Sammamish-Washington Analysis

and Modeling Program

HUMAN HEALTH RISK ASSESSMENT

Problem Formulation,

Tiers 1 and 2

King County Department of Natural Resources & Parks
Water and Land Resources Division

February 2008

King County

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Acknowledgements

A large number of WLRD staff have contributed to this report, including: Deb Lester, Debra Williston, Jonathan Frodge, Dean Wilson, Todd Klinka, Sandy Kraus, Laurel Preston, Wendy Collins, and Megann Devine. All of their respective efforts are much appreciated and made this report much stronger.

Citation

King County. 2008. Human Health Risk Assessment. Prepared by Richard Jack and Jenée Colton, Water and Land Resources Division. Seattle, Washington.

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Acronyms

ABSd	Dermal absorption fraction
ABSgi	Chemical-specific gastrointestinal absorption efficiency
AF	Adherence factor of soil to skin
AT	Averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient water quality criteria
B	Dimensionless ratio of the permeability coefficient of a compound through the strata corneum relative to its permeability coefficient across the viable epidermis
BW	Body weight
CDDF	Chlorinated dibenzo-*p*-dioxin or furan
CR	Contact rate
CF	Fish concentration
CS	Sediment concentration
CW	Water concentration
CSF	Cancer slope factor
CSFd	Adjusted dermal cancer slope factor
CSFo	Oral cancer slope factor
CSO	Combined sewer overflow
DADs	Dermal absorbed dose of chemical from sediment
DADw	Dermal absorbed dose of chemical from water
DAevent	Absorbed dose per event
Ecology	Washington State Department of Ecology
ED	Exposure duration
EF	Exposure frequency
EV	Event frequency
FA	Fraction absorbed water
FI	Fraction of total sediments ingested which are contaminated
FOD	Frequency of detection
HEAST	Health Effects Assessment Summary Tables
HQ	Hazard quotient

IRIS	Integrated Risk Information System
IrS	Sediment ingestion rate
Kp	Dermal permeability coefficient of compound in water
MRL	Minimum risk levels
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzo-p-difurans
RAGS	Risk Assessment Guidance for Superfund, various parts
RBC	Risk-based concentration
RfD	Reference dose
RfDd	Adjusted dermal reference dose
RfDo	Oral reference dose
SA	Skin surface are available for contact
SEER	Surveillance, Epidemiology, and End Results Program, National Cancer Institute
SC	Screening Concentration
SWAMP	Sammamish-Washington Analysis and Modeling Program
TDS	Total dissolved solids
τevent	Lag time per event
tevent	Exposure time per event
TSS	Total suspended solids
t*	Time to reach steady state
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WQI	Water quality index
WQS	Water quality standard
WRIA 8	Water Resource Inventory Area 8 (Cedar/Sammamish Watershed)
WTD	Wastewater Treatment Division

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1.0 EXECUTIVE SUMMARY

1.1 Introduction and approach

This human health risk assessment (HHRA) describes which chemicals in streams and lakes in the Greater Lake Washington watershed are predominantly responsible for human health risks and the relative magnitudes of these risks. This HHRA also provides a list of important exposure routes in the Greater Lake Washington watershed. The risk assessment process was utilized to ensure that King County's environmental monitoring projects and programs are appropriately addressing those chemicals and media which pose the greatest risks. To the extent possible using water, sediment, and tissue data from 1995 to 2003, the risk assessment identifies locations with elevated risks. No new data were collected as part of this HHRA.

This risk assessment used two tiers to evaluate chemicals of concerns. Tier 1 was a screening using conservative exposure assumptions. Tier 2 is a detailed estimation of risk using site-specific data when available. For both tiers, the principal exposure pathway evaluated is the ingestion of and/or with contact surface water. For one scenario, the risk assessment assumes that surface waters are being used as drinking water. Lake Washington has been suggested by some jurisdictions as potential drinking water source for the region and the Federal Clean Water Act sets the goal of maintaining fishable, swimmable, and drinkable water quality (Title 33, Chapter 26, Subchapter I, § 1251) for all Greater Lake Washington waterbodies. Sediment has been evaluated as if it were garden/yard soil present at a residence. In some locations this may be the situation, e.g., stream or lake sediments are exposed during low water conditions and these are adjacent to residences within the study area. In most cases, sediments are too deep for more than rare contact (e.g. from boat anchors, or fishing activities). Fish tissues were evaluated with consideration to high users such as Asian pacific islanders and tribal consumers.

