g. Oregon's human health water quality criteria, OAR 340-041-0033, Table 40). There are several methods to address PCB contamination in blanks. Some jurisdictions follow EPA guidance for validation, which suggests flagging results that are within five times the method blank concentrations as nondetects (EPA 1995). Other jurisdictions flag results that are within three or 10 times the blank concentrations (City of Spokane 2015, pers. comm.), while others subtract method blank concentrations from sample results, or "blank correct" (Brown and Caldwell 2014). The congener method is specialized for low PCB concentrations and may not be appropriate for samples with particularly high PCB concentrations. These issues are important to consider before selecting the PCB congener method.

The PCB homologue method uses a low-resolution gas chromatography/mass spectrometer method (EPA Method 8270D modified, EPA 1994), and detected results are summed to calculate total PCBs. This method was developed as a potential compromise between the Aroclor and congener analytical methods, but has not been promulgated by the EPA. This method generally results in detection limits below risk-based thresholds, but with costs about half those of the congener analysis (Ecology 2014b). Identification of homologue groups can be used to develop general PCB profile patterns, including rough estimates of toxicity (Ecology 2014b).

Determination of the appropriate analytical method can depend on the sample matrix, the expected level of contamination, and how the data will be used. If PCB concentrations are expected to be relatively high, and/or only a general estimate of total PCBs is needed, the Aroclor method may be appropriate. Given the hydrophobicity and persistence of PCBs, concentrations are generally higher in solid matrices (i.e., sediment or tissue), or in areas with legacy contamination. The potential for weathering must also be considered when using Aroclor analysis. In areas without known PCB point sources, or for water column samples, use of the more sensitive methods (congeners or homologs) may be appropriate. It is also important to consider how the data will be used. The Aroclor method can work well for screening purposes, but quantitating PCBs at lower levels generally requires the use of more sensitive methods. Other considerations include future use of data for source

profiling analysis (as performed in Spokane), methods mandated in statute or regulation, and comparability with historical data. Due to differences in quantification (as described above), the different analytical methods are not necessarily interchangeable (Narquis et al. 2007). A study conducted by Ecology (2014a) provides additional information about the comparability and tradeoffs of Aroclor, homologue and congener methods.

6.0 CHALLENGES WITH PCB SOURCE TRACING AND LESSONS LEARNED

Challenges facing PCB source tracing range from sampling logistics to property access issues. This section discusses the most common hurdles that can impede effective source tracing and how some jurisdictions manage their programs to minimize some of these challenges given their resources and constraints. The challenges discussed here are in no way comprehensive, but highlight those shared amongst multiple jurisdictions consulted for this report.

6.1 Public Awareness

Unless one is experienced working on PCB contamination, PCBs are commonly considered to be a contaminant of the past, only associated with legacy spills or remnant electrical equipment (e.g., old transformers). The fact that building materials, such as caulk and paint, can be significant PCB sources with ongoing releases is frequently unknown to the general population. Even less frequently understood is the fact that PCBs can be legally present in off-the-shelf commercial products (e.g., inks and pigments) when resulting from inadvertent production during manufacturing and in concentrations less than 50 mg/Kg (per TSCA limits).

DRBC has noted that misperceptions about where PCBs can be located often results in regulated parties not realizing that potential PCB sources could be present at their facilities (Cavallo 2014). Regulated parties may not be aware of to the most effective methods to reduce PCB loads from their properties, and may believe the majority of the load is from air deposition, and, thus, outside their control (Cavallo 2014). Ecology has also found that business owners without experience in site contamination, usually small–to–medium size businesses, can be less cooperative in response to business inspections (Ecology 2015, pers. comm.).

Public education programs have been implemented to change the general public perception that PCB sources are limited to industrial sources. Education of the public may be one of the most important tools when consumer product use is believed to contribute significant PCB mass to stormwater or wastewater systems. Spokane County is pursuing public education because their largest PCB sources appear to be from product use. The County has distributed a PCB Primer pamphlet (Appendix D) to wastewater customers to start this process.

6.2 Sampling

Numerous technical and logistical issues can be encountered when sampling media of any kind for source tracing purposes. However, the greatest challenges are encountered when working inside a piped conveyance system. These systems have restricted access points that may or may not present opportunities to collect solids or water samples. In addition,

tidal influences can be confounding factors (e.g., in LDW) and system flow rates can be highly variable. These factors make planning for sampling events challenging and require more sophisticated, often more expensive, sampling instruments (e.g., autosamplers). At the same time, PCB concentrations in stormwater runoff are variable during a storm (i.e., across the hydrograph) making the sampling technique a critical factor with the potential to heavily influence the analytical results. Advanced equipment, such as autosamplers, has the dual benefit of allowing programmable and remote initiation of sample collection and the compositing at regular (time or flow-weighted) intervals. However, use of this type of equipment can also pose sample contamination issues (See Section 6.3).

For example, stormwater sampling in Spokane is challenging due to the reasons discussed above and because storm events tend to be intense and short in duration, making sampling windows narrow. Limited funding for Ecology's Urban Waters Program prevented their use of autosamplers (their desired instrument) for stormwater sample collection; they implemented grab sampling as the alternative (Fernandez 2015, pers. comm.). This presented difficult design questions such as the frequency of grab sample collection. Unlike composite samples, grab samples are not integrative; thus, the timing of sample collection can greatly influence the resulting concentrations. Based on the experience in Spokane, collection of grab samples, at a minimum, during the beginning, middle, and end of the hydrograph is recommended as most representative (Fernandez 2015, pers. comm.). Even with the ability to use autosamplers, the City of Spokane experienced the common problem of equipment failure in the field requiring additional sampling attempts (City of Spokane, 2015 pers. comm.).

