Lake Washington PCB Modeling

Quality Assurance Project Plan

Part of the Study: Modeling PCB/PBDE Loadings Reduction Scenarios for the Lake Washington Watershed

February 2013

FINAL

King County

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Final Quality Assurance Project Plan

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Disclaimer:

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ABSTRACT

We propose to model PCB fate and bioaccumulation in Lake Washington using a relatively simple box model with a water column and sediment compartment to simulate long-term fate and contaminant accumulation in Lake Washington biota. The coupled fate and bioaccumulation models will be used to evaluate the effect of hypothetical reductions in PCB loading to reduce PCB levels in resident fish and the time frame over which the observed response may occur. The end result will be a more complete understanding of the processes controlling the ultimate fate of PCBs in the lake and the potential for management actions to reduce health risks from consuming contaminated fish from Lake Washington.

1.0. INTRODUCTION

King County was awarded a Puget Sound Action Agenda: Technical Investigations and Implementation Assistance Grant by the U.S. Environmental Protection Agency (USEPA) to estimate loading of polychlorinated biphenyls (PCBs) and polybrominated diphenylethers (PBDEs) to Lake Washington, Lake Union and Puget Sound; and model potential reduction in Lake Washington fish tissue concentrations associated with selected PCB loading reduction scenarios. A field study was designed and implemented from 2011 to 2012 to measure PCB and PBDE concentrations in key contaminant loading pathways to Lakes Washington and Union (i.e., rivers, streams, stormwater, combined sewer overflows, highway bridges and atmospheric deposition) and measure the concentrations in the export pathway leaving the lake system through the Ship Canal locks to Puget Sound (King County 2012a). By combining the contaminant concentration data with long term flow estimates for these pathways, mass loading estimates to Lakes Washington and Union and subsequent export to Puget Sound for total PCB (tPCB) and total PBDE (tPBDE) were developed (King County 2012b).

This project is considered a first step toward understanding the relative importance of major contaminant loading pathways that contribute PCBs and PBDEs to these lakes as well as understanding their long term fate and the potential for recovery. This Quality Assurance Project Plan (QAPP) describes the proposed development of a tPCB mass balance (fate) and food web bioaccumulation model for Lake Washington.

The end result is expected to be a more complete understanding of the processes controlling the ultimate fate and the potential for management actions to reduce health risks from consuming PCB-contaminated fish from Lake Washington. The study will also provide a better understanding on which future monitoring and modeling efforts can be planned.

1.1 Problem Definition and Background

PCBs are chlorinated organic compounds that were manufactured for uses that required chemical stability and low flammability. PCBs include 209 individual compounds known as congeners that vary to some degree in physical, chemical and toxicological properties based primarily on the degree of chlorination. Due to their chemical stability and low water solubility, PCBs are persistent in the environment, bind strongly to sediment and soil particles; and bioaccumulate in aquatic organisms, wildlife and humans.

The bioaccumulation of PCBs presents a potential health risk to aquatic life, terrestrial wildlife, and humans. The Washington Department of Health (WADOH) issued a fish consumption advisory for PCBs in Lake Washington which covers yellow perch, cutthroat trout, carp and northern pikeminnow (WADOH 2004).[1] PCB concentrations in Lake Washington fish exceed

[1] Washington State Department of Health Fish Consumption Advisories (see: http://www.doh.wa.gov/CommunityandEnvironment/Food/Fish/Advisories.aspx

both the National Toxics Rule[2] levels for protection of human health and the 95th-percentile of concentrations measured in fish collected statewide (Seiders and Deligeannis 2009).

Commercial production of PCBs began in the 1920s, initially for use as a dielectric fluid in electrical transformers, capacitors and electric motors. After World War II, production increased substantially and PCB use diversified to include heat transfer fluids, hydraulic fluids, plasticizers, carbonless copy paper, lubricants, inks, laminating agents, paints, adhesives, waxes, additives in cements and plasters, casting agents, sealing liquids, fire retardants, immersion oils and pesticides (De Voogt and Brinkman 1989). PCBs were voluntarily phased-out of production in the 1970s and manufacture and most uses were banned in 1979 in the United States (44 FR 31514).[3] While the sale and production of PCBs have been banned for over three decades, considerable amounts of PCBs remain in use – primarily as dielectric fluid in so-called closed sources like transformers and capacitors and in open sources such as building caulks and sealants in older structures (Diamond et al. 2010; Robson et al. 2010).

In general, halting the production of PCBs, elimination of many uses, and a declining inventory of PCBs in use has resulted in declining concentrations in environmental media, including fish tissue and aquatic sediments (Peterman et al. 1990; Van Metre and Mahler 2005). However, studies of fish tissue and sediment concentrations in many areas of the world indicate that the initial rate of decline appears to have slowed or halted completely (Van Metre et al. 1998; Hickey et al. 2006; Bhavsar et al. 2007).

