501 Avis Drive
Ann Arbor, MI 48108
734.332.1200
www.limno.com

# Memorandum

**From:** Dave Dilks **Date:** March 9, 2016

**Project:** SRRTTF

**To:** SRRTTF

**SUBJECT:** **DRAFT: Sources and Pathways of PCBs in the Spokane River Watershed**

## Summary

The Spokane River Regional Toxics Task Force (SRRTTF) is developing a comprehensive plan to reduce polychlorinated biphenyls (PCBs) in the Spokane River, and has contracted with LimnoTech to assist in development of the plan. Development of the comprehensive plan will benefit from an understanding of the sources of PCBs in the Spokane River watershed and how they are delivered to the river. This memorandum describes the key sources and transport mechanisms affecting PCBs in the Spokane River and its contributing watershed. Sources are broadly characterized as

- Legacy sources of PCBs currently present in the Spokane watershed study area
- New sources of PCBs continuing to be introduced to the watershed via inadvertent production in commercial products
- Environmental transport (e.g. via the atmosphere) of PCBs into the study area, which may either be legacy or continuing sources

A network of transport processes exist that deliver PCBs from their current location to the Spokane River, including erosion of contaminated surface soil and delivery to storm sewer systems, delivery to wastewater treatment plants, and transmission via groundwater.

The magnitude of these sources and transport mechanisms will be quantified in subsequent project work. Those sources and pathways of the greatest magnitude will be targeted for control in the comprehensive plan.

## Introduction

The SRRTTF is developing a comprehensive plan to reduce PCBs in the Spokane River, designed to identify specific management actions that can be undertaken to control PCB loads to the river. Work on Comprehensive Plan will be conducted through five tasks:

1. Develop Inventory of PCB Sources and Pathways
2. Evaluate Best Management Practices to address PCB Sources and Pathways
3. Attain Consensus on Alternatives to Be Included in Plan
4. Develop Comprehensive Plan
5. Project Management and Coordination

This memorandum corresponds to the first task: Develop Inventory of PCB Sources and Pathways. PCBs are introduced to the watershed from many different sources, and delivered to the river via many different pathways. The magnitude of individual sources can vary widely, as can the magnitude of individual pathways. Selection of the most appropriate management actions will be facilitated by an understanding to the magnitude of the various sources and pathways.

Sources and pathways will be represented in this memorandum through the use of conceptual models. A conceptual model is a graphic depiction of all of the processes believed to be potentially significant in effecting pollutant concentrations. Conceptual models provide a means to convey complicated processes and relationships in a simplified manner to a wide audience, and allows non-technical reviewers to understand and provide input on the sources and pathways to be considered. An example conceptual model of PCB sources and pathways for San Francisco Bay is shown in Figure 1.