Solids sampling from accumulation structures, such as catch basins or pump stations, may result in a different temporal representation of PCBs than suspended solids sampling. Unless the system has recently been cleaned, assuring removal of historic sediment accumulation, sampled solids represent accumulation of PCBs over an unknown time period. This uncertainty was discussed for the Ettie Street Pump Station by Salop et al. (2002). Suspended solids samples more reliably represent only the sample collection period. However, collection of suspended solids using sediment traps is also associated with uncertainties due to a potential bias toward certain particle size ranges and/or variability in size of particles trapped. To address this issue, SPU is developing a new type of sediment trap that has the ability to collect a more predictable particle size range (City of Seattle 2015, pers. comm.). Another factor to consider is the overall size of the sediment trap; larger traps can limit the pipe diameter where they can be deployed. The trap type originally designed by Ecology, and commonly used in Washington State, has been used by SPU. However, due to its' large size, it cannot be deployed in the City of Seattle's smaller diameter pipes. Thus, a second design goal is to target a trap size to fit inside SPU's smaller diameter 12–18" pipes (City of Seattle 2015, pers. comm.). Suspended solids sampling by water filtration results in less bias by sampling a consistent and larger particle size distribution, but the water volume requirements of this method make it infeasible in conveyance systems.

Solids sampling at accumulation structures, such as catch basins or pump stations, can alleviate the challenge of meeting minimum mass requirements for laboratory analysis posed by sediment traps. However, some agencies have run into issues with the ability to collect sufficient mass at planned collection points. The cities of Spokane, Tacoma and Oakland experienced this problem resulting in sample collection at fewer stations than expected (City of Spokane 2013; City of Tacoma 2013; Salop et al. 2002). Planning ahead, along with identification of potential backup sampling stations, can optimize study designs to avoid this problem.

6.3 Laboratory Analysis, Data Validation, and Data Management

Some of the most commonly cited challenges related to PCB source tracing are the cost of PCB analysis, method blank contamination, and variable detection limits (Spokane County 2015, pers. comm.; City of Spokane 2015, pers. comm.; DRBC 2015, pers. comm.). The low level PCB congener (i.e., EPA Method 1668) method is particularly expensive, often over $700 per sample. Analytical costs limit the number of samples that can be collected, which challenges the spatial coverage of study designs. To optimize sample value for the analytical cost, sample compositing is often conducted. Several agencies have taken this approach during source investigations as previously described (Section 4.0). Composite sampling is particularly effective when starting with a large spatial area relative to the analytical budget.

Method blank contamination is commonly observed when using the PCB congener method. This is due to low detection limits, which results in the ability to detect background PCB concentrations. Although laboratories can clean their facilities and become certified for low level PCB analysis, it is not unusual to observe detectable PCB concentrations in method blank samples. Due to the background level of PCBs in the environment, equipment blank contamination is also common. However, method blank and equipment contamination are generally only problematic when samples have low (i.e., pptr) PCB concentrations. There are various approaches to interpret PCB data in situations where method blank contamination is approaching the level of sample results. This evaluation is usually conducted during the data validation stage. A type of sample “correction” is subtraction of average method blank PCB concentrations from sample concentrations; this method has been performed by Spokane County. Others (e.g., City of Spokane) have followed federal or local guidance or established their own data management rules to account for method blank contamination; these rules involve requalifying sample results that fall below an uncertainty factor (e.g., within 3, 5 or 10 times the concentration) of the corresponding method blank concentration as nondetect. For example, EPA provides guidance for Superfund sites (EPA 1995) to assist with evaluation of method blank contamination by PCBs using EPA Method 1668. However, each of these approaches can result in biased results. Therefore, careful consideration of how method blank evaluation options may affect the magnitude and direction (i.e., low or high) of bias is important.

Because of the sensitivity of low level PCB methods and products that inadvertently contain PCBs, decontamination of equipment and inclusion of equipment blank samples in a sampling program is important. DRBC found that equipment blank contamination can be a challenge (DRBC 2015, pers. comm.). Common sampling supplies, like silicon tubing used in autosamplers, have been found to contain PCBs (Perdih and Jan 1994) and are generally not recommended for use when collecting samples for low-level PCB analysis (Rodenburg 2015). King County is currently conducting a study to assess potential equipment contamination by comparing PCB concentration in samples collected using autosamplers (with silicon tubing) to those in concurrently collected composite grab samples. This study will also include equipment blanks collected using platinum-cured silicone tubing (King County 2015). The SFEI found that platinum-cured silicone tubing for autosampler pumps in combination with Teflon tubing on the main lines did not result in equipment blank contamination with PCBs (McKee 2016, pers. comm.).

Solids samples typically contain several co-occurring contaminants which sometimes pose analytical challenges, particularly for Aroclor-based methods. Gas Chromatograph/Mass Spectrometer (GC/MS)-based Aroclor methods are one of the most cost effective analyses available for PCBs, but oily waste and residues can obscure the GC/MS chromatogram and make identification and quantification of the PCB pattern difficult or impossible. This raises detection limits, sometimes above screening values used to prioritize areas for further investigation. A related issue is the potential interference of pesticides during analysis due to co-elution in gas chromatography. Salop et al. (2002) experienced this interference from pesticides in some samples collected for Ettie Street Pump Station investigation in Oakland. This also resulted in elevated detection limits, which increased uncertainty of nondetect values.

The selection of an analytical method may also be influenced by mandated methods required in regulations. For example, NPDES wastewater permits require use of EPA Method 608 for permit monitoring (40 CFR Part 136). However, this method is the least sensitive (i.e., high detection limits); therefore, the results may provide a significant number of nondetect results, particularly in wastewater effluent. When discharge limits or water quality goals are in the picogram per liter range, addition of a second, more sensitive analytical method may be necessary.