Historical data on PCB levels in non-anadromous fish collected from Lakes Washington and Union are insufficient to evaluate long-term trends in PCB concentrations (McIntyre 2004). Studies have been conducted on anadromous fish; however these fish generally spend only a portion of their life cycle in these lakes and the measured contaminant concentrations are generally lower than those observed in resident (non-anadromous) fish species (McIntyre 2004; Fletcher 2009).

Substantial declines in sediment PCB concentrations in Lake Washington have been documented for Lake Washington, which are now about a third or less of the peak concentrations measured in the early 1970s (Yake 2001; Van Metre et al. 2004; Van Metre and Mahler 2005; Furl et al. 2009 Era-Miller et al. 2010). Van Metre and Mahler (2005) collected and dated one core from the central basin of Lake Washington. They reported a median concentration of 199 µg/kg dw for the 1965-1975 period and 59 µg/kg dw for the 1990-2000 period. The increase and subsequent decrease in sediment PCB concentrations coincide with the national trends in production, use and subsequent use limitations and elimination of production. In the case of Lake Washington, the increase and decline also coincides generally with the development and growth of cities around the lake and subsequent diversion of inputs of treated wastewater from Lake Washington to Puget Sound that was completed in 1968 (Edmondson and Lehman 1981).

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[2] U.S. Environmental Protection Agency (USEPA) National Toxics Rule (see: http://water.epa.gov/scitech/swguidance/standards/wqsregs.cfm)

[3] U.S. Environmental Protection Agency (see: http://www.epa.gov/history/topics/pcbs/01.html)

1.2 Project Goals and Objectives

Overall, this study will fill data gaps and develop modeling tools to help answer three management questions:

1. Which types of loading pathways are the highest priorities for PCB/PBDE load reduction?
2. Will potential loading reductions from these pathways reduce fish bioaccumulation, and contribute substantially towards lifting the fish consumption advisory on Lake Washington?
3. How long might it take the system to respond to these hypothetical loading reductions?

This modeling QAPP describes the proposed approach to the development, testing and application of coupled box models of contaminant fate and bioaccumulation of PCBs in Lake Washington.

1.3 Modeling Objectives

The ultimate goal of the development of fate and bioaccumulation models for Lake Washington is to reliably forecast the recovery of fish from PCB contamination under a variety of possible management scenarios. This effort is considered to be a multi-phased process in which the development of a relatively simple mass budget model coupled to an ecosystem bioaccumulation model is a first step. This first step will be accomplished during the grant project period but other phases are expected to occur beyond this period.

The specific objectives of the proposed modeling effort are as follows:

- Develop a quantitative understanding of the long-term fate of PCBs in Lake Washington.
- Provide quantitative estimates of the time and magnitude of the response of lake water, sediment and fish tissue to reductions in PCB loading.

These two modeling objectives address overall project study questions 2 and 3 above.

2.0. PROJECT ORGANIZATION AND SCHEDULE

The team members directly involved in this project includes EPA staff that provide grant administration, oversight and technical support to the project; King County staff that manage the project and conduct the technical work; stakeholder representatives who volunteer in an advisory capacity; and staff technical support provided by Ecology. Specific team members and their responsibilities for the modeling component of the study are listed in Table 1. The proposed schedule for performing the planned modeling effort and associated deliverables is outlined in Table 2.

Table 1. Organization of project staff and responsibilities

Staff	Title	Responsibilities
Melissa Whitaker EPA Region 10 Phone: (206) 553-2119	Project Officer	Review and approval of QAPP
Michael Cox EPA Region 10 Phone: (206) 553-1597	Technical Officer	Review and approval of QAPP
Gina Grepo-Grove EPA Region 10 Phone: (206) 553-1632	QA Manager	Review and approval of QAPP
Jenée Colton King County Phone: (206) 296-1970	Project Manager	Review and approval of QAPP, bioaccumulation model development and testing, co-authors draft and final report
Richard Jack King County Phone: (206) 405-5151	QA Officer	Review and approval of QAPP
Curtis DeGasperi King County Phone: (206) 684-1268	Lead Hydrologist	Prepare QAPP, fate model development and testing, scenario analysis, co-author draft and final report
Greg Pelletier Ecology - EAP Phone: (360) 407-6485	Environmental Engineer	Review and approval of QAPP, review and assistance with model development, review final report

Table 2. Proposed schedule for completing modeling work and reports.

