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Memorandum

From: Dave Dilks, Tim Towey, Kat Ridolfi
Date: October 4, 2013
Project: SRRTTF
To: SRRTTF
CC:

SUBJECT: **DRAFT: Initial Conceptual Models of PCBs and Dioxins in the Spokane River Watershed**

Summary

The Spokane River Regional Toxics Task Force (SRRTTF) is developing a comprehensive plan to reduce toxic pollutants in the Spokane River, and has hired LimnoTech to serve as a technical advisor. This memorandum documents draft conceptual models describing the processes affecting polychlorinated biphenyl (PCB) and polychlorinated dibenzo-*p*-dioxin and dibenzofuran (dioxin) levels in the Spokane River. The conceptual models will be used as an organizing framework to identify data gaps, as well as to determine which processes are significant enough to ultimately be included in the models used to develop the comprehensive plan. This memorandum serves as the draft deliverable for Subtask 6-1: Development of an Initial Conceptual Model. The overall conceptual models are quite complex, so this memorandum presents them in terms of discrete components (with the full conceptual models provided in the appendix).

Introduction

The SRRTTF is developing a comprehensive plan to reduce toxic pollutants in the Spokane River, designed to identify specific management actions that can be undertaken to control pollutant loads such that water quality objectives can be attained. Comprehensive plans of this type are typically developed based upon mathematical models that describe the relationship between pollutant sources and resulting environmental concentrations.

Development of a conceptual model is a key initial step in the development of a detailed mathematical model. A conceptual model is a graphic “box and arrow” depiction of all of the processes believed to be potentially significant in effecting pollutant concentrations. The conceptual model serves several purposes:

- <u>It provides a means to convey complicated processes and relationships in a simplified manner to a wide audience:</u> This graphic format allows non-modelers to review and comment on the content of the model before it is developed.
- <u>It provides a framework for assessing data gaps:</u> The conceptual model describes all processes that may be ultimately simulated in the final model. These processes will be cross-referenced with available data to define which processes can be accurately defined with existing data and which processes require additional data to describe them.
- <u>It facilitates a determination of which processes should and should not be included in the final model.</u> The conceptual model is intended to include all processes that could potentially be important to describing pollutant concentrations. Follow-up calculations will be made with site-specific data to assess each individual process and determine whether they are significant enough to be included in the final model.

The remainder of this memorandum describes conceptual models of PCB and dioxin behavior in the Spokane River and watershed. It is divided into sections of:

- Broad conceptual model
- Conceptual model for PCBs
- Conceptual model for dioxins

Broad Conceptual Model

The models to be developed for this project are designed to link sources of PCBs and dioxins in the Spokane River watershed to resulting pollutant concentrations in the Spokane River. The processes that need to be considered in the conceptual model are depicted at a very broad level in Figure 1. The process begins with defining all "true sources" of pollutants in the watershed, i.e. tracing the source of the pollutant in the watershed as far back to its origin as possible. For example, wastewater treatment plants or stormwater systems are not "true sources" of PCBs, they are primarily delivery mechanisms. Examples of "true sources" would be PCB-containing caulk that was used historically in home construction, or PCB-contaminated pigments in products that are imported into the watershed.