1.2 Results

Chemistry data were available for 382 chemicals in water, 141 chemicals in sediment and 119 chemicals in tissue. Of these, the following 47 exceeded Tier 1 screening levels and received Tier 2 analysis. A few chemicals exceeded Tier 1 screening levels but were not able to be evaluated further. Chemicals screened in fish tissue were not further evaluated in Tier 2 because a health assessment had been previously conducted by the Department of Health (DOH, 2004) and thus, no further evaluation was conducted for this HHRA.

The following list of chemicals were identified as contaminants of potential concern (COPCs) and evaluated in Tier 2.

1. 2-Methylnaphthalene
2. 4,4'-DDD
3. 4,4'-DDE
4. 4,4'-DDT
5. 4,6-Dinitro-O-Cresol
6. Acenaphthene
7. Acenaphthylene
8. Aldrin
9. Anthracene
10. Antimony
11. Aroclor 1248
12. Aroclor 1254
13. Aroclor 1260
14. Arsenic
15. Barium
16. Benzo(a)anthracene
17. Benzo(a)pyrene
18. Benzo(b)fluoranthene
19. Benzo(k)fluoranthene
20. Bis(2-Ethylhexyl)Phthalate
21. Cadmium
22. Chromium
23. Chrysene
24. Copper
25. Dibenzo(a,h)anthracene
26. Disulfoton (Di-Syston
27. Fluoranthene
28. Fluorene
29. Hexachlorobenzene
30. Indeno(1,2,3-cd)pyrene
31. Iron
32. Lead
33. Manganese
34. Mercury
35. Methyl Mercury
36. Naphthalene
37. N-Nitrosodimethylamine
38. Pentachlorophenol
39. Phenanthrene
40. Pyrene
41. Simazine
42. Thallium
43. Total DDT
44. Total PAHs
45. Total PCB
46. Vanadium
47. Zinc

Tier 2 used a local survey of recreational exposures, local climate data, and customary national exposure statistics to estimate chemical intake for various scenarios and exposure routes. These included: drinking water consumption, dermal water contact, incidental water consumption while swimming/wading, incidental sediment ingestion, and dermal sediment contact. These exposure routes were combined into 3 hypothetical exposure scenarios; domestic water supply with backyard wading, wading only, and swimming.

EPA toxicity values (i.e. slope factors [SFs]) for evaluation of carcinogenic risks or reference doses [RfDs] for evaluation of effects other than cancer) were identified for all COPCs. For carcinogens, the calculated intake multiplied by the slope factor estimates excess cancer risk. For Tier 2, "excess risk" is defined in this document as a cancer risk greater than 1 in one million. For non-carcinogens, thresholds are believed to exist below which metabolism and excretion can detoxify chemical intakes. For non-carcinogens, the calculated intake divided by the acceptable intake is called a hazard quotient (HQ) and health risks may occur when HQs are greater than 1.0. Chemicals exceeding these levels are referred to as chemicals of concern (COCs). "Risk drivers" are those COCs making up the preponderance of the risk at each location.

Polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides, especially pentachlorophenol, and arsenic were identified as the predominant risk drivers for both the intentional and incidental ingestion of water, and to some extent sediment. For fish tissues, PCBs and mercury were the

prominent risk driver chemicals identified by Tier 1 and evaluated in DOH, 2004. Direct exposure to sediment rarely posed much human health risk.

The locations with excess risks were mapped and two sets of recommendations were produced from the prevalence and spatial analyses. The first group of recommendations focuses on generic scientific and technical data needs for further assessment, while the second are potential risk management directions. The remainder of this summary discusses these recommendations.

1.3 Conclusions and recommendations

A human use survey conducted for the HHRA (Parametrix, 2003) characterized the ranges and central tendencies of recreational exposures on the three major lakes in the study area. However, other than occasional anecdotal information about possible surface water withdrawals for drinking water purposes, no information is available about the use of non-public stream, river and lake shorelines and waterbodies. A statistically robust usage survey of these areas is merited to refine King County DNRP understanding of these potential exposures.

Urbanized areas with high population densities appear to have the highest levels of chemicals in water and sediment. While arsenic, PAHs, and chlorinated pesticides in water apparently pose substantive risks, the media about which the least is known and understood are sediment and fish tissue. From a scientific perspective, further understanding of the spatial variability and impacts of chemicals in sediments is warranted, since this led to the HHRA's general insufficiency in evaluating nearshore sediments.