Activity	Time period	Staff	Description
Draft Modeling QAPP	Dec 2012	Curtis DeGasperi, Jenée Colton, Greg Pelletier	Preparation and distribution of draft Modeling QAPP for review.
Final Modeling QAPP	January 2013	Curtis DeGasperi, Jenée Colton, Greg Pelletier	Preparation and distribution of final Modeling QAPP
Draft Field Study Data Report	January 2013	Jenée Colton, Richard Jack	Preparation of draft report documenting project field study data used to develop PCB loading estimate and provide lake water data for model development and testing
Final Field Study Data Report	February 2013	Jenée Colton, Richard Jack	Final report
Draft PCB/PBDE Loadings Report	January 2013	Curtis DeGasperi	Preparation of draft report documenting methods and results of PCB (and PBDE) loading estimates
Final PCB/PBDE Loadings Report	February 2013	Curtis DeGasperi	Final report
Draft Data Report Addendum	February 2013	Richard Jack	Presentation of QA-reviewed, existing sediment and biota data for model development and testing
Final Data Report Addendum	March 2013	Richard Jack	Final Data Report Addendum
Fate Model Development	April 2013	Curtis DeGasperi, Greg Pelletier	Development of model and documentation of support for assumptions and selected parameter values
Fate Model Testing	May – Jun 2013	Curtis DeGasperi, Greg Pelletier	Hindcast testing of model against estimated mass of PCBs in water and sediment
Fate Model Scenarios	Jun – Jul 2013	Curtis DeGasperi, Greg Pelletier	Test model response to load reduction scenarios
Bioaccumulation Model Development	Feb – Apr 2013	Jenée Colton	Development of model and documentation of support for assumptions and selected parameter values

Activity	Time period	Staff	Description
Bioaccumulation Model Testing	Apr – Jun 2013	Jenée Colton	Hindcast testing of model against observed PCB concentrations in modeled biota
Internal Review	June 2013	Greg Pelletier	Review of fate and bioaccumulation model framework
Bioaccumulation Model Scenarios	Jun – Jul 20132	Jenée Colton	Test model response to load reduction scenarios (requires output from fate model)
Develop Recommendations	July 2013	Jenée Colton, Curtis DeGasperi, Richard Jack	Develop recommendations for next phase with advisory panel
Draft Report	September 2013	Curtis DeGasperi, Jenée Colton, Greg Pelletier	Draft report describing model development, testing, scenario results and significant findings/recommendations
Final Report	October 2013	Curtis DeGasperi, Jenée Colton, Greg Pelletier	Final report

3.0. STUDY AREA AND MODEL DOMAIN

The study area encompasses 1,550 km^2 (598 mi^2) from the Lake Washington outlet at Montlake Cut (Figure 1).[4] The area experiences a generally mild maritime climate with heaviest precipitation occurring in winter months, primarily as rain at lower elevations and as snow at higher elevations. Elevations are generally less than 1,000 m (3,281 ft), but the total amount of annual rainfall is very dependent on elevation which ranges from about 6 m above mean sea level (msl) to 1,700 m (4,464 ft), and this results in a range of annual precipitation from almost 1,000 mm (39 in) at lake level to over 2,500 mm (100 in) at the highest elevations. Winds are highly variable, but during the winter, major storms and associated winds typically originate from the southwest.

Two major rivers drain to Lake Washington. The Sammamish River drains Lake Sammamish and tributaries in the Sammamish River valley and enters Lake Washington from the north, providing about 30 percent of the total inflow to lake. The Cedar River enters the south end of the lake and contributes about 50 percent of the total inflow (Edmondson 1977; King County 2003; Cerco et al. 2004). Lake Washington then drains through the Montlake Cut to Lake Union, which drains through the Lake Washington Ship Canal (Ship Canal) and Locks to Puget Sound.

Historically, Lakes Washington and Union were not connected. By 1916 a canal was completed between the two lakes, the outlet of Lake Union was widened and deepened and a lock and dam system was in operation (Chrzastowski 1983). Prior to canal and lock construction, the main inflow to Lake Washington was from the Sammamish River and outflow was through the Black River at the southern end of the lake. To provide sufficient water for lock operation and to reduce flooding, the Cedar River, which had previously joined the Black River near the southern end of the lake, was diverted to Lake Washington (Chrzastowski 1983). These engineering changes resulted in the summer intrusion of saltwater from Puget Sound that enters through the Locks and Ship Canal into Lake Union, resulting in a layer of denser saline water at depth in the lake, which is then entrained and flushed from the lake during winter high flows. The extent of intrusion of saline water is limited to Lake Union through various mitigation measures, including a salt water barrier at the upstream side of the larger of the two locks and a saltwater drain located in a depression at the head of both locks. Salinity is monitored continuously in summer at the University Bridge and is not to exceed 1 ppt (173-201A WAC).

The immediate area around Lake Washington is highly developed and includes the major cities (i.e., >50,000 residents) of Seattle, Bellevue, and Renton. While Lake Washington received wastewater from a number of municipal treatment plants until 1968, there are still approximately 40 combined sewer overflows (CSOs) that intermittently discharge to locations along the Seattle shoreline of the lake. Lake Washington is crossed by two floating bridges – State Route 520 (SR 520) to the north and Interstate 90 (I-90) to the south.