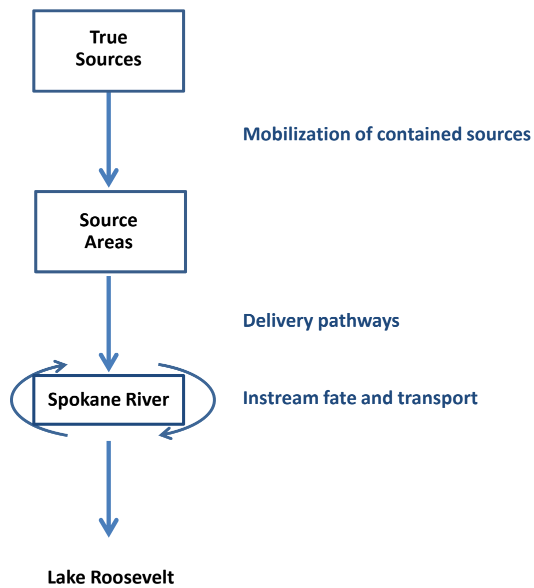


Figure 1. Broad Conceptual Model of PCBs/Dioxins in Spokane Watershed

Some of the true sources are contained in products in a manner that they are not readily available to environmental exposure, and which must undergo a mobilization step. The collection of mobilized sources is then grouped into what are termed Source Areas, such as landfills and recycling centers. The next step of the broad conceptual model describes the environmental pathways (e.g. erosion of surface soils, leaching to groundwater) by which pollutants in each source area are delivered to the Spokane River. Finally, the fate and transport of pollutants delivered to the Spokane River system must be described, e.g. resuspension of settled pollutants from the Spokane River sediments, settling of sorbed pollutants in Lake Spokane, downstream transport to Lake Roosevelt.

The remainder of this memorandum will expand each of the component pieces of the broad conceptual model to develop detailed conceptual models for PCBs and dioxins in the Spokane River and watershed.

Conceptual Model for PCBs

The full conceptual model for PCBs is developed by providing a more detailed description of each of the components of broad conceptual model shown in Figure 1:

- True sources of PCBs
- Mobilization of contained PCBs
- PCB delivery pathways
- PCB fate and transport in the Spokane River

This section provides a more detailed discussion of each individual component. The full conceptual model, integrating the components described in this section, is provided in the appendix to this memorandum.

True Sources of PCBs

The identification of true sources of PCBs consists of tracing the source of the PCBs in the watershed back as far to their origin as possible. It is important to identify these true sources, because the most effective control measures often remove pollutants at their sources, rather than trying to capture them after they have been mobilized in the environment. Table 1 describes the true sources of PCBs in the Spokane watershed, and categorizes them on several levels.

Table 1. True Sources of PCBs in the Spokane Watershed

Legacy Sources		Ongoing Sources		
Buildings	Environmental	Industrial Uses	Contaminants in Consumer Products	Other
• Fixed • Non-Fixed	• Landfills • Recycling Facilities • Other Contaminated Soil Sites • Aquatic Sediments	• Electrical Equipment • Hydraulic Equipment • Recycled newsprint	• Dyes/pigments • Motor boat oil	• Road oil/paint • Agricultural chemicals • Global atmosphere

The first level of categorization corresponds to legacy versus ongoing sources. Legacy sources correspond to PCBs that were brought into the Spokane watershed in the past, but do not continue in the present. Legacy sources are divided into categories of Buildings and Environmental sources. True sources in buildings can either be fixed sources inherent 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 soils in landfills, recycling facilities, or other contaminated soil sites, and in-place aquatic sediments (e.g. PCBs in the bottom sediments of Lake Spokane).

Ongoing sources of PCBs include industrial uses such as electrical and hydraulic equipment, contaminants in consumer products corresponding to pigments and dyes contained and other sources such as global atmospheric sources.

Mobilization of Contained PCBs

Some of the true sources of PCBs are contained within products and must undergo a mobilization step before they are available for environmental exposure. These contained sources, and the routes in which they are mobilized, are described in Figure 2. Fixed building sources can either be released to contaminated soil during building renovation, or transferred to recycling facilities and/or landfills. The primary routes of mobilization for non-fixed building sources are transfer to recycling facilities or disposal in landfills. PCBs contained in industrial sources can be mobilized via spills to surrounding soils, or delivery to recycling facilities. PCBs in recycled newsprint are mobilized via wastewater treatment plant (WWTP) effluent, while pigments/dyes in consumer products can be delivered to WWTPs, incorporated in contaminated soils (e.g. via littering), delivered to recycling facilities, or disposed in landfills.