The DOH (2004a) risk assessment of fish tissues in Lake Washington identified risks from PCBs and mercury through fish tissue consumption. Their assessment was based on relatively small numbers of fish and was limited to Lake Washington. For instance, only 3 smallmouth bass and 10 of the larger size classes of cutthroat trout and northern pikeminnow were available. Additionally, all of the fish were analyzed as whole body samples, not as fillets which are typically consumed. There were even fewer samples and species available for Lakes Union and Sammamish. These limitations pose significant constraints on the understanding of human health risks from the consumption of fish in the study area. Further study of the fate and transport of bioaccumulative chemicals into fish tissue is warranted.

In addition to insufficient information regarding the concentrations of COPCs in tissues, there is little information regarding sources of these chemicals. Further information on the nature of bioaccumulative tissue contaminant sources and particularly whether those sources are historic or ongoing is prudent.

Chlorinated dioxins and furans, and PCBs are two potential sources of risk which were never analyzed or only sporadically analyzed, respectively. From a human health perspective, these chemicals and the risk drivers mentioned above merit the most study since they appear to contribute the highest risk and/or the highest uncertainties.

In addition to the chemical assessment, pathogen risks using *E. coli* were also evaluated to help inform and focus future monitoring efforts. *E. coli* bacteria data were evaluated using a statistical technique called Monte Carlo analysis. This technique uses re-sampling from a small population

of samples to generate an estimate of the true distribution of concentrations. These results were applied to the dose-response relationship utilized by EPA in the Ambient Water Quality Criteria (USEPA, 1986) to estimate illness rates from swimming. The hypothetical illness rates were used to rank the sampling locations. Nine locations had significant illnesses potential based on the majority of their sampling events.

1)	0434	Thornton Creek
2)	A434	Tributary to Thornton Creek
3)	C446	Juanita Creek
4)	0446	Juanita Creek
5)	A432	McAleer Creek
6)	A620	Idylwood Creek
7)	0430	Lyon Creek
8)	0444	Mercer Slough
9)	KSHZ06	Piper's Creek

These locations are assigned the highest priority for future investigations and controls of *E. coli*.

The HHRA results are principally intended to identify data gaps and guide future assessment and monitoring efforts, but given the large geographic area of assessment, the data requirements are very high to provide sufficient data density. With proper definition of populations of interest, statistically robust random sampling can reduce data requirements. However, such a broad scale investigation requires concrete objectives to ensure the data answer definite questions and hypotheses.

To this end, collecting additional information to inform and guide the public and management about the risks and status of study area water, sediment and fish tissue quality, including data to develop spatial and temporal averages, should be planned with risk management objectives and goals in mind.

> "It is important to recognize that information should be developed *only* to help EPA [or other responsible agencies] determine what actions are necessary to reduce risks, and *not* to fully characterize site risks or eliminate uncertainty from the analysis." (USEPA, 1989. pg 3-1, emphasis added)

Thus, to ensure that public health concerns are addressed with the best available science, the DNRP needs to define specific risk management objectives consistent with its mission and goals prior to conducting further investigations or filling data gaps. With risk management goals in mind, DNRP scientists can work with other affected jurisdictions like the Port and cities. These collective resources can develop the sampling and analysis plans to evaluate and address the greatest risks. Economic expertise could be utilized to direct source control efforts where the greatest risk reductions can occur. Thus, the recommended approach is to elucidate programmatic risk management objectives prior to making changes to King County's environmental monitoring efforts.

Under broad programmatic objectives addressing sources under potential DRNP control, King County scientists can develop concrete, testable hypotheses. With defined management objectives and testable hypotheses, project specific investigations can utilize the appropriate analytical and statistical methods to address analytes of concern. Best available science requires

all of these elements working in concert. This approach would allow for most efficient use of public resources to address the more prominent, potential management concerns: PAHs, pentachlorophenol, arsenic, and bacteria in water, and PCBs and mercury in sediment and fish tissue.

2.0. INTRODUCTION

The Sammamish-Washington Analysis and Modeling Program (SWAMP) is a water quality and quantity monitoring and modeling project focused on the Greater Lake Washington Watershed. SWAMP was initiated in 2000 to support a variety of potential water resource decisions for the majority of the Greater Lake Washington watershed. SWAMP included human health and ecological risk assessments using existing empirical data representing current conditions. The first phase, Tier 1, is a screening level risk assessment where conservative assumptions are used to develop a priority list of chemicals/stressors that may pose risk of adverse effects to ecological or human receptors. The second phase, Tier 2, is a more extensive risk assessment of these priority chemicals/stressors that uses refined and more realistic assumptions as well as additional supporting data. This document presents the problem formulation for the human health risk assessment (HHRA), the methods, and results of the first and second Tiers of the risk assessment. The problem formulation presents the framework for the risk assessment by describing elements such as risk assessment objectives, a conceptual site model, and the risk assessment approach.