The study area also includes relatively undeveloped, primarily forested, areas in the headwaters of the two major river basins. The headwaters of tributaries along the southeast shoreline of Lake Washington are also relatively undeveloped. The headwaters of the Cedar River are in a

[4] This watershed area estimate includes the surfaces of all lakes, streams and wetlands in the watershed.

protected watershed for the Chester Morse water supply reservoir that provides Seattle Public Utilities (SPU) with a portion of its potable water supply.

The model domain is defined as Lake Washington, which is the second largest natural lake in the state. The lake is an elongated north-south trending glacial trough approximately 35 km (21.7 mi) long with an average depth of 32.9 m (108 ft), a maximum depth of 65.2 m (214 ft), a surface area of 87.6 km^2 (33.8 mi^2) and a volume of 2.884 x 10^9 m^3 (2,338,000 acre-ft) (Anderson 1954).[5] Edmondson and Lehman (1981) provide estimates of annual lake hydraulic renewal times, which indicate that on average the fraction of lake volume renewed each year with incoming water (corrected for evaporation) is 0.43 per year. The reciprocal of this is 2.3 years – the average hydraulic residence time of water in the lake.

[5] King County geographic information system (GIS) data indicate a lake surface area (including Union Bay) closer to 89 km^2 (34.4 mi^2), but this may be due to the exclusion of Union Bay from the earlier estimate. Also, Edmondson and Lehman (1981) report a total lake volume of 2.885 x 10^9 m^3 (2,339,000 acre-ft).

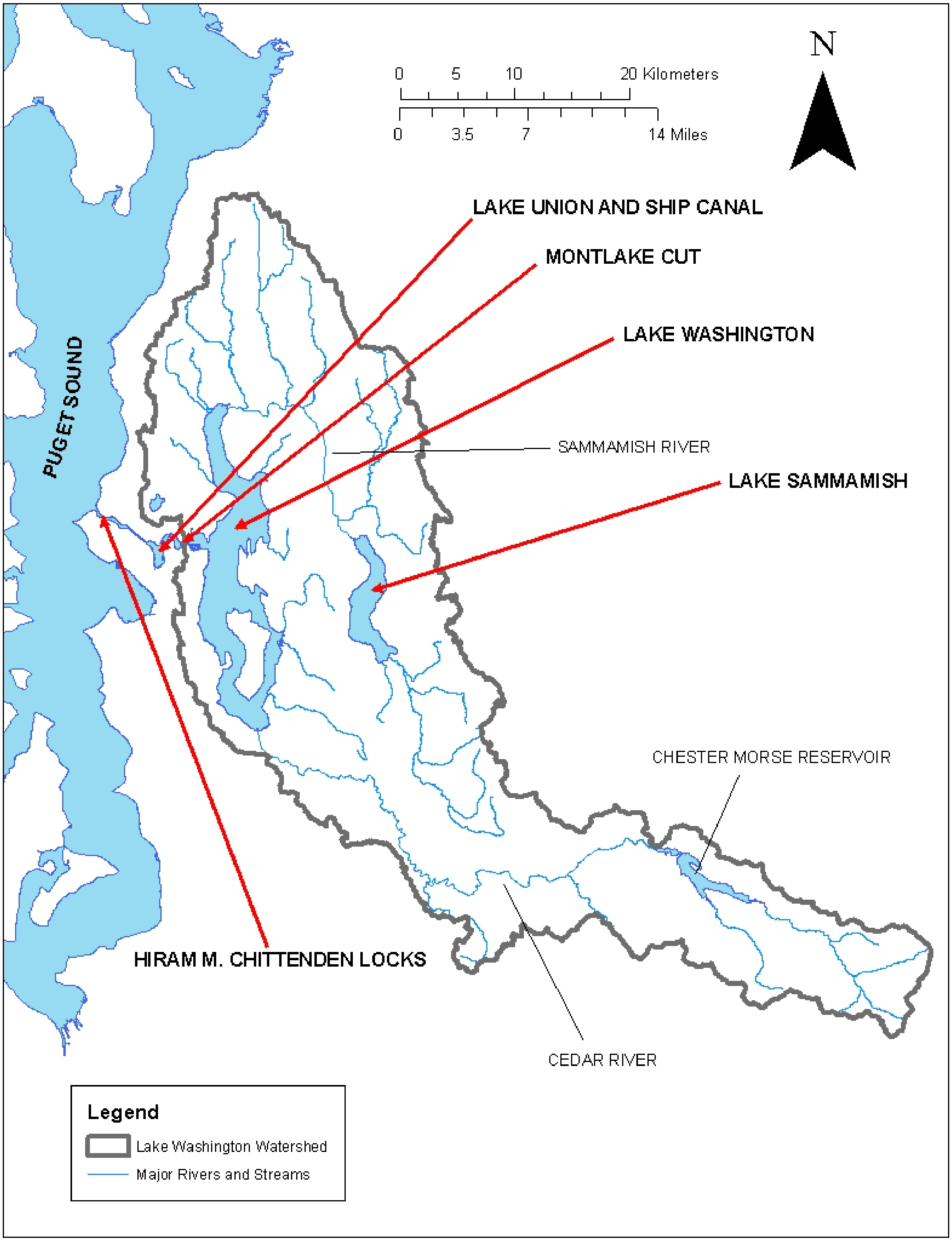

Figure 1. Lake Washington Watershed

4.0. MODEL DEVELOPMENT

In theory, model development should be an iterative approach that involves initial conceptualization and implementation based on management information needs and available resources followed by testing and model refinement. However, the application of models as an aid in management decision-making typically requires a more finite project timeline. The modeling framework described in this QAPP establishes a finite timeline consists of model development, testing and communication of the model results and implications for management.