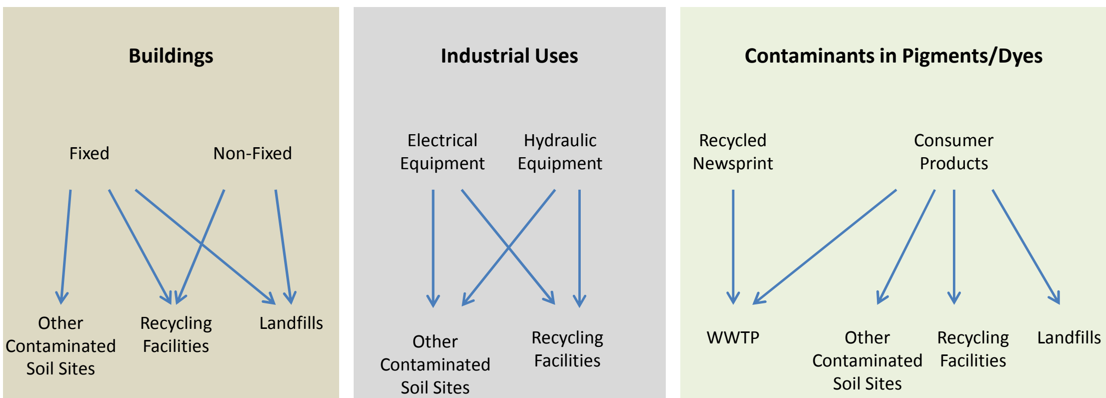


Figure 2. Mobilization of Contained Sources

The mobilization steps shown in Figure 2 collapse the eleven true sources in Table 1 into six Source Areas that can serve as the basis for a mathematical model:

- Landfills
- Recycling facilities
- Other contaminated soil
- Aquatic Sediments
- WWTPs
- Atmosphere

PCB Delivery Pathways

Delivery pathways describe how pollutants contained in source areas in the watershed are delivered to the Spokane River. In addition to describing specific environmental pathways, this step also provides a translation between Source Areas and the specific mechanisms where pollutants are delivered to the river. This translation is shown at a broad level in Figure 3.

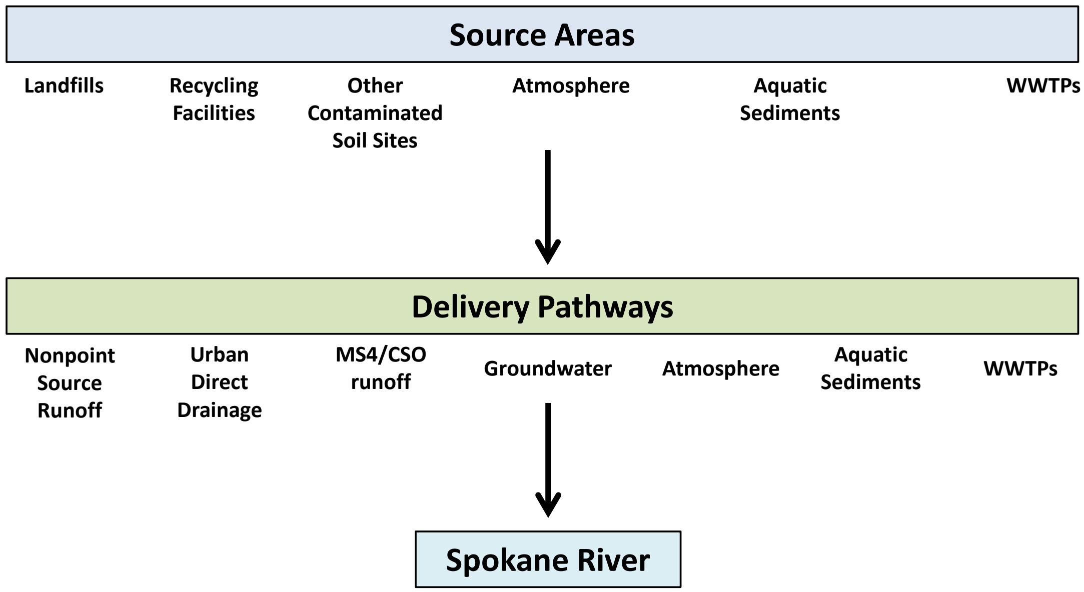


Figure 3. Broad Conceptual Description of Translation of PCB Sources Areas to Categories of Delivery