Lastly, the complexity of data management for PCB data is often underestimated. This may be due to inexperience with PCB data and the high volumes of records resulting from congener analysis. However, even with Aroclor data, if sampling events occur regularly and include other contaminants, the volume of data may grow rapidly and require more sophistication than spreadsheet software. The City of Seattle found substantial time-savings after moving from spreadsheets to the relational design of Earthsoft's EQuIS database (http://help.earthsoft.com/default.asp?W647) for data management (City of Seattle 2015, pers. comm.). Relational database programs (e.g., Microsoft Access®) not only improve data quality control and organization, but also data preparation for advanced analyses, such as homologue/congener pattern and PMF analysis. However, database software can require specialized skills and, hence, may add staff or professional service costs (e.g., a database manager) to any software license fees. These costs can be substantial.

For example, initial purchase costs for SPU's EQuIS® database, hosted externally, totaled $80,500 plus annual fees for licenses and external maintenance of approximately $20,000 (Arthur et al. 2016)[36]. However, modern databases often provide more value than just a data storage tool. Online accessibility and sharing, visualization tools (e.g., GIS), and customized data reports are some of the common features available. In addition, high quality congener analysis demands availability of metadata (e.g., quality control sample results) (Rodenburg 2015, pers. comm.) which increases data management complexity. The benefits to data management costs become more visible over time and it is recommended to plan ahead for data management needs and related resources.

6.4 Legal and Regulatory Authority

Successful efforts by city, county or stormwater/wastewater utilities to locate PCB sources can meet obstacles when there is a lack of legal authority to address identified or suspected sources on private property. CCMUA faced this challenge after identifying two parcels that were releasing PCBs into the stormwater system (Belton et al. 2008). Without legal authority to address sources on the parcel, CCMUA pursued new relationships with local and state regulatory agencies that could compel source control actions (Kricun 2016, pers. comm.). Agencies that conduct source tracing often work closely with regulatory agencies that have access and authority to enter private property and compel cleanup actions. For example, the City of Portland has a legal agreement with ODEQ that defines a process whereby parcels identified by the City as potential PCB sources are investigated by ODEQ. ODEQ has the legal authority to access private properties and pursue source control. In Oakland, the City could rely on the local arm of the state hazardous waste authority to further investigate parcels identified as potential PCB sources. However, across all programs surveyed the authorities for these type of actions varied. The most common authority was with a local or state solid and hazardous waste agency.

Some local agencies in Washington State consulted for this report indicated that the response of, or assistance provided by Ecology and/or EPA, was slower than expected once they had been informed of parcels identified with active PCB releases. There was suggestion of providing guidance for local agencies on how to best coordinate with state and federal agencies when pursuing source investigations on private parcels. The level of assistance received by state and federal agencies may be related to the regulatory tools at hand and the level of resources available. However, establishing procedures and working relationships with the regulatory agencies necessary to successfully locate and abate PCB sources appears to have aided the success of source tracing in areas such as Portland, Oakland and Camden City.

Ecology does not have authority to enter private property if MTCA regulations are not violated or if there is no immediate public safety concern, except for NPDES permit-related business inspections (Ecology 2015, pers. comm.). Thus, when a property owner is

[36] Costs vary depending on the options selected.

unaware of potential sources on their property, or denies the presence of a release it can be challenging and time-consuming for Ecology to exert MTCA authority, gain site access, and initiate site investigations.

EPA is limited by TSCA and available resources to pursue source control actions on parcels identified by others to be releasing PCBs. When a property is already listed under CERCLA or is identified as having MTCA-regulated releases, many additional legal resources become available to compel site investigations. In EPA Region 10, TSCA funding has tightened resulting in a current lack of inspectors and minimal resources for enforcement (EPA 2015, pers. comm.). Given the lack of available resources, it is necessary to provide data to EPA to demonstrate that materials on a parcel contain PCBs in excess of 50 mg/Kg for legal action by EPA. This lack of federal resources puts a larger burden on local and state agencies to pursue source identification and control on private parcels. Considering the spatial variability in PCB concentrations at a site, even within building caulk samples, proving exceedance of the TSCA threshold can be very expensive and time-consuming for local and state agencies.

6.5 Key Lessons Learned from PCB Source Tracing Professionals

The professionals experienced in PCB source tracing who were consulted for this report offered valuable recommendations for others. Almost all of the agencies consulted have been conducting PCB (and other contaminants) source tracing efforts for many years and continue to look for sources. For example, SFEI has been conducting PCB source tracing in San Francisco Bay for 16 years (McKee 2015b, pers. comm.) and continues their efforts, while the DRBC started the ongoing multistep PCB TMDLs in the Delaware River Basin in 2003. Both SFEI and Ecology encouraged new entities and jurisdictions embarking on PCB source tracing to reach out and learn from the experiences of more seasoned staff that have a history of working in this area. Experience has demonstrated that PCB source tracing requires time (>5 years) and funding and is usually not straightforward. Therefore, common advice is to establish partnerships and collaborations, combine resources, and build on the work of others.

Numerous jurisdictions have been challenged by the volume of data collected over the years from their efforts. As more PCB congener data are collected, this issue is becoming increasingly challenging. Thus, planning for data management in terms of data storage, security, and database software is recommended. Several programs (City of Seattle, City of Spokane, DRBC, and SFEI) highlighted that data management was a significant challenge that should be anticipated by jurisdictions developing a source control program.

Many jurisdictions use multiple lines of evidence, including current land use, historical aerial photographs and maps, interim measures like line cleaning along with the sampling, and analysis of stormwater and stormwater solids. It is important to tailor the information gathered to the legal authorities and mechanisms available to remedy the potential sources (City of Portland 2016, pers. comm.). For instance, for TSCA authority to be utilized, a

product or material like paint, caulk, or other building materials in current use with >50 mg/Kg PCBs would need to be found on a property, and gaining access may be challenging and time consuming. Alternatively, demonstrating that PCBs are migrating off a property using catch basin solids from adjacent public ROWs may be sufficient to initiate MTCA designation and authority. Several jurisdictions cautioned against relying too heavily on source tracing; in some situations installing stormwater treatment (e.g., T117 property in the LDW) may be more effective than source tracing. At the Terminal 117 property in the LDW, extensive source tracing did not identify a source and treatment was selected in lieu of spending further resources on source tracing (Ecology 2015, pers. comm.). Unfortunately, the circumstances when this may be the best choice may only be obvious in hindsight.