The HHRA results principally identify data gaps and guide future assessment and monitoring efforts. SWAMP was closely coordinated with King County's Green-Duwamish Watershed Water Quality Assessment (GD-WQA) Program, although this evaluation did not include a HHRA. Both programs are part of the County's region-wide Freshwater Program and have similar program goals and objectives, as well as being linked both regionally and programmatically.

The remainder of this section provides background on the study area and the objectives and approach for the SWAMP HHRA.

2.1 Study Area

The study area encompasses most of the Greater Lake Washington watershed (Figure 1). The study area is delineated by the Water Resource Inventory Area (WRIA) 8 boundaries with the exception of the Puget Sound shoreline drainages and the area upstream of the Landsburg Dam. The Puget Sound shoreline drainages are not part of the Lake Washington watershed and the waters upstream of the Landsburg Dam are Seattle Public Utility owned and protected as a water supply. In addition, King County has not conducted environmental sampling above the dam.

The watershed encompasses about 692 mi^2 (1,792 km^2), from its mouth at the Ballard Locks to the Landsburg Dam on the Cedar River, and into Snohomish County at the headwaters of Bear and Swamp Creeks. The major lakes in the study area are Lakes Washington, Sammamish, and Union. Two major rivers in the study area are the Sammamish River, which connects Lakes Washington and Sammamish, and the lower reaches of the Cedar River from its outflow into Lake Washington to Landsburg Dam.

Major cities located within the SWAMP study area include Seattle (pop. 563,000), Bellevue (pop. 109,000), Redmond (pop. 46,900), Renton (pop. 54,800) and Kirkland (pop. 45,500).

Overall, the study area has a population of about 1 million and, at the current rate of growth, has a predicted population of 1.7 million in 2020 (Kerwin, 2001). Over 40 percent of the watershed's population resides in Seattle. Extensive population growth is currently occurring on the Sammamish Plateau east of Lake Sammamish, and throughout the northern drainages.

The study area also consists of relatively undeveloped locations, consisting of evergreen and deciduous forests, riparian shorelines, and wetlands. The ratio of developed to undeveloped land in a given sub-basin, as well as the relative distribution of land use types, can be quite variable, ranging from heavily urbanized to almost entirely undeveloped. Consequently, the types and sources of chemicals in the study area can vary substantially between aquatic resources.

Figure 1-1

SWAMP Study Area

Streams
Major Roads
Study Area Boundary
Lakes

King County
Department of Natural Resources and Parks
Water and Land Resources Division

N

0 3 6 Miles

February 2005

2.2 Objectives and Approach

The focus of this risk assessment is to describe which aquatic chemicals are predominantly responsible for human health risks and identify the important contaminant pathways and exposure routes. To the extent possible using the available data, the risk assessment identifies locations with elevated risks. No new data were collected as part of this HHRA. The overall objective of this process is to ensure that King County's environmental monitoring projects and programs are appropriately addressing those chemicals and media which pose the greatest risks. Thus, this document is generally limited to recent King County data. A limited amount of data from other agencies has been included; however an exhaustive literature search of historic information was not conducted.

The risk assessment uses existing chemical and bacteriological data to identify chemicals/stressors that currently pose risk to human health, aquatic life or aquatic-feeding wildlife and the locations in the watershed where these risks occur. This document provides the methods and results for the human health portion of the assessment in a tiered approach. Tier 1 is comprised of a human health risk screening of available water, sediment, and tissue chemical data using conservative exposure and effect assumptions. Chemicals with concentrations above Tier 1 screening levels are further assessed in Tier 2. The primary goals of Tier 2 are to (1) assess risk to human health using more realistic and site-specific exposure and effects assumptions; and (2) examine the exposure pathways and locations within the study area that drive risk.

Risk assessment is, by definition, a consideration of the likelihood of adverse effects. Sometimes these adverse effects are described by a probability estimate, e.g. 1 in 10,000 risk of cancer. Sometimes the effect is described by reference to a "safe" level when considering chemicals which the body may detoxify in small amounts. Risk assessment cannot derive a value of zero risk. Therefore all risk is "potential" and this assessment has not attempted to differentiate risks which may actually be occurring to King County residents and those which are more hypothetical.