Figure 4 shows the conceptual model of all relevant PCB delivery pathways. PCBs contained in soils can erode and be delivered to the Spokane River via non-point source runoff from non-urban areas (either directly to the river or via tributaries), direct surface drainage from urban areas, municipal separate storm sewer systems (MS4), combined sewer overflows (CSOs), or routed to a WWTP as part of a combined sewer system. PCBs from these contaminated soils can also leach into groundwater or volatilize to contribute to atmospheric sources. Atmospheric sources can contribute to soil contamination in the watershed, as well as directly provide loading to the river or Lake Spokane.

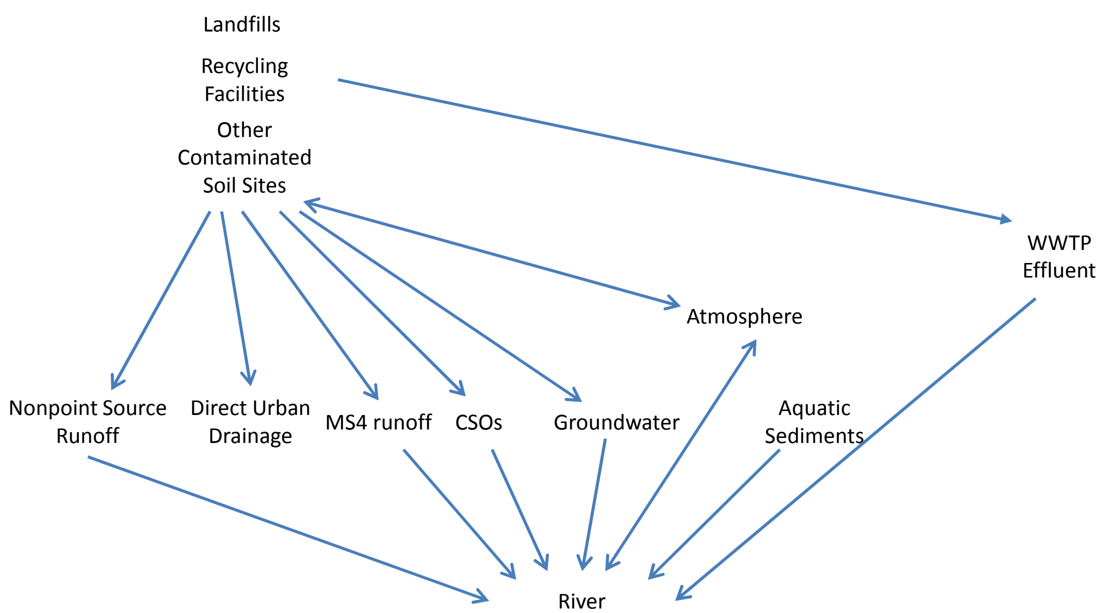


Figure 4. Conceptual Model of PCB Delivery Pathways

PCB Fate and Transport in the Spokane River

The final component of the conceptual model for PCBs consists of describing pollutant fate and transport once the PCBs are delivered to the Spokane River, and is depicted in Figure 5. All of the delivery categories listed previously serve as sources of PCBs. Potentially relevant mechanisms include volatilization of dissolved water column PCBs to the atmosphere; diffusion of dissolved PCBs in the sediment pore water back into the water column, settling of sorbed PCBs from the water column to the bottom sediment, resuspension of contaminated bottom sediments back into the water column, and biodegradation of PCBs in the bottom sediment.