Several jurisdictions cautioned against making assumptions about sources and attempting to narrow in on suspected source types or properties too early in the investigation process (e.g., SFEI, Urban Waters). Industrial land use information is important (City of Portland 2016, pers. comm.), as significant sources have been found at several metal shredders and old transformer sites, but this information can also be a red herring if the source is inaccurate or is the only line-of-evidence used. As existing databases often contain errors, Ecology (Fernandez 2015, pers. comm.) recommends that GIS data be groundtruthed to correct errors and improve understanding of conveyance system connections. One strategy recommended by Ecology, and used by several jurisdictions, is to clean stormwater lines to remove any historic contamination and then use a combination of sediment traps, inline solids, and catch basin solids samples to isolate areas or parcels with on-going sources. This has the combined benefit of removing PCB contamination before it reaches surface waters and sediments and serves to inform future source control efforts.

7.0 CONCLUSIONS

PCB source tracing is challenging, resource-intensive, and time consuming. Due to the multitude of sources, both historical and current, PCB source tracing rarely ends with discovery of only one or two source-generating properties. It is a process of surveying (or monitoring), prioritization, and focused investigation, likely requiring repetition of these steps. All the programs described in this report used a variety of tools with no one tool or combination being consistently effective; this is likely a result of the unique history, regulatory situation and characteristics of each watershed. However, solids sampling by trap or catch basin grabs is a commonly used tool to characterize stormwater basins and trace upstream sources. Line cleaning and resampling can be effective to test the presence of ongoing versus legacy sources. Many programs have also found historical data (e.g., former land use, contaminated site databases) helpful in concert with conveyance system PCB chemistry to guide prioritization of more focused investigations. Business inspections have varied results and their success depends, in part, on owner experience and the strength of their relationship with inspectors. The final steps of source identification and control can be critically dependent on the available legal authority structure to grant property access and enforce cleanup actions.

Sources of PCBs are often industrial with metals recyclers and businesses associated with transformers among some of the most common identified by the reviewed source tracing programs. However, due to state and federal cleanup standards that are still in the mg/Kg concentration range, contaminated sites that were historically remediated can remain active PCB sources. In addition, construction materials (e.g., caulk, sealant, paint) have been found to contain very high PCB concentrations (e.g., at a scale of 100,000 mg/Kg). The current TSCA regulations allow products to contain less than 50 mg/Kg and laboratory testing has confirmed some PCB congeners are present in off-the-shelf products. This is due to inadvertent production of PCBs during the manufacturing process, not the intentional addition of PCBs. While legal, the inadvertent production of PCBs represents a new type of PCB source – different from the legacy Aroclor sources typically targeted by source control programs. These products contain fewer congeners and the relative importance of these as sources to the environment are unknown, at least with regard to toxicity. The relative contributions from Aroclor versus incidentally produced PCB sources will vary between watersheds. Regardless of source type, the stormwater pathway is often a major pathway of PCBs to receiving waters.

Although some programs have relied solely on the lower resolution analytical methods (e.g., Aroclor analysis), many programs have also, or exclusively, used the high resolution methods for PCB congeners. PCB congener data have enabled advanced statistical analysis that can tease apart PCB types and pathways. With the relatively recent consideration of inadvertently-produced PCBs, this added information may be valuable, especially if factors such as toxicity are taken into account. The congeners produced inadvertently are far fewer in number than contained in Aroclors and may be cumulatively less toxic. With over 200 PCB congeners, each of variable toxicity and environmental persistence, congener identity is relevant when the final goal is protection of human health and wildlife. However, if

regulatory goals are based on total PCBs (a sum of all Aroclors or congeners) in discharges or receiving waters, regulated entities will be driven to focus on reducing PCB loads regardless of congener identity and toxicity. The development and acceptance in the San Francisco Bay area of a 40 congener sum as a TMDL monitoring index acknowledges that a limited number of congeners are significant in relation to their goal – reducing bioaccumulation in fish to protect human health and wildlife. Davis et al. (2014) emphasized that although PCB 11, a ubiquitous, inadvertently-produced congener, enters San Francisco Bay it is neither persistent nor accumulating in fish. Therefore, it should not be included in the index with Aroclor-based congeners that are the risk drivers for humans and wildlife. The City of Spokane is also interested in considering congener toxicity to focus source tracing and control on the most important congeners from a risk perspective (City of Spokane 2015, pers. comm.). As PCB source tracing evolves, closer examination of individual congeners may guide the prioritization of source pathways, source types, and the tools applied.

Given the resource-intensive nature of PCB source tracing, tools and strategies that optimize efficiency are needed to improve success. For this to occur, it will be critical to continue sharing information, including challenges and successes, between and among source tracing communities. For more information, web links to general source tracing resources and to additional information on source tracing programs discussed in this report, can be found in Appendix C.

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Appendix A: Off-The-Shelf and In-Use Products Found to Contain PCBs

Table A-1. Summary of PCB product sampling results (City of Spokane 2015).