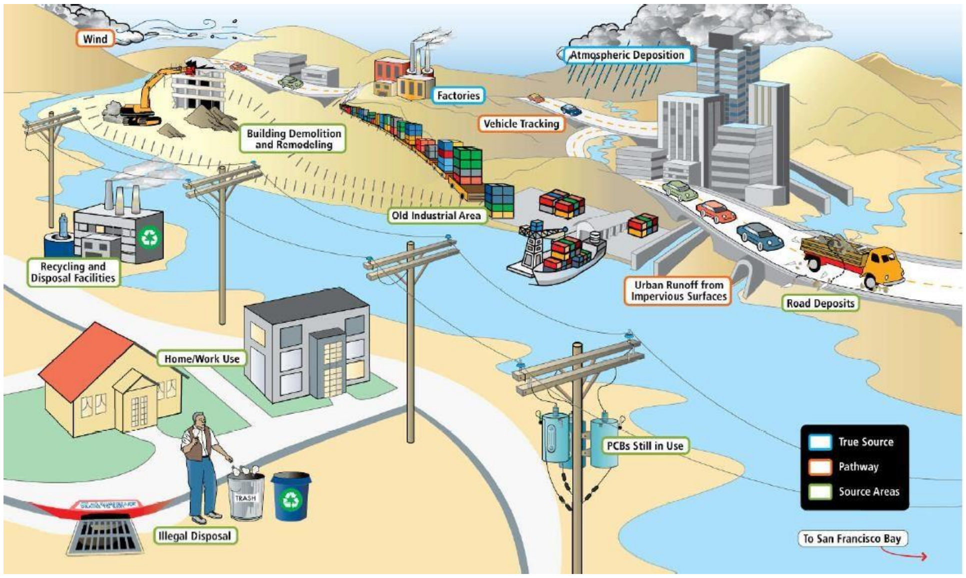


**Figure 1. Example Conceptual Model of PCB Sources and Pathways (from SFEI, 2010)**

Conceptual models can also be drawn as "box and arrow" diagrams, with boxes representing environmental compartments and arrows representing processes that transfer PCBs between compartments. An example box and arrow summarizing PCB fate processes in the Spokane River and its sediments is shown in Figure 2.

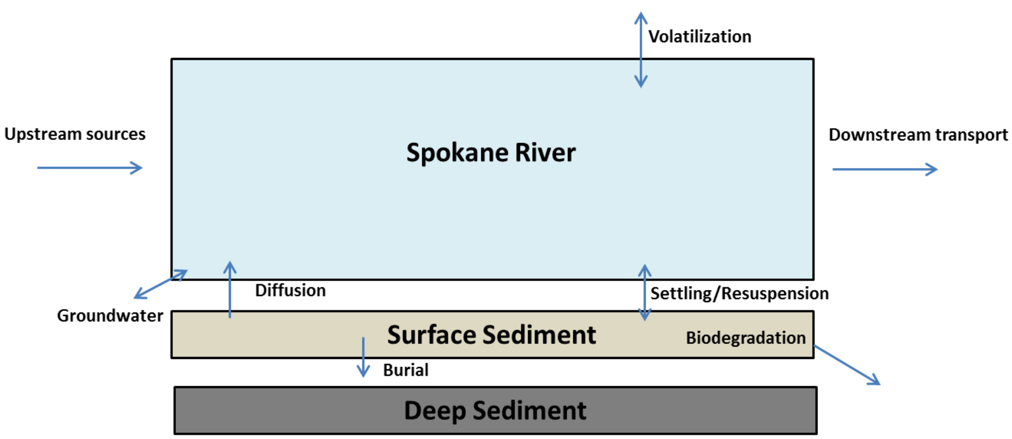


**Figure 2. Example Box and Arrow Conceptual Model**

This memorandum is intended to describe the sources of PCBs in the Spokane River watershed and the pathways by which these PCBs are delivered to the river, in support of subsequent steps to define the magnitude of these sources and pathways. It is divided into sections of:

- Sources of PCBs
- Delivery mechanisms of PCBs to the Spokane River
- Transport pathways between sources and delivery

## Sources of PCBs

Sources of PCBs are divided into three broad categories, based on refinement of earlier PCB source characterization done for San Francisco Bay (SFEI, 2010) and Spokane (LimnoTech, 2013).

- Legacy sources of PCBs currently present in the Spokane watershed
- Ongoing sources of PCBs continuing to be introduced to the watershed via inadvertent production in commercial products
- Environmental transport of non-local PCBs into the watershed study area, which may either be legacy or continuing sources

### *Legacy Sources*

Legacy sources correspond to PCBs that were brought into the Spokane watershed in the past, but are not continuing to be produced. These were produced by Monsanto and marketed as Aroclors which were used in machine oils, transformers, etc. As shown in Table 1, legacy sources are divided into categories of buildings, environmental, and industrial equipment. Building sources can either be fixed to the building itself (e.g., paint, caulk) or non-fixed and removable (e.g., light ballasts). Legacy environmental sources of PCBs correspond to contaminated surface soils, contaminated subsurface soils/groundwater, and in-place aquatic sediments in the Spokane River and Lake Spokane. Historically produced PCBs are also still contained in various forms of electrical equipment such as transformers, and hydraulic equipment.