Ideally, modeling and management decision making would be a coupled iterative process that allows for additional data collection, model testing, model refinement, and re-evaluation of model results and the management decisions based on them. The model development framework proposed herein should be viewed as an initial step, with a finite timeline, in a potentially iterative process as the results of this study are communicated to water resource managers who can determine if further model refinements similar to second phases of San Francisco Bay (Davis et al. 2007, Oram et al. 2008) and Puget Sound (Osterberg and Pelletier 2012) modeling efforts are warranted.

4.1 Model Selection

The most important criteria for selecting the modeling framework for this project include:

1. The framework uses algorithms and solution techniques that are appropriate for the intended application.
2. Peer review of model theory and past applications has occurred.
3. Technical documentation is available.
4. Active development of the framework is ongoing and technical support is available.

In addition to these key criteria, other considerations that would be beneficial include the following:

- Successful past applications in the Puget Sound region have occurred.
- Program source code is available for review as part of program documentation.
- Team members responsible for modeling tasks are familiar with the selected model(s)

Based on the model selection criteria outlined above, the contaminant fate and bioaccumulation modeling framework developed for San Francisco Bay (Davis et al. 2007) and adapted to use for Puget Sound (Pelletier and Mohamedali 2009) is proposed for use in this study.

tPCBs encompass 209 congeners that vary widely in their chemical and toxicological properties. To simulate tPCBs, the framework of the fate/transport and bioaccumulation modules allow for either (1) use of the properties of a single congener to represent the entire chemical class, or (2) separate simulations of a number of different congeners or homologs which are then summed to determine the “total” result for the entire class. Davis (2004) and Pelletier and Mohamedali

(2009) used the first strategy to simulate mass fluxes of tPCBs according to the chemical properties of a single congener, PCB-118. Selection of PCB-118 as the "representative" congener was based on its intermediate chemical properties and level of chlorination, abundance in the ecosystem, similarity to a highly toxic congener, and data availability. The first strategy is proposed for development of the Lake Washington PCB fate model.

In contrast, the bioaccumulation module as employed by Condon (2007) and Pelletier and Mohamedali (2009) used the second strategy, simulating the movement of 57 different PCB congeners through the food web and then summing to get "total" concentrations for the various organisms. The modeled congeners were chosen due to their presence in regional sediment and biota data and because those congeners were known to comprise the majority of the Total PCB mass (and were thus considered to be reasonably representative of the behavior of the entire family of PCB congeners). However, PCB concentrations measured in Lake Washington biota have only been analyzed as Aroclors; no congener data are available. Therefore, the first strategy described above will be used to develop the Lake Washington bioaccumulation model.

4.2 Contaminant Fate Model

The proposed contaminant fate model is a two-compartment (lake water and bottom sediment) fate model described by Davis et al. (2007). The steps required for development and testing of the model include the following:

- Compile data on concentrations of PCBs in Lake Washington water and sediment that will provide the basis for testing model assumptions (current estimated loads and parameter values). This step will be completed as part of the Field Study Data Report and Report Addendum (see project schedule in Section 2.0)
- Set up and test the two-compartment box model developed for San Francisco Bay (Davis 2007) for Lake Washington.

Model testing will be based on a hindcast modeling approach used in the development of the initial San Francisco Bay PBDE model (Oram et al. 2008). Fluvial and atmospheric loading estimates developed as part of this study (King County 2012b) will provide the estimated current tPCB load for hindcast testing the fate model.

A rigorous calibration of the fate model is not possible because the decadal time history of PCB loading to the lake is not known. Although such a calibration approach is feasible, it would require the development of an estimated time history of historical PCB loading to Lake Washington over the last 100 years, the incorporation of a multi-level sediment compartment model into the fate model, and calibration of the modified model to concentration profiles of sediment PCBs. This level of effort is beyond the scope of this project.

An estimate of historical PCB loading to San Francisco Bay has been developed along with a multi-level sediment compartment model that has been tested against observed sediment PCB concentration profiles (Oram et al. 2008). Dated profiles of sediment PCBs are available for Lake Washington (Van Metre et al. 2004, Van Metre and Mahler 2005, Furl et al. 2009). Depending on the results of this initial modeling effort, further model development and testing may be a reasonable recommendation for a follow-up study.