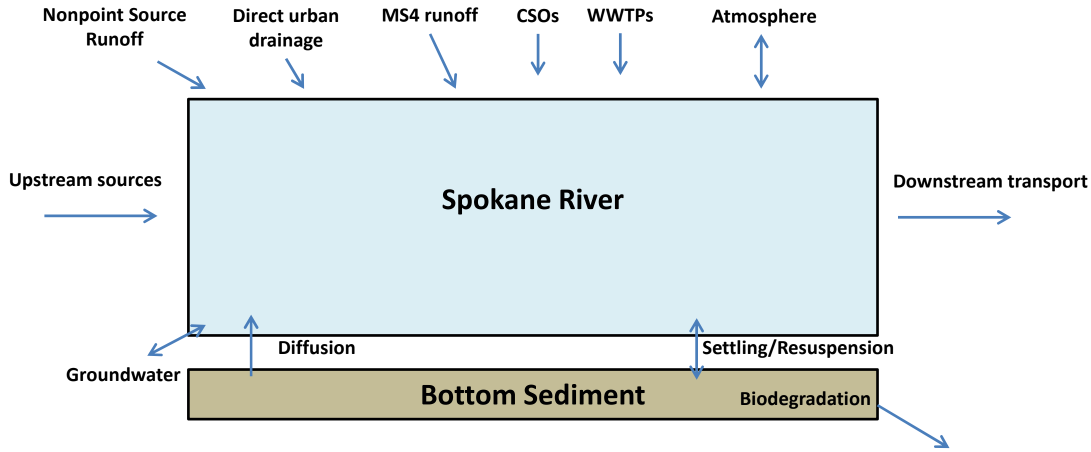


Figure 5. Conceptual Model of PCB Fate and Transport in the Spokane River

Conceptual Model for Dioxins

The conceptual model for dioxins is similar to that for PCBs. The primary difference is in the nature of the sources. Dioxins are not contained in products to the extent that PCBs are, such that description of the mobilization step is not necessary. This leads to the broad conceptual model shown in Figure 6.

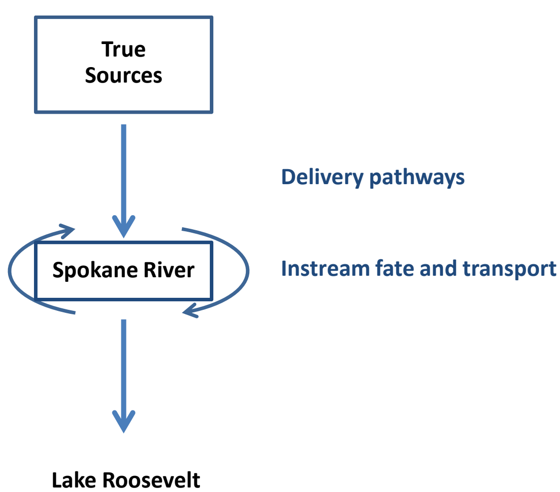


Figure 6. Broad Conceptual Model of Dioxins in Spokane Watershed

The remainder of this section expands upon the components of the broad conceptual model, and is divided into discussions of:

- True sources of dioxins
- Dioxin delivery pathways
- Dioxin fate and transport in the Spokane River

The full conceptual model, integrating the components described in this section, is provided in the appendix to this memorandum.

True Sources of Dioxins

The identification of true sources of dioxins also consists of tracing the source of the dioxins in the watershed back as far to their origin as possible. It is important to identify these true sources, because the most effective control measures often remove pollutants at their source, rather than trying to capture them after they have been mobilized in the environment. Table 2 describes the true sources of dioxins in the Spokane watershed, and categorizes them on several levels.

Table 2. True Sources of Dioxins in the Spokane Watershed

Legacy Sources		**Ongoing Sources**		
Contaminated Soil Sites	Aquatic Sediments	Global Atmosphere	Manufacturing	Combustion
			• Pulp Bleaching	• Municipal Waste Incinerator • Yard Waste, Wood Burning and Forest Fires • Vehicle emissions • Smelters

The first level of categorization corresponds to legacy versus ongoing sources. Legacy sources correspond to dioxins that were brought into the Spokane watershed in the past, but do not continue in the present and are divided into categories of Contaminated Soil Sites and Aquatic Sediments. Ongoing sources of dioxins include global atmospheric sources, manufacturing sources such as pulp bleaching, and a range of combustion sources.