| Buildings | Environmental | Industrial Equipment |
|---|---|---|
| • Fixed • NonFixed | • Surface soils<br>• Subsurface soil/ groundwater<br>• Aquatic Sediments | • Electrical Equipment<br>• Hydraulic Equipment |

**Table 1. Categories of Legacy Sources of PCBs in the Spokane Watershed**

### *Ongoing Sources*

Despite the ban on the intentional production of PCBs instituted in 1979, PCBs still continue to be inadvertently produced in the chemical synthesis of many commercial products. These sources are divided into categories in Table 2. Characterization of PCB loads from inadvertent sources have identified pigments in printed materials/fabrics (Guo et al, 2013) and paints (Hu and Hornbuckle, 2010) as two primary categories of inadvertent production. Combustion of chemicals can also be an inadvertent source. It is recognized that inadvertent PCB production occurs in other categories of products as well, although the magnitude of these other sources is largely unknown and/or considered to be much smaller than other sources.

| Pigments in Printed Materials/Fabrics | Paints | Other |
|---|---|---|

| | | |
|---|---|---|
| • Newsprint<br>• Commercial Packaging<br>• Colored Clothing | • Architectural paint<br>• Road paint | • Motor oil<br>• Agricultural chemicals |

**Table 2. Categories of Ongoing Sources of PCB Production**

### *Non-Local Environmental Sources*

PCBs also enter the Spokane watershed study area (presently defined as having an upstream boundary at Lake Coeur d'Alene) via non-local environmental sources. Non-local sources can either be delivered via the atmosphere or enter the river from Lake Coeur d'Alene. The term "non-local" is used to distinguish sources that originate outside of the watershed from atmospheric sources that originate from the volatilization of PCBs in the Spokane watershed. It is recognized that these non-local environmental sources can originate from either legacy PCB sources or ongoing inadvertently produced sources.

## Delivery Mechanisms of PCBs to the Spokane River

PCBs can be delivered to the Spokane River study area via a number of mechanisms, as depicted in Figure 3. Categories of delivery include:

- Transport of PCBs from upstream sources through Lake Coeur d'Alene
- Atmospheric deposition
- Groundwater loading
- Stormwater runoff, either as part of an MS4 stormwater system or via direct drainage
- Combined sewer overflows (CSOs)
- Tributaries
- Discharge from municipal and wastewater treatment plants
- Discharge of waste water and stocking of fish from fish hatcheries
- Diffusion or resuspension of PCBs from bedded sediments in the Spokane River and Lake Spokane

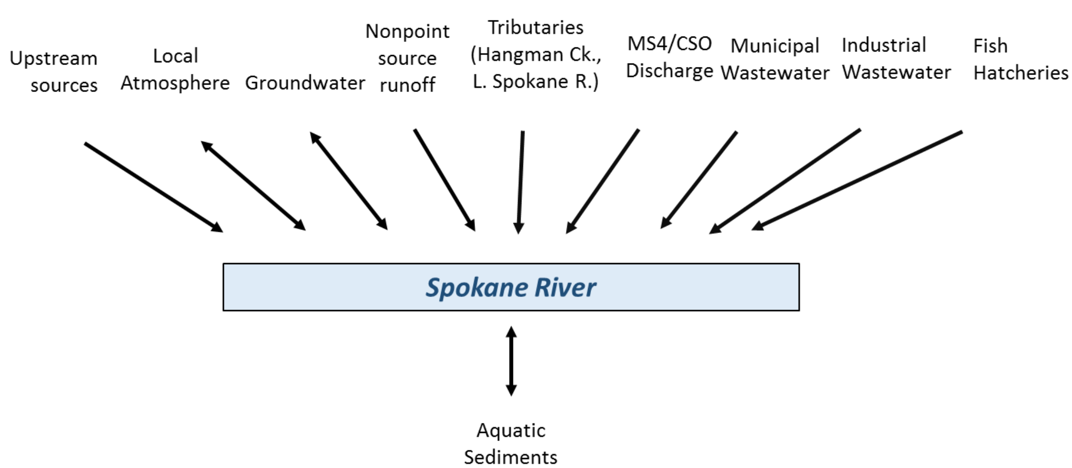


**Figure 3. Categories of Delivery of PCBs to the Spokane River**

## Intermediate Transport Pathways

It is recognized that there are a number of intermediate pathways by which the pollutant sources listed above get transported to the delivery mechanisms shown in Figure 1. The pathways are depicted in Figure 4 under the broad categories of:

- Mobilization in the watershed
- Volatilization to the atmosphere
- Delivery to sewer infrastructure  Contribution to groundwater

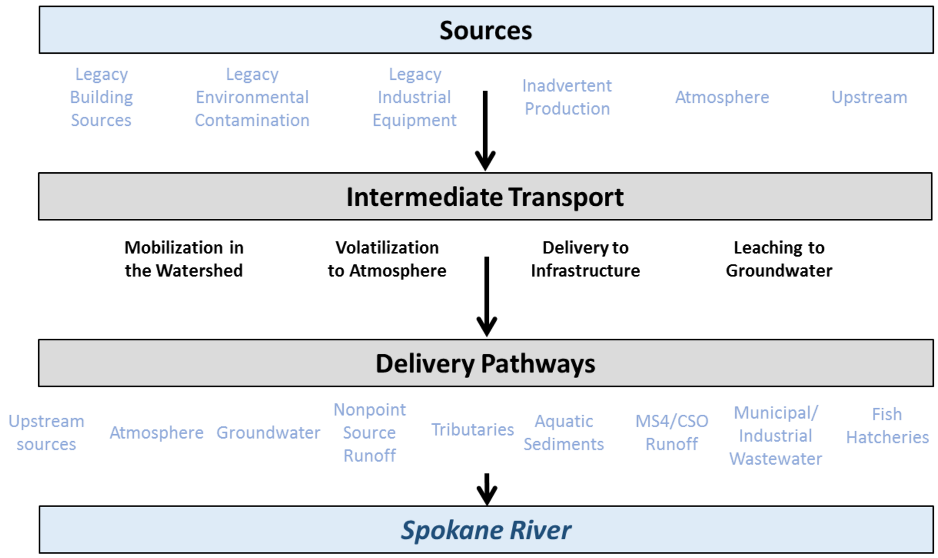


**Figure 4. Intermediate Transport Pathways for Delivery of PCBs**

Each of these pathways contains multiple components, which are described in subsequent subsections of this memorandum.

### *Mobilization in the Watershed*

Many of the sources of PCBs are contained within products of some kind. They are not immediately available for transport from the watershed to the river, and must first undergo a mobilization step. These sources, and the routes in which they are mobilized, are depicted in Figure 5. Fixed building sources can either be released to surface soil during building demolition, or transferred to recycling facilities[1]. The primary routes of watershed mobilization for non-fixed building sources are transfer to recycling facilities. PCBs contained in industrial sources can be mobilized via spills to surrounding soils, or through delivery to recycling facilities. PCBs in consumer products can be mobilized in surface soils via littering or processing at recycling facilities. Local atmospheric sources can contribute to watershed contamination via deposition and gas transfer. Finally, inadvertently produced PCBs can be directly applied to watershed soils via hydro-seed, de-icer, herbicides and pesticides, and biosolids or fertilizer applications.

[1] Transfer to landfills is discussed in the "Contribution to Groundwater" section.