4.3 Ecosystem (Food Web) Bioaccumulation Model

The proposed model is a food web bioaccumulation model originally developed by Arnot and Gobas (2004), which was adapted for use in San Francisco Bay (Gobas and Arnot 2010). The San Francisco Bay bioaccumulation model was also adapted for use in modeling contaminant accumulation in biota at various trophic levels for the Strait of Georgia (Condon 2007). This model was then adapted to modeling contaminant bioaccumulation in selected Puget Sound biota (Pelletier and Mohamedali 2009).

The model predicts whole-tissue contaminant concentrations in food web components (e.g., phytoplankton, zooplankton, benthic invertebrates, and fish) by calculating rates of chemical uptake from water and diet as well as elimination rates to the water, feces and growth dilution. The model assumes steady-state conditions, i.e. the chemical concentrations have reached equilibrium conditions in water, sediment and biota. The main implication of this assumption is that predicted biota PCB concentrations are directly proportional to sediment and water concentrations at any point in time. This assumption is reasonable considering the relatively long expected response time of the lake (i.e., years) to changes in PCB loads relative to the typical response time of organisms (days) (Gobas and Arnot 2010).

The steps required for development and testing of the Lake Washington bioaccumulation model include the following:

- Gather existing information on the food web structure of Lake Washington and develop a conceptual model of the food web with the species of interest.
- Compile data to establish reasonable model input values for model parameters (e.g., biota lipid content, dietary absorption efficiency, growth rate factor).
- Compile data on concentrations of PCBs in Lake Washington biota that will provide the basis for testing model assumptions (model coefficients).

Testing will be based on the approach used in the development of the San Francisco Bay and Puget Sound models (Davis et al. 2007, Gobas and Arnot 2010, Pelletier and Mohamedali 2009). Available sediment, water column and biota tissue tPCB data will provide the basis for model testing. Fundamentally, the testing of the bioaccumulation model will be based on comparison of model predicted biota tPCB concentrations to observed concentrations.

4.4 Data Requirements

A variety of environmental data will serve as inputs and boundary conditions for the models. The required for model development and testing include physical, chemical and biological data. The types of data required (and sources where known and/or applicable) are described below.

4.4.1 Physical

The fate model requires a variety of physical data. Required data include the physical dimensions of Lake Washington, including the lake volume and areas of the surface and bottom as well as the mean depth of the lake. These physical measurements will be taken from published sources (see Section 3.0).

In addition to the physical dimensions of the lake, other data are needed such as the mean outflow rate, mean lake temperature, etc. Model input values will be derived from data found in published literature on Lake Washington to the extent possible and supplemented with values published for other systems if local data are unavailable. Lake Washington has been the focus of scientific research, so there is a wealth of published data that will be reviewed to identify lake-specific sources of model inputs.

As examples, the mean outflow rate will be based on the long-term (2002-2011) lake outflow rate derived in King County (2012b). Wakeham et al. (2004) and Furl et al. (2007) provide the most recent estimates of sediment burial rates. The sources of all model inputs will be documented in the draft and final report (see Section 2.0 above).

4.4.2 Chemical

The fate and bioaccumulation models also require water, sediment and biota PCB data from Lake Washington. The fate model also requires long-term PCB loading estimates and data on the average organic content of particles settling in the water column and the organic content of bottom sediments.

A field sampling effort was already implemented as part of this study that provided lake water column PCB concentration measurements in support of model development and testing (King County 2012a). PCB source pathways to the lake, including combined sewer overflows (CSOs), atmospheric deposition, and river and stream inputs were also sampled and the data were used to developed current long-term (2002-2011) tPCB loading estimates to Lake Washington for use as inputs to the fate model (King County 2012b).

Additional data will be needed to support the development and testing of the proposed models. These data include surface sediment concentrations of tPCB and organic carbon for development and testing of the fate model and concentrations of tPCB in lake biota for development and testing of the bioaccumulation model.

These additional data will be obtained primarily from the King County environmental database that contains data generated by the King County Environmental Laboratory following project-specific QAPPs and published laboratory Standard Operating Procedures.

Summaries of the extent of available sediment contaminant data for Lake Washington, including data for PCBs can be found in Moshenberg (2004). Additional sediment contaminant data are available from Ecology (e.g., Era-Miller et al. 2010) and King County (2008).

Biota contaminant data for Lake Washington, including PCB data, are available from McIntyre (2004), Ecology (Johnson et al. 2006, Seiders and Deligeannis 2009) and King County (2010).

Relevant descriptive statistics (e.g, mean, median, 25^{th} and 75^{th} percentiles, minimum, maximum) will be calculated for water and sediment based on the compiled historical data. Summary statistics for historical data compiled for tPCB concentrations in lake biota (on a species-specific basis) will also be reported. The compiled historical data, data quality review and summary statistics will be documented in an addendum to the study data report (see Section 2.0 above).