The remainder of this document presents the human health problem formulation, methodologies, and results of Tiers 1 and 2. The ecological problem formulation and assessment are presented in a separate document.

3.0. PROBLEM FORMULATION

This section presents the problem formulation for the HHRA. A problem formulation presents the framework for the risk assessment by describing the overall objectives (assessment questions), the human uses to be protected, and how the chemicals/stressors of interest will be assessed. The problem formulation presents a conceptual model depicting how receptors are exposed to chemicals/stressors in the study area. Lastly, the problem formulation describes the analytical approach to the risk assessment.

3.1 Human Health Risk Assessment

For the study area, the HHRA is conducted to document the magnitude of risks posed by existing conditions within the study area and the primary causes of these risks. To the extent possible, using the available data, the HHRA identifies sampling locations associated with elevated risks. The HHRA is unable to quantitatively evaluate the risks posed by chemicals which were never detected, although these chemicals are discussed in the uncertainty section.

This section first describes the human health questions initially considered for each Tier. This is followed by a site conceptual model incorporating the receptors and exposure routes evaluated, and the chemicals/stressors of potential concern. Finally, an analysis plan is presented that summarizes the analytical risk assessment methods that will be implemented in the HHRA.

3.1.1 Assessment Questions

Assessment questions were developed to establish the scope and goals for the HHRA. These questions were constructed after consideration of King County's human health objectives and evaluation of the available data within the study area.

The human health assessment questions were:

Tier 1

1. Based on conservative exposure assumptions, which COPCs in study area aquatic resources pose sufficient risk to human health to warrant additional investigation?

Tier 2

2. Based on site-specific exposure estimates in the study area, which chemicals of concern (COCs) in aquatic resources pose a carcinogenic, non-carcinogenic, or pathogen risk to human health?

3. For COCs that pose a human health risk under Tier 2 assumptions, which exposure routes and locations contribute the greatest risk?

It is recognized that this evaluation will include a mixture of anthropogenically derived and background concentrations of some constituents. Background is defined as chemicals derived from natural geologic weathering. Atmospheric deposition may contribute to background chemical concentrations, for example, polychlorinated biphenyls (PCBs), mercury, and arsenic can be regionally and/or globally transported. For the purposes of Tier 1, background chemical levels have not been developed.

3.1.2 Receptors/Exposure Scenarios

An enormous variety of potential exposure scenarios are possible for King County residents and other users of Greater Lake Washington aquatic resources. People visit, reside, recreate, and/or work within the study area and may be either directly or indirectly exposed to chemical constituents present in water bodies. There are some differences in exposure pathways with each of these activities, however; the most conservative scenario to evaluate is residential use. Ingestion of surface water as a domestic/residential water supply includes exposure pathways present within other exposure scenarios, like dermal exposures. The domestic water supply scenario presumes a lifetime (70+ years) of exposure to the various media (i.e., water, sediment and fish). The other possible scenarios that could be evaluated are less conservative because individual receptors and/or exposure pathways are excluded, e.g., industrial/work exposures do not include children and limit exposures to 8 hours per workday. Thus, for the Tier 1 screening, a domestic/residential water supply scenario is the only one considered for surface water. Because sediment exposures may vary considerably, no established screening values were available for sediment. As a conservative alternative, sediments were considered as if they were residential soils.

In Tier 2, a domestic water supply scenario with additional wading exposure pathways. This scenario is intended to represent a resident who withdraws water from local waterbodies and plays/gardens along their shoreline. Also in Tier 2, a Swimming scenario is added for the three major lakes in the study area. Lastly, a Wading scenario is provided in Tier 2 for residents with waterfront property, whether by a stream or major lake, but who do not withdraw water for domestic uses from the waterbody. Table 1 summarizes the scenarios considered in each Tier while the following section describes the exposure pathway selection rationale in more detail

Table 1. Exposure scenarios considered by HHRA Tier.

HHRA Tier	Domestic water supply + sediment	Swimming	Wading	Fish consumption
Tier 1	Yes	No	No	Yes
Tier 2	Yes	Yes	Yes	Evaluated by WA Dept. of Health

3.1.3 Exposure Pathways

Because this HHRA is intended to characterize the risks posed by exposure to aquatic resources, only exposure pathways relevant to surface water, sediment, or fish tissue have been considered herein.