Because dioxins are not contained within products to the degree that PCBs are, the mobilization step required for PCBs is not required for dioxin. Translation of true sources to into Source Areas used in the mathematical model requires only the combination of global atmospheric and combustion source into a single category, resulting in four Source Area categories:

- Contaminated soil
- Aquatic Sediments
- WWTPs
- Atmosphere

Dioxin Delivery Pathways

Delivery pathways describe how pollutants contained in source areas in the watershed are delivered to the Spokane River. In addition to describing specific environmental pathways, this step also provides a translation between source areas and the specific mechanisms where pollutants are delivered to the river. This translation is shown at a broad level in Figure 7.

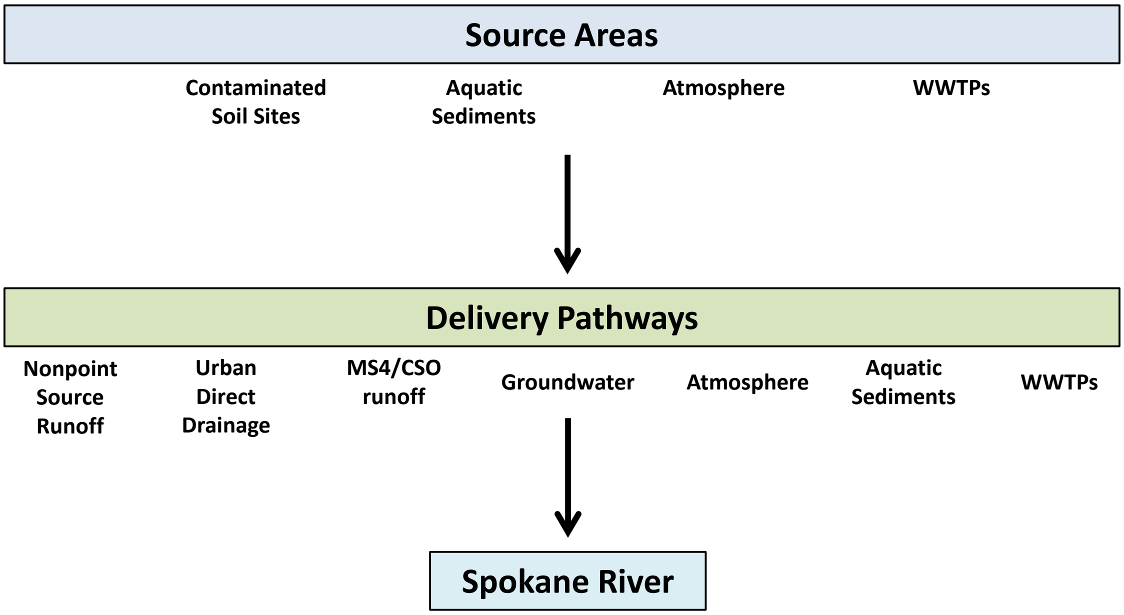


Figure 7. Broad Conceptual Description of Translation of Dioxin Sources Areas to Categories of Delivery

Figure 8 shows the conceptual model of all relevant delivery pathways. Dioxins contained in soils can erode and be delivered to the Spokane River via direct surface drainage, municipal separate storm sewer systems (MS4), combined sewer overflows (CSO), or routed to a WWTP as part of a combined sewer system. Small amounts of dioxins from these contaminated soils may also leach into groundwater. Atmospheric sources can contribute back to soil contamination in the watershed, as well as directly provide loading to the river or Lake Spokane.