Product Type [1]	Total PCB[2] (ppb)	Brand
Cleaners and Degreasers		
Vehicle wash soap	0.003	SuperXL, Hotsy
Vehicle wash soap	0.068	Simple Green
Motor Oil, Gasoline, Lubricants, and Antifreeze		
Motor oil	0.856	SAE 15W-40 Firebird Heavy Duty EC (bulk), Connell Oil
Motor oil	0.969	Valvoline Full Synthetic 5W-30
Used motor oil	0.502	SAE 15W-40 Firebird Heavy Duty EC, Connell Oil
Diesel	<0.019	#2 Diesel, dyed
Gasoline	0.935	Regular unleaded
Lubricant	0.623	MP Gear Lube SAE 85W-140, Phillips 66 Company
Antifreeze	0.018	Kool Green Extended Life (recycled)
Pipe Material		
PVC pipe	1.999	ASTM 303 8", Diamond PVC
CIPP liner	1.11	Cast in place pipe liner, installed by SAK
Shortliner	17.78	Infrastructure Repair System Inc.
Paint and Traffic Marking Material		
Yellow road paint	0.732	Ennis standard #2 - Product # 983712
Yellow road paint	64.88	Sherwin Williams Promar TM 5713
White road paint	0.414	Ennis standard #2 - Product # 983711
White road paint	0.281	Sherwin Williams Promar TM 5712
Hydrant paint	0.003	Rustoleum Pro HP Enamel - Aluminum
Utility locate paint	21.527	Rustoleum Industrial Choice, Solvent-based -green
Yellow road paint, dried	0.565	Ennis standard #2 - Product # 983712
Yellow road paint, dried	0.379	Ennis standard #2 - Product # 983711
Thermoplastic tape road striping	10.766	Ennis-Flint Pre-Mark
Thermoplastic tape road striping	3.325	Ennis-Flint Pre-Mark
Personal Care Products		
Hand soap	0.037	Dial Antibacterial, pomegranate and tangerine
Laundry soap	0.174	Tide original liquid
Dish soap	0.083	Dawn Ultra antibacterial
Shampoo	0.058	Suave naturals
Toothpaste	0.032	Aquafresh Extreme Clean Whitening

Product Type [1]	Total PCB[2] (ppb)	Brand
Deicer		
Deicer	1.332	MgCl Freezegard
Deicer	0.038	Enhanced salt brine with SB Boost
Dust suppressant		
Dirt road dust suppressant	0.091	Asphalt emulsions-EADA
Dirt road dust suppressant	0.086	Lignosulfonate-Lingo Road Binder (natural polymer in wood)
Dirt road dust suppressant	3.574	Dustguard Liquid MgCl (different concentration than deicer)
Asphalt Related Products		
Asphalt tack	0.085	SSR1 asphalt tack
Crack sealer	7.975	Special Asphalt SA Premier (3405-midrange crack sealer)
Asphalt release agent	0.558	Soy What, ThechniChem Corp
Pesticides		
Pesticide/herbicide	<0.0001	2-4D: Nufarm Weedar 64
Pesticide/herbicide	6.89	Portfolio 4F, Wilbur-Ellis
Pesticide/herbicide	0.012	Roundup Pro Max, Monsanto
Pesticide/herbicide	0.316	Crosshair, Wilbur-Ellis
Hydroseed		
Hydroseed	2,509.09	Nature’s Own Hydroseeding Multch, Hamilton Mfg Inc.
Hydroseed Retest [3]		
Hydroseed	<4.3	Product #1
Hydroseed	<0.294	Product #2
Hydroseed	4.65	Product #3
Hydroseed	<0.284	Product #4
Firefighting foam		
Class B firefighting foam	0.029	Alcoseal 3-3 (AR-FFFP)

[1] Unless otherwise noted, data are from: City of Spokane. 2015. PCBs in Municipal Products, Revised. Prepared by City of Spokane, Wastewater Management Department. Funded by Ecology Municipal Stormwater Grants of Regional of Statewide Significance. Grant No. G1400545.

[2] Total PCB values have been blank corrected: congeners < 3 times the associated blank value not included in total.

[3] Data from: SRRTF. 2015. Hydroseed Pilot Project Summary Report. July 31, 2015. Spokane River Regional Toxics Task Force.

Notes:
ppb = parts per billion

Table A-2. Building materials in the Lower Duwamish Waterway in King County, the San Francisco Bay Area in California, and Tacoma in Washington.

Sample Type	Building Type	# of Samples	Minimum Total PCBs (ppb)	Maximum Total PCBs (ppb)
Lower Duwamish Waterway, King County [1]				
1940				
Caulk: door frame/expansion joint	Industrial	1	<740	<740
Paint: building	Industrial	3	<750	<760
1950				
Paint: building	Commercial	6	<740	61,000
Paint: building	Industrial	4	1,100	46,000
1960				
Caulk: door frame	Industrial	3	<760	3,600
Caulk: expansion joint	Industrial	2	3,000	920,000
Caulk: window frame	Industrial	2	<750	770
Caulk: window glazing	Industrial	1	<750	<750
Caulk: vent	Industrial	1	<6,100	<6,100
Paint: building	Commercial	2	<800	<1,200
Paint: building	Industrial	14	<720	32,000
Paint: building	Residential	1	<770	<770
1970				
Caulk: expansion joint	Industrial	1	<19,000	<19,000
Caulk: door frame	Industrial	1	20,000	20,000
Caulk: window frame	Industrial	1	<31,000	<31,000
Paint: building	Industrial	8	<0740	<36,000
1950/1970*				
Caulk: expansion joint	Industrial	1	3,000	3,000
San Francisco Bay Area [2]				
1950				
Caulk: window/concrete	Concrete	6	3,600,000	220,000,000
Caulk: window/door frame/concrete	Wood	8	<25,000	15,000
1960				
Caulk: window/concrete	Concrete	3	2,000	89,000
Caulk: window	Masonry	1	<25,000	<25,000