4.4.3 Biological

Biological data are required for development of the bioaccumulation model. The primary biological data required for bioaccumulation model development is a conceptual food web. The food web structure of Lake Washington has been studied in part (e.g., Hampton et al. 2006, Nowak et al. 2004, Fayram and Sibley 2000), and as a whole (e.g., Overman et al. 2009, McIntyre 2004) by multiple investigators. Peer-reviewed publications will be used to determine the food web structure and develop a conceptual food web model for Lake Washington. The conceptual food web model will not include trophic levels above predatory fish (i.e., birds or mammals) in accordance with the project objectives. The species of interest will include species of phytoplankton, zooplankton, benthic invertebrates; and selected herbivorous, omnivorous, and predatory fishes. Fish species which have been sampled for contaminants previously (McIntyre 2004; King County 2010) will be included in the food web such as stickleback, yellow perch, smallmouth bass and northern pikeminnow.

Once the conceptual food web model is established, information on dietary composition, lipid content, and body weight will be compiled from sources preferably with data from Lake Washington. If data for Lake Washington is unavailable, assumptions guided by studies from other water bodies will be made.

4.5 Data Acceptance Criteria and Rules

The following acceptance criteria will be applied to all data used for model development and testing:

- *Data Reasonableness*. The quality of existing data will be evaluated through review of any written reports and graphically. Anomalous or questionable results will be removed. Statistical tests may be used to identify additional erroneous or outlier data; these observations will also be removed from the data set.
- *Data Representativeness*. Data will be used that are reasonably complete and representative of typical conditions at the location under consideration (e.g., model region, water column layer, watershed). Data from highly contaminated "hot spots" will be included if it is representative of current conditions; however, data collected prior to a known or suspected cleanup action will not be used.
- Data Comparability. Long-term water quality monitoring programs often collect, handle, preserve, and analyze samples using methodologies that evolve over time, particularly for highly regulated or recently banned chemicals. Advances in analytical methods in recent decades have improved the capability of detecting extremely low concentrations of contaminants such as metals and organic compounds. Older PCB Aroclor analysis methods frequently resulted in non-detected concentrations, but with detection limits much higher than current state-of-the-art analytical methods. Best professional judgment will be used to determine whether data from the various sources are comparable. The final project report will detail any caveats or assumptions that were made when using data collected with differing sampling or analysis techniques.

Non-detect data (laboratory results below the detection limit often qualified as "U" or "UJ") will be handled in a consistent manner. Guidance provided in Pelletier and Mohamedali (2009) and Osterberg and Pelletier (2012) will provide the foundation of the proposed approach.

Summation of PCB congener and Aroclor PCB data into tPCB concentrations for use in model development and testing will also require the development of summing rules that include rules developed above for handling non-detect data. In general, tPCB will be calculated by *summing the detected values as reported for individual addends (congeners or compounds).* Rules developed for summing PCB congeners or Aroclors for existing data used in model development and testing will be documented in the final report. Guidance provided in Pelletier and Mohamedali (2009) and Osterberg and Pelletier (2012) will provide the foundation of the proposed approach.

5.0. MODEL ASSESSMENT ACTIONS

The elements in this section identify activities that will be performed during the project to ensure that the selected models and the data selected for use in the models conform to the stated project objectives.

5.1 Assessment and Response/Corrective Actions

Final assessment of model performance will be conducted to determine whether the model, including its uncertainty, can be appropriately used to inform decision making. This determination will be based on assessment of the quality of the data used, evaluation of how well the model predictions correspond to the natural system, and analyses of sensitivity and uncertainty. The project team will make an overall recommendation for the appropriate use and application of the model and will summarize any important limitations in the final report.

5.2 Data Management

PCB data produced by King County are maintained in an Oracle-based laboratory information system (LIMS). Data will be downloaded from King County's LIMS and imported to an Access database to facilitate data analysis and reporting. Data obtained from other sources will also be imported into a Microsoft Access database maintained on file servers maintained by King County. Data will also be downloaded from King County's LIMS and imported to an Access database to facilitate data analysis and reporting. An interim data report summarizing the sediment and biota PCB data will be produced for EPA and the project advisory team.

5.3 Model Sensitivity and Uncertainty Analysis

To evaluate model performance and the variability of results, sensitivity and uncertainty analyses will be carried out. Uncertainty can arise from a number of sources that range from errors in the input data used to calibrate the model, to imprecise estimates for key parameters, to variations in how certain processes are parameterized in the model domain. Regardless of the underlying cause, it is good practice to evaluate these uncertainties and reduce them if possible (USEPA 2009, Taylor 1997, Beck 1987). By investigating the "relative sensitivity" of model parameters, a user can become knowledgeable of the relative importance of parameters in the model. By knowing the uncertainty associated with parameter values and the sensitivity of the model to specific parameters, a user will be more informed regarding the confidence that can be placed in the model results (USEPA 2009).