A principal exposure pathway evaluated is the ingestion of surface water. For Tier 1, the risk assessment assumes that surface waters are being used as drinking water. Some jurisdictions have suggested Lake Washington might be used as a drinking water supply and the Federal Clean Water Act sets the goal of maintaining fishable, swimmable, and drinkable water quality (Title 33, Chapter 26, Subchapter I, § 1251). However, WAC 173-508 has closed all of Lake Washington and its tributaries to further consumptive appropriations. The only exception to this prohibition is the Cedar River. Thus, the consideration of Lake Washington and its tributaries as drinking water sources is a legal and policy mandate by EPA and King County, but is unlikely to be realized on a broad scale.

Although not a likely exposure scenario for the majority of the population in the study area, there is anecdotal evidence that a small number of residents remove water for potable uses directly from some surface waters in the study area (J. Frodge, personal communication). This assumption requires a comparison of available surface water data with drinking water screening values. This is conservative, given that the majority of the study area has potable water supplied by local or regional water suppliers. Most of these potable water sources are from dedicated drinking water reservoirs outside of the study area. In addition to direct ingestion, using potable water exposes consumers to volatile chemicals in the water. Thus, the inhalation of volatile chemicals from water during showering is also included as an exposure pathway in Tier 1. Other water exposure pathways considered in Tier 2 include: dermal contact from swimming and wading.

Sediment has been evaluated as if it were “soil”, present at a residential property. In some cases this may be a reasonable assumption, e.g., stream or lake sediments are frequently exposed during low water conditions and these are adjacent to residences within the study area. However, in other cases, available sediment data are from the deep waters of lakes or rivers, where direct exposure is very unlikely. In this case, the sediment/soil exposure medium assumptions are very conservative, since exposures would be rare and/or very intermittent.

Residents may be exposed to soil/sediment via both incidental and intentional ingestion. The intentional ingestion of soil, called “pica,” only occurs with children. This exposure pathway could be realized by residents, both those who live adjacent to study waterbodies and by visitors to parks and public shorelines. Residents may also be exposed to chemicals in sediment from dermal contact. This pathway was not considered in Tier 1 because the highly conservative ingestion exposure assumptions are protective of the slightly increased exposure to sediment chemicals via the dermal pathway. Dermal contact with water and sediment was considered in Tier 2.

There are additional sediment/soil exposure routes which have not been considered, principally the intake of chemicals through homegrown fruits and vegetables. Because the aquatic resources of concern are sediments, there is little opportunity for waterfront residents to grow produce in

areas below the seasonal high water mark or on public shorelines of lakes and streams. There are very limited opportunities to collect aquatic plants for human consumption, although this practice may occur (Parametrix, 2003). Also not considered is the inhalation of volatile or particulate bound chemicals from sediments; this pathway was not assessed in this HHRA. Given that large fluctuations of water level followed by sediment desiccation is not common in local waterbodies, the inhalation of volatile or particulate-bound chemicals from sediments would not be expected to be a significant exposure pathway.

The last exposure route for COPCs is through consumption of fish or shellfish resources from local waterbodies. A watershed-specific human use survey was conducted (Parametrix, 2003) to estimate recreational exposure frequencies. But for the purposes of Tier 1, EPA-derived screening concentrations for fish tissue ingestion are applied in lieu of calculation of site-specific screening values using ingestion rate and species preference information from the human use survey. The screening concentrations use more conservative exposure assumptions which are protective of subpopulations (i.e., Native American or Asian-Pacific Islander) with potentially high fish consumption rates. Table 2 identifies the exposure pathways considered in Tier 1. Tier 2 re-evaluated pathways and exposure assumptions based on more site-specific information.

Table 2. Exposure pathways considered in Tier 1 screening.

Media	Ingestion	Inhalation	Dermal
Water	Yes	Yes	No
Sediment	Yes	No	No
Tissue	Yes	No	No

Because a wide variety of daily activities occur within the Greater Lake Washington watershed, any myriad of other exposure pathways are potentially possible. This assessment has not attempted to define or quantify these pathways. The variety of incomplete exposure pathways have also not been identified.