Sample Type	Building Type	# of Samples	Minimum Total PCBs (ppb)	Maximum Total PCBs (ppb)
Caulk: window	Wood	1	12,500,000	12,500,000
1970				
Caulk: window	Wood	2	10,000	11,000
Caulk: wood/door frame	Wood	2	8,000	60,000
1980				
Caulk: unknown	Masonry	1	87,000	87,000
Year Unknown				
Caulk: window	Unknown	1	15,000	15,000
Tacoma WA Downtown [3]				
Year Unknown				
Caulk: brick	Commercial	2	4,300	190,000
Caulk: building	Commercial	3	87,000	17,000,000
Caulk: roof	Commercial	1	4,600	4,600
Caulk: sidewalk	Commercial	16	3,000	53,000,000
Caulk: window	Commercial	1	4,100	4,100
Paint: wipes	Commercial	7	<1**	<1**
Paint: chips/building	Commercial	2	<12,000	6,200
Paint: sump pump	Commercial	1	9,600	9,600
Soil: near sidewalk caulk	Commercial	1	490	490
Soil: roof/drain	Commercial	3	790	7,500
Tar: roof	Commercial	1	<12,000	<12,000

[1] SAIC (Science Applications International Corperation). 2011. Lower Duwamish Waterway Survey of Potential PCB-Containing Building Material Sources-Summary Report. Prepared by Science Applications International Corporation for the State of Washington Department of Ecology. June 2011.

[2] Klosterhaus, S., L. J. McKee, D. Yee, J. M. Kass, and A. Wong. 2014. Polychlorinated biphenyls in the exterior caulk of San Francisco Bay Area buildings, California, USA. Environment International. 66:38-43.

[3] City of Tacoma. 2013b. Letter from Geoffrey Smyth to Chris Montague-Breakwell. Re: Update to May 22, 2013 General Condition G3 notification. Sent to Ecology by City of Tacoma. Dated Nov. 8. 2013.

Notes:

*Sample years 1950 and 1970 where composited.

**Units are μg/wipe for these samples.

ppb = parts per billion

<# = nondetect at reported value (#)

Figure A-1. Tacoma WA Wells Fargo building example of paint sample.

Figure A-2. Tacoma WA Wells Fargo building example of building caulk.

Figure A-3. Tacoma WA Wells Fargo building example of building caulk.

Figure A-4. Tacoma WA Wells Fargo building example of sidewalk caulk adjacent to bricks.

Figure A-5. Tacoma WA Wells Fargo building example of sidewalk caulk.

Figure A-6. Tacoma WA Wells Fargo building example of sidewalk caulk.

Figure A-7. Tacoma WA Wells Fargo building example of soil sample location next to caulk.

Figure A-8. San Francisco Bay area example of caulk repair area.

Figure A-9. San Francisco Bay area example of peeling paint near storm drain.

Table A-3. Select PCB congeners in caulk, paint, and food (Ecology 2014a).

Product Description[1]	PCB-11 (ppb)	PCB-206 (ppb)	PCB-208 (ppb)	PCB-209 (ppb)
Caulk				
Big Stretch white	0.0256 (<RL)	--	--	--
DAP Kwick Seal-kitchen and bath adhesive caulk	--	--	--	--
DAP Beasts the nail construction adhesive-all purpose	0.0625 (<RL)	--	--	--
DAP Alex Plus Acrylic latex caulk plus silicone	0.0606 (<RL)	--	--	--
Loctite polyseamseal all purpose	--	--	--	--
Red Devil Color Cure Pink 2 White advanced acrylic sealant plus silicone	--	--	--	--
OSI Quad Advanced Formula Sealant	7.55	--	--	--
White Blanco Phenoseal-vinyl adhesive caulk	--	--	--	--
Paints and Related Materials				
Behr Thalo Green colorants No. 45514Z	0.0512 (<RL)	--	--	1.00

Product Description[1]	PCB-11 (ppb)	PCB-206 (ppb)	PCB-208 (ppb)	PCB-209 (ppb)
Behr titanium dioxide low VOC colorants (white) No. 46512Z	0.0620 (<RL)	0.110 (<RL)	0.0635 (<RL)	1.26
Behr medium yellow colorants No. 46814Z	45.0 (<RL)	--	--	0.0957 (<RL)
Dutch Boy Dirt Fighter paint and primer	0.0608 (<RL)	--	--	0.184 (<RL)
HD Designs Interior/Exterior Spray Paint-green	0.527	0.0216 (<RL)	0.0151 (<RL)	1.27
HD Designs Interior/Exterior Spray Paint-yellow	29.7	--	--	0.0114 (<RL)
Krylon Indoor/Outdoor Blue Ocean Breeze Gloss spray paint	0.101 (<RL)	--	--	0.0646 (<RL)
Krylon Indoor/Outdoor Sun Yellow Gloss spray paint	13.1	--	--	0.0143 (<RL)
Novocolor II Universal colorant-phthalo blue	0.113 (<RL)	--	--	0.0867 (<RL)
Novocolor II Universal colorant-phthalo green	4.27	5.24	1.41	320
Novocolor II Universal colorant-med. yellow	4.94	--	--	0.0702 (<RL)
Parker Paint Wall Kolor interior acrylic	0.0600 (<RL)	--	--	--
Rust-oleum fluorescent neon green spray paint	0.219	0.483 (<RL)	0.573 (<RL)	3.33
Rust-oleum fluorescent neon yellow spray paint	0.0793 (<RL)	0.644 (<RL)	0.605 (<RL)	2.48
Food				
French's classic yellow mustard-mustard sample	0.0526 (<RL)	--	--	--
Fred Meyer yellow mustard-mustard sample	0.0732 (<RL)	--	--	0.0411 (<RL)
MDL Range	0.001 to 0.088	0.004 to 0.175	0.002 to 0.057	0.002 to 1.23
RL Range	0.0912 to 0.857	0.456 to 4.28	0.456 to 4.28	0.0228 to 4.46

[1] Ecology. 2014b. Polychlorinated Biphenyls (PCBs) in General Consumer Products. Washington State Department of Ecology, Olympia, WA. Publication No. 14-04-035. https://fortress.wa.gov/ecy/publications/publications/1404035.pdf

Notes:
ppb = parts per billion
-- = nondetect, less than method detection limit (MDL)
<RL = below the reporting limit (RL), but above the MDL

Appendix B: Ettie Street Pump Station Inspection Checklist (City of Oakland Case Study)

ETTIE STREET PUMP STATION WATERSHED INSPECTION CHECK LIST

Activities:

- ☐ Electrical Applications (transformers, appliances, televisions, fluorescent light ballast, motors, etc.)
- ☐ Hydraulic Fluids (lifts, die-casting machinery, etc)
- ☐ Plasticizers (sealants, caulk, PVC, polyurethanes, polycarbonates, etc.)
- ☐ Drum cleaning/recycling
- ☐ Auto recycling/scrap
- ☐ Outdoor burning or combustion
- ☐ Miscellaneous (coatings, printing inks, pesticides, etc.)