Model *sensitivity* describes the degree to which results are affected by changes in selected inputs. Sensitivity analyses can help improve understanding of the relative importance of model parameters, indentifying which parameters do not significantly affect model outputs and which parameters and processes strongly influence results.

For sensitivity evaluations, the models will be executed with +/- 10 percent of a specific parameter's estimated (i.e., "best estimate") value. Using this standard variation (+/- 10%) will allow comparison of the relative influence of each parameter on model results. The final report will describe the degree of relative influence of each parameter on model results. The final report will describe the degree of relative influence of the tested parameters and will discuss implications for the interpretation of results.

Model *uncertainty* is used to describe incomplete or imperfect knowledge about parameters, data and assumptions. Uncertainty can arise from many sources, including measurement and analytical errors for model input data and imprecise estimates for key parameters. Uncertainty analyses investigate how the model results are affected by this lack of knowledge of the true values of certain inputs and parameters.

For this project, uncertainty analyses will follow the procedures employed by Pelletier and Mohamedali (2009). Key model inputs will be selected to evaluate the effect of their uncertainty on the predicted concentration of tPCB in water, sediment and biota. At a minimum, the model inputs selected for uncertainty analysis will include key model parameters the (e.g., octanol-water partition coefficient, Henry's Law constant, and tPCB degradation rates, sediment burial rates, sediment active layer thickness), tPCB loads and initial tPCB concentrations in water and sediment.

To evaluate the uncertainty of a specific parameter, tPCB load and initial conditions; the model will be executed using the low and the high values from the interquartile range of estimates values (i.e., 25th and 75th percentiles, respectively) as input to the model. Meanwhile, all of the other model inputs will be held at their "best estimate" values. Model predictions using the low and high estimates will yield a range of possible outcomes and will help reveal whether uncertainty in the true value of the parameter, load or initial conditions has a significant effect on predictions of tPCB concentrations in water, sediment or biota. The final report will document the parameters that were tested and will identify any parameters that have great uncertainty.

6.0. PROJECT DELIVERABLES

The following deliverables will be completed for this project according to the schedule presented in Table 2.

- Interim report summarizing the sediment and biota data compiled for use in model development and testing, including statistics characterizing the total mass of tPCB in sediments, water and aquatic biota.
- Draft and final modeling report documenting the development, testing, model sensitivity and scenario analyses conducted for this study. The report will include, at a minimum, the following:
    - Summary of contaminant data compiled for model development and testing (data sources and summary statistics)
    - Details of model setup, such as physical characteristics of the boxes, loading inputs and selected parameter values/coefficients and references to documentation supporting their use.
    - Quantitative and qualitative discussion of model testing results and sensitivity and uncertainty analyses.
    - Description of model scenarios and forecasted magnitudes of reductions in biota contaminant concentrations and system response times.
    - Recommendations for additional data collection and further model developments

7.0. INDEX TO QAPP ELEMENTS

Table 3 provides an index to the sections (or sub-sections) above that correspond to U.S. Environmental Protection Agency (USEPA) QAPP elements for the development, modification and use of models (USEPA 2012).

Table 3. Index to EPA Quality Assurance Project Plan Guidance CIO 2106-G-05 QAPP (USEPA 2012)

EPA QAPP Element from Section 4.0 QAPP Elements for Development, Modification and Use of Models	Section(s)	Start page
4.2 Project Management		
4.2.1 Title, Version and Approval/Sign-off		i
4.2.2 Document Format and Table of Contents		iv
4.2.3 Distribution List		vi
4.2.4 Project Organization and Schedule	2.0	4
4.2.5 Problem Background, Overview, and Intended Use of Model	1.0	1
4.2.6 Data/Project Quality Objectives and Measurement Performance Criteria	4.4, 4.5	12, 14
4.2.7 Special Training Requirements and Certification	na	na
4.2.8 Documentation and Records Requirements	6.0	18
4.3 Data Acquisition: Model Development, Modification, and Use (Do)		
4.3.1 Problem Specification and Identification of Model Purpose and Scope	1.0	1
4.3.2 Model Development or Selection Process	4.0, 4.1	10
4.3.3 Data Requirements for Model Input	4.4	12
4.3.4 Evaluation of the Model	5.0	16
4.4 Assessments: Model Assessment Actions (Check)		
4.4.1 Assessments to Acceptance Criteria and Responses/Corrective Actions	5.0	16
4.4.2 Data Management Tasks	5.2	16
4.4.3 Model Output Sensitivity and Uncertainty Analysis	5.3	16
4.5 Review, Evaluation of Usability: Model Usability and Reporting Requirements (Act)		
4.5.1 Model Evaluation Methods and Activities	5.3	16
4.5.2 Description of Model Documentation	6.0	18
4.5.3 Specifications for Model Maintenance and User Support	na	na
4.5.4 Reports to Management	6.0	18

na = Not applicable to this project

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