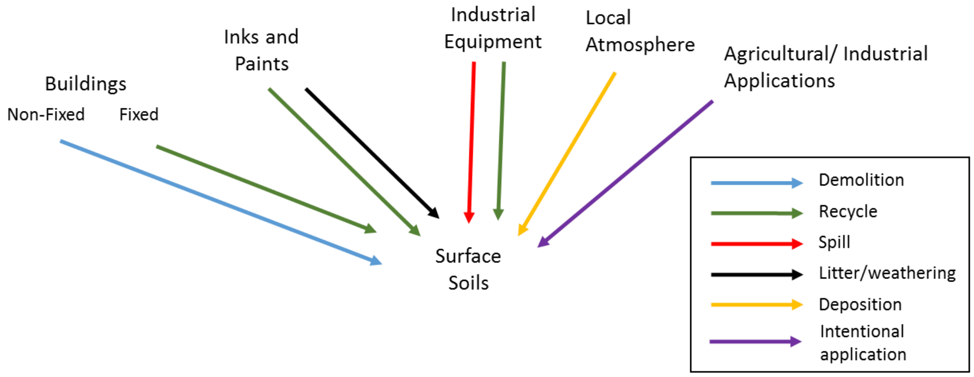


**Figure 5. Mobilization of Sources in the Watershed**

## *Mobilization to the Atmosphere*

Numerous sources contribute to local atmospheric concentrations of PCBs via volatilization, i.e. conversion into a gas phase. Most of these pathways consist of volatilization directly from one of the previously listed source categories (i.e., buildings, surface soils, industrial equipment). Combustion sources include internal combustion engines, incinerators, used oil burning and residential burning. Shanahan, et al. (2015) also identified volatilization of PCBs from sludge drying at wastewater treatment plants as an important source of atmospheric PCBs. The final source of local atmospheric sources is transport of PCBs generated outside of the watershed (Figure 6).

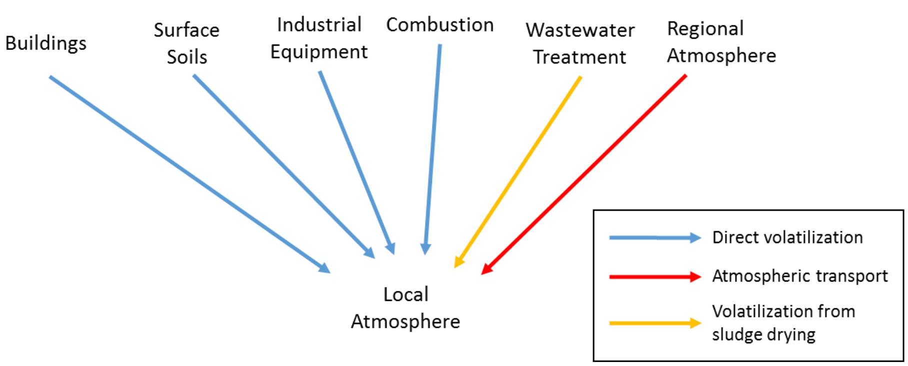


**Figure 6. Mobilization of Sources to the Atmosphere**

## *Delivery to Sewer Infrastructure*

The Spokane watershed contains a range of sewer infrastructure capable of delivering PCBs, either directly or indirectly, to the river. This infrastructure can be broadly divided into categories of stormwater and wastewater. Stormwater infrastructure can be further divided into categories of systems that directly discharge to the river and those that do not directly discharge (e.g., dry wells). Wastewater infrastructure can be divided into categories of municipal wastewater and industrial/other (i.e., Kaiser Aluminum, Inland Empire Paper, and the Spokane fish hatchery) and private septic systems. The mechanisms by which PCBs are delivered to the infrastructure are depicted in Figure 7.

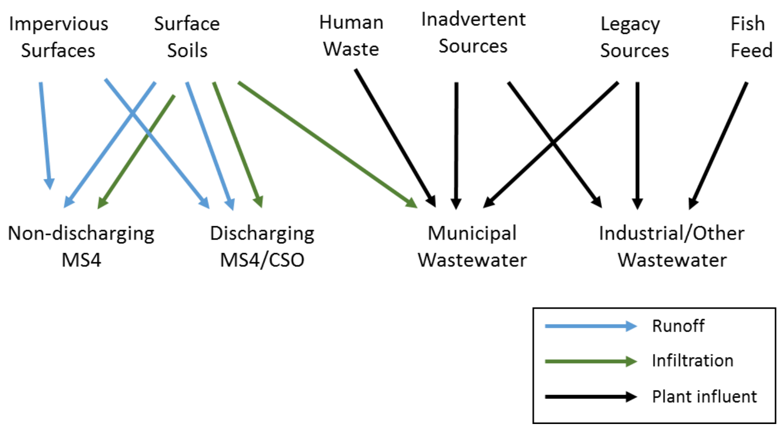


**Figure 7. Delivery of Sources to Sewer Infrastructure**

Potential sources of PCBs to the stormwater network are erosion of contaminated surface soils and infiltration of contaminated subsurface flow. Municipal wastewater treatment plants can get PCBs from infiltration of contaminated surface soils, as well as from printed materials/fabrics and legacy sources in their influent. The industrial/other wastewater treatment plants receive PCBs in their influent, with the specific nature of the PCB source depending upon the facility.