Historical Questions:

1. What type of the business did the previous tenant/owner have?
2. Are PCBs in use now or have been in the past on this facility?
3. Any building fires in the past? Any major exterior renovation or window replacement?
4. What type of business was on the neighboring properties? (if applicable)

Sites of Principal Interest for Inspection: Open lots with poor housekeeping

SKETCH

Number of Photos: Photo File Name:

Appendix C: Additional Resources

General Resources

Resources for Program Implementation and Management

DRBC PCB data management guidelines:
http://www.state.nj.us/drbc/quality/toxics/pcbs/monitoring.html

New York Academy of Sciences (2005) Pollution Prevention and Management Strategies for PCBs in the New York/New Jersey Harbor:
http://www.state.nj.us/drbc/library/documents/PMP_Resources/NYAS_PCBs_NY-NJHarbor.pdf

Resources for Identifying and Storing Electrical Equipment with PCBs

Environment Canada (2006) Handbook on PCBs in Electrical Equipment, Chapter 2: Identification and Labeling of PCB Equipment:
http://www.state.nj.us/drbc/library/documents/PMP_Resources/chapter2_CAhandbook.pdf

Environment Canada (2006) Handbook on PCBs in Electrical Equipment, Chapter 6: Preparation of PCB Equipment for Storage:
http://www.state.nj.us/drbc/library/documents/PMP_Resources/chapter6_CAhandbook.pdf

EPA (2004) PCB Inspection Manual, Chapter 4: Equipment-Specific Information:
http://www.state.nj.us/drbc/library/documents/PMP_Resources/chapter4_EPAmanual.pdf

Guidelines for Determining PCB Status of Distribution Transformers:
http://www.state.nj.us/drbc/library/documents/PMP_Resources/Guidelines_PCBtransformers.pdf

Other Resources

New York Academy of Sciences (1983) Organic Chemical Processes Potentially Containing PCBs:
http://www.state.nj.us/drbc/library/documents/PMP_Resources/inadvertentPCBproduction.pdf

Program Specific

Greater Seattle Area

Ecology's Source Control Status Reports
http://www.ecy.wa.gov/programs/tcp/sites_brochure/lower_duwamish/source_control/sc.html

Ecology's recent source control documents:
http://www.ecy.wa.gov/programs/tcp/sites_brochure/lower_duwamish/latestInfo.html
North Boeing Field Cleanup documents:
https://fortress.wa.gov/ecy/gsp/CleanupSiteDocuments.aspx?csid=4765

Ecology's Lower Duwamish Waterway source control status reports and fact sheets:
http://www.ecy.wa.gov/programs/tcp/sites_brochure/lower_duwamish/source_control/sc.html
Duwamish Superfund documents:
https://fortress.wa.gov/ecy/gsp/CleanupSiteDocuments.aspx?csid=1643
http://www.ldwg.org/resources.html

MS4 NPDES permit and related documents:
http://www.ecy.wa.gov/programs/wq/stormwater/municipal/PermitsPermittees.html

Tacoma

EPA Commencement Bay Superfund documents:
https://yosemite.epa.gov/r10/cleanup.nsf/sites/cbnt

City of Tacoma Thea Foss Waterway monitoring plan
http://cms.cityoftacoma.org/surfacewater/FOSS2012/Year6AnnualOMMPReport.pdf

City of Tacoma's Thea Foss Waterway Cleanup webpage
http://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=7283

City of Tacoma's 2014 Source Control and Stormwater Monitoring Report
http://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=12065

City of Tacoma's website for East Tacoma PCB investigation:
http://www.cityoftacoma.org/cms/one.aspx?pageId=41852

Spokane

City of Spokane website on PCBs with Adaptive Management Plan:
https://my.spokanecity.org/publicworks/wastewater/pcbs/

SRRTTF website: http://srrttf.org/

SRRTTF Yearly accomplishments: http://srrttf.org/?page_id=1281

SRRTTF Projects/Progress: http://srrttf.org/?page_id=4280

SRRTTF Technical Consultant Deliverables: http://srrttf.org/?page_id=1632

Portland

ODEQ stormwater pathway evaluation guidance:
http://www.deq.state.or.us/lq/cu/stmwtrguidance.htm

Most recent stormwater source control annual report:
http://www.portlandoregon.gov/bes/64448

Outfall studies:
http://www.deq.state.or.us/Webdocs/Forms/Output/FPController.ashx?SourceId=2425&SourceIdType=11

Portland Harbor Superfund documents:
http://www.portlandoregon.gov/bes/56848

MS4 NPDES permit and related documents:
http://www.deq.state.or.us/lq/ECSI/ecsidetail.asp?seqnbr=2425

Portland River Sediment Study:
http://www.deq.state.or.us/lq/cu/nwr/willametteriver.htm

EPA/ODEQ Portland Harbor Joint Source Control Strategy with additional related documents website:
http://www.deq.state.or.us/lq/cu/nwr/PortlandHarbor/jointsource.htm