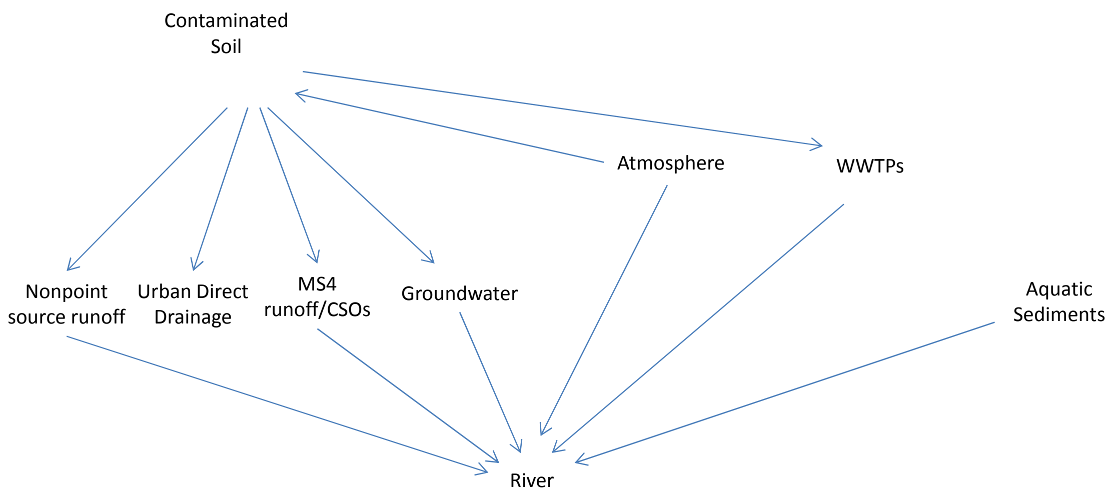


Figure 8. Conceptual Model of Dioxin Delivery Pathways

Dioxin Fate and Transport in the Spokane River

The final component of the conceptual model for dioxins consists of describing pollutant fate and transport once the dioxins are delivered to the Spokane River, and is depicted in Figure 5. All of the delivery categories listed previously serve as sources of dioxins. Potentially relevant mechanisms include volatilization of dissolved water column dioxins to the atmosphere, photolysis of dioxins in the water column, diffusion of dissolved dioxins in the sediment pore water back into the water column, settling of sorbed dioxins from the water column to the bottom sediment, resuspension of contaminated bottom sediments back into the water column, and biodegradation of dioxins in the bottom sediment.