3.1.4 Conceptual Model

The purpose of a site conceptual model is to depict the receptors and exposure pathways of concern. Based on the pathways and receptors of potential concern discussed in the previous section, a conceptual model of exposures by human receptors was developed (Figure 2). The figure shows the aquatic media of concern, and exposure pathways evaluated in this HHRA. The exposure pathways for recreational water users are complete (i.e. contact with a contaminant present at a location) for chemicals in sediment and surface water via incidental ingestion and direct contact while wading and/or swimming. Waders and swimmers may also have complete exposure pathways for biological contaminants, for this evaluation these are the indicator agents *E. coli* and fecal coliform bacteria. In addition, populations in the study area that consume fish and/or shellfish have complete exposure pathways to chemicals in fish/shellfish tissue.

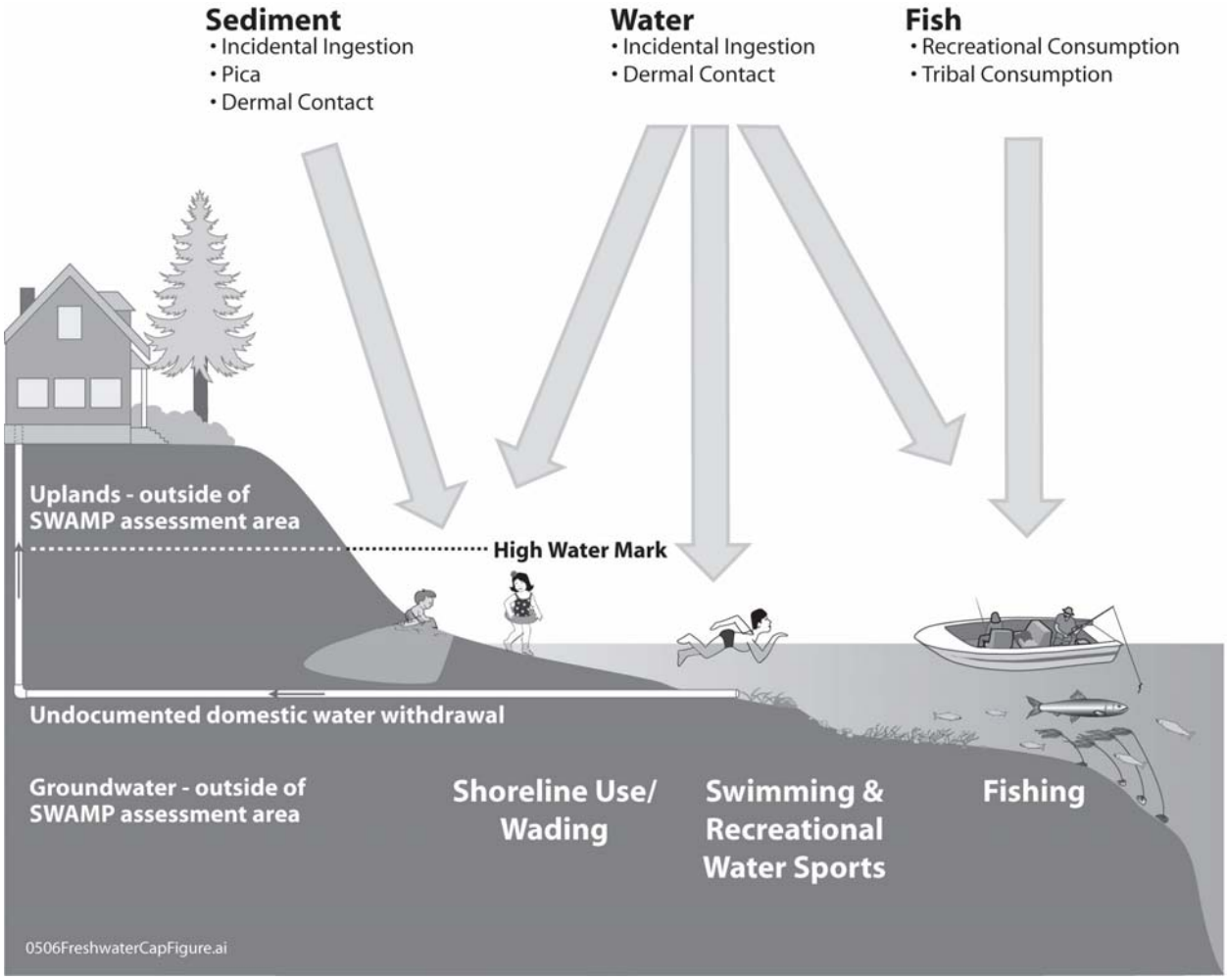

Figure 2. Conceptual Model for Human Health in the Study Area.