Delaware River Basin

PCB monitoring program
http://www.state.nj.us/drbc/quality/toxics/pcbs/monitoring.html

Pollutant Minimization Plans (PMPs) for PCBs in the Delaware River Basin:
http://www.nj.gov/drbc/programs/quality/pmp.html

Water Quality Model for Carbon and PCB Homologs for Zones 2-6 of the Delaware River Estuary (2011)
http://www.nj.gov/drbc/library/documents/PCBhomolog_model-rpt0511.pdf

PCB Water Quality Model for Delaware Estuary (2003)
http://www.state.nj.us/drbc/library/documents/TMDL/WQModelRptDec2003.pdf

San Francisco Bay

Alameda County Clean Water Program monitoring data and technical reports:
http://www.cleanwaterprogram.org/watersheds/watershed-monitoring/item/monitoring.html

San Francisco Basin Plan containing the PCB TMDL:
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/basinplan/web/bp_ch7b.shtml#7.2.3

SFEI Regional Monitoring Program, Status and Trends website:
http://www.sfei.org/rmp

SFEI searchable library:
http://www.sfei.org/biblio/author/212%3Fsort%3Dyear%26order%3Dasc

San Francisco Bay TMDL website:
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/sfbaypcbstmdl.shtml

San Francisco Bay Fish project website: http://www.sfei.org/sfbfp

City of Oakland Ettie Street Source Identification and Abatement Studies (Downloadable deliverables): http://ec2-54-235-79-104.compute-1.amazonaws.com/Government/o/PWA/o/FE/s/ID/OAK024739.htm

PCB Screening and Analytical Methods

PCBs as Aroclors: EPA Method 8082A (gas chromatography)[37]
http://www3.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/8082a.pdf

PCBs as Congeners: EPA Method 1668B (high resolution gas chromatography/mass spectrometry): http://www.specialtyanalytical.com/pdfs/EPA_1668.pdf

PCBs as Homologues: EPA Method 680 (gas chromatography/mass spectrometry)
http://nepis.epa.gov/Exe/ZyNET.exe/20016OGU.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1981+Thru+1985&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C81thru85%5CTxt%5C00000013%5C20016OGU.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

PCBs in solids: EPA Method 8270D (gas chromatography/low resolution mass spectrometry), 8081 modified by EPA 625 (AXYS in-house method MLA 007)
http://www3.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/8270d.pdf

[37] This method can also be used for a subset of PCB congeners (Section 4.2.2 and Section 5.0).

PCB Screening:

X-ray Fluorescence (chlorine detection)
http://www.cpeo.org/techtree/ttdescript/xrayfl.htm

ELISA, RaPID Assay PCB Test Kit:
http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/7137/Freitag_duke_0066D_17/RaPIDPCBtestkitinstructions.pdf?sequence=3

Appendix D: PCB Primer from Spokane County Wastewater

A PCB Primer

Even though the intentional production of **Polychlorinated Biphenyls (PCBs)** was banned in the U.S. in 1979, many manufactured and imported products still have significant levels of PCBs which can endanger our health and pollute the environment. PCBs in very low levels can be found in our bodies, our food, our homes, the air, the groundwater, and surface water. They find their way to our environment through many pathways, such as:

Spokane County
Water Resources, Utilities Division

- **Consumer products** (e.g. personal care products, dyes in clothing, pigments in packaging and newsprint, oil, caulking, paint, fire retardant materials),
- **Wastewater Collection Systems** (residues from products rinsed off in showers, human waste, dyes washed from clothing, improper disposal of household chemicals),
- **Stormwater runoff** (carrying oil from our cars, paints, and other products from all types of surfaces into storm drains) and
- **Atmospheric deposition** (transferred from a variety of new and "legacy" sources via the air to the earth's surface)

What is being done?

Spokane County – as a member of the Spokane River Regional Toxics Task Force – is collaboratively researching and learning more about the ubiquitous nature of PCBs in our environment and their impact on the Spokane River and the Spokane Valley-Rathdrum Prairie Aquifer. Spokane County Water Resources staff will continue to update county residents as more information becomes available. Stay tuned!

Want to learn more?

Visit www.spokanecounty.org/water and locate the "PCB" page under "Rivers, Lakes and Streams".

What can I do?

There is much yet to learn about PCBs before we'll know all the ways we can help eliminate them from our environment.

Here are a few early tips:

- Be aware that a lot of common packaging contains PCBs because of the inks and dyes (the color **yellow** typically has higher concentrations). Be a consumer advocate for plain packaging that uses less ink.
- Don't flush chemicals, solvents, oil, paints, etc.! The County's treatment facilities do an excellent job of removing PCBs from wastewater, but let's do what we can to keep them out of the wastewater collection system entirely.
- When shopping for motor oils, paints and inks, ask the seller if these products have been tested for PCBs. The seller may not initially have this information, but you're contributing to awareness simply by asking the question.

Legacy PCBs
PCBs are extremely persistent, remaining in the environment long after they were first introduced.

- When it comes to personal diet, know your fish and other meats. PCBs that bio-accumulate in fish and other animal fats have been found to be carcinogenic. Be aware of consumption advisories for various fish, and choose lean cuts of meat. Allow fatty tissue of both to drip away when grilling/cooking. Choosing low-fat dairy products is also a good idea.
- Keep learning! Visit www.spokanecounty.org/water and locate the "PCB" page under "Rivers, Lakes and Streams".
- When disposing of any possibly hazardous items, use the Spokane EnviroStars Waste Directory to learn how and where to dispose of them properly.

Need to get rid of waste?
Visit the Spokane EnviroStars Waste Directory!
www.SpokaneWasteDirectory.org
Working together to protect our river and aquifer through pollution prevention.

EnviroStars Certified

Consumers: Support businesses that display the EnviroStars Certified logo!
Businesses: Become EnviroStars Certified!
Both: Visit www.spokaneenvirostars.org to learn how!