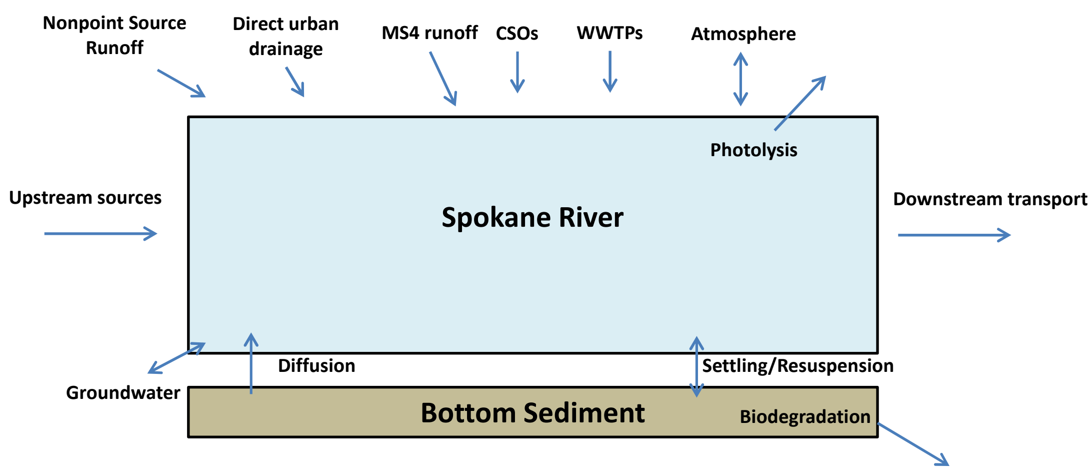
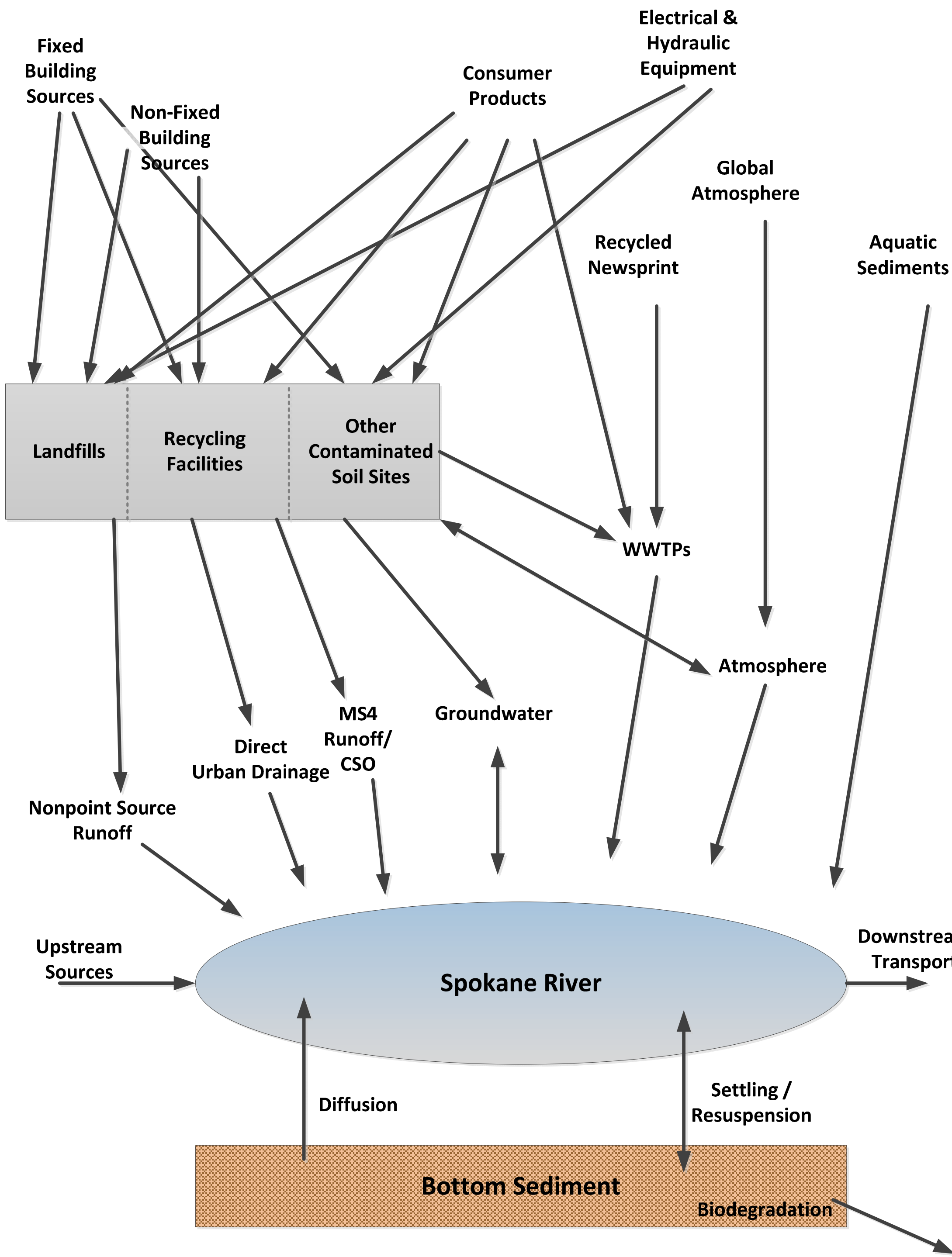


Figure 9. Conceptual Model of Dioxin Fate and Transport in the Spokane River

Appendix

Integrated Conceptual Model for PCBs



Integrated Conceptual Model for Dioxins