### *Contribution to Groundwater*

The final intermediate transport pathway is contribution to groundwater, with specific transport mechanisms shown in Figure 6. Subsurface soils can contribute to groundwater either via legacy contamination, landfill disposal of PCB-containing products or private septic systems. Surface soils can also contribute to groundwater contamination via infiltration. A special case is included in Figure 8 to consider detention of stormwater in the non-discharging system such as drywells and swales, as this mechanism has the potential to be a larger source of PCBs than infiltration from other soil areas.

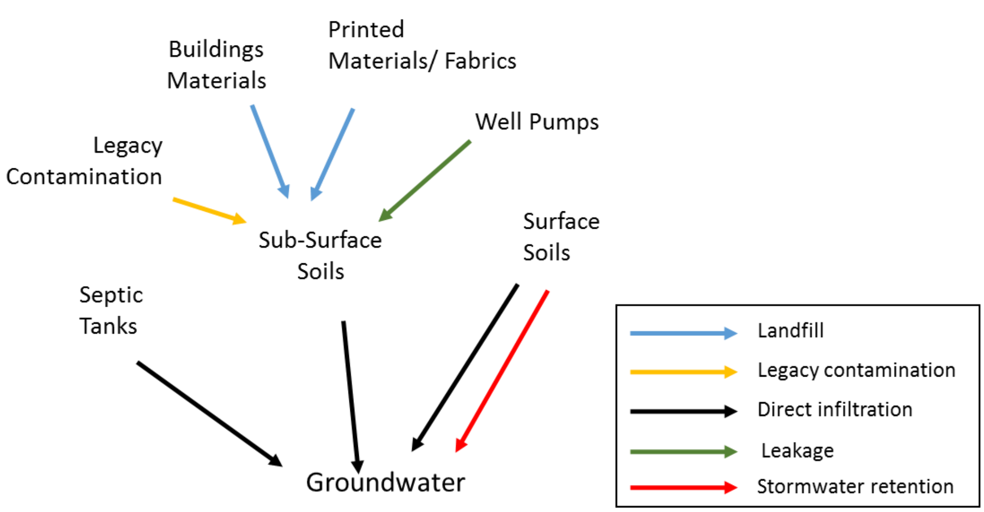


**Figure 8. Delivery of Sources to Groundwater**

## References

Guo, J., P. Praipipat, and L. A. Rodenburg. 2013. PCBs in Pigments, Inks, and Dyes: Documenting the Problem. 17th Annual Green Chemistry & Engineering Conference. June 18-20, 2013.

Hu, D., and K. C. Hornbuckle. 2010. Inadvertent Polychlorinated Biphenyls in Commercial Paint Pigments. Environ. Sci. Technol. 2010, 44, 2822–2827.

LimnoTech, 2013. Initial Conceptual Models of PCBs and Dioxins in the Spokane River Watershed. Prepared for the Spokane River Regional Toxics Task Force. Spokane, WA. November 14, 2013.

San Francisco Estuary Institute, 2010. A BMP Tool Box for Reducing Polychlorinated Biphenyls (PCBs) and Mercury (Hg) in Municipal Stormwater. San Francisco Estuary Institute, Oakland CA.

Shanahan, C.E., S. N. Spak, A. Martinez, and K. C. Hornbuckle. 2015. Inventory of PCBs in Chicago and Opportunities for Reduction in Airborne Emissions and Human Exposure. Environ. Sci. Technol., 2015, 49 (23), pp 13878–13888.