3.1.5 Chemicals/Stressors of Potential Concern

COPCs in the Tier 1 evaluation include chemical constituents such as metals and organic compounds, including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and pesticides, as well as conventional stressors that may be of potential concern to human health (e.g., nitrates). The biological indicators *E. coli*, fecal coliforms, and toxic cyanobacteria were also evaluated in Tier 1. Some sources of these chemical and biological agents include residential lawn, agricultural and stormwater runoff; combined sewer overflows (CSOs), industrial discharges, and atmospheric deposition.

3.1.6 Tier 1 Analysis Plan

The analysis plan describes the general approach for the risk assessment and the data to be used. Specific details of the methods can be found in Section 3.1.1 which describes the Tier 1 screen in detail.

3.1.6.1 Tier 1 analytical approach

The screening approach selected for Tier 1 is designed to efficiently and conservatively narrow the COPC list to chemicals that have the greatest potential to adversely affect human health. Conservative assumptions were used that encompass the broad range of potential exposures across the watershed. In Tier 2, more site-specific exposure estimates are brought in to allow for a more specific, realistic exposure assessment. The EPA established toxicity values: cancer slope factors (CSFs) and reference doses (Rfds) used in Tier 1 were retained in future tiers.

3.1.6.2 Environmental data sources

King County collects ambient environmental data for a variety of purposes, including routine surface water quality monitoring as well as targeted sampling for projects addressing, for instance, water reuse and salmon habitat restoration. Water chemistry data are available from the ambient monitoring program, small streams toxicity studies, and Department of Ecology Pesticide Monitoring Programs, among others (Table 3 and Figure 3). Sediment chemistry results are available from special projects, the Major Lakes program and ambient monitoring of stream sediments (Figure 4) while fish tissue results predominantly come from special studies. For water, results for 8 years from January of 1995 through December of 2003 were used. The available sediment data were collected from September of 1998 through September 2003. And lastly, tissue results from August 1997 through April 2003 were utilized. The largest waterbody with tissue data is Lake Washington which was systematically sampled by McIntyre (2004). Fish tissue data available for Lake Union were neither randomly nor systematically collected, although it is a much smaller area and hence tissue concentrations are not suspected to exhibit spatial variability.

The chemical concentrations in surface water, surface sediment, and tissue, available from the multiple water bodies in the study area, are generally not co-located. The data types that were applied in the HHRA are summarized in Table 4. Not all data listed in Table 4 are available for all areas within the study area.

Table 3. Overview of Data Types for the Human Health Risk Assessment

Media and Available Data Types	Date range of available data
Water Chemistry, bacteria, cyanobacteria	1/1995 through 12/2003
Sediment Chemistry	Lakes: 8/1999 through 8/2001 Streams: 9/1998 through 9/2003
Tissue Chemistry	8/1997 through 4/2003

These data will be used to represent the entire watershed. However, it is important to note that the data were not specifically collected for risk assessment purposes. Sampling locations were not stratified or randomized and thus, known data gaps in spatial and/or temporal coverage exist. The most significant known data gap for human health risk characterization surrounds established, contaminated property [e.g. Gas Works Park, Port Quendall Terminals, Former

Coleman Creosoting Works Site (Ecology, 2006)]. These properties are under cleanup orders from State and Federal regulatory agencies, not King County. Also, stormwater data collected from pipes and point discharges are not included in this assessment. Additionally, the sampling regime was not designed to describe "background" or "natural" conditions. Thus, the available data are assumed to predominantly cover the central range of ambient conditions in King County water, sediment and fish tissue.

With these data limitations in mind, the HHRA is not intended to describe areas requiring remedial actions. It is conducted with 3 goals:

1. Inform management and the public about the relative magnitude of human health risks facing residents using study area aquatic resources.

2. Identify the relative level of human health concerns for different areas and chemical parameters.

3. Provide sufficient information to allow future study objectives and monitoring plans to target the analytes and areas of greatest uncertainty and concern; thus warranting collection of additional data.

Table 4. Overview of Existing Data Used in the Human Health Risk Assessment

Data Type	Media	Source	Program Name/Report	Water Body	Parameter Categories
Chemistry	Water	King County	Ambient Surface Water Monitoring Program	Cedar and Sammamish Rivers, tributary streams, Lakes Sammamish, Washington, Union, 1998-2003	Conventional parameters[a], metals, organics, bacteria
		King County/USGS /WDOE	Small Streams Toxicity Study	Sammamish River and tributaries to Lakes Washington and Sammamish, and Sammamish River, 1999-2003	Conventional parameters[a], metals, organics
		King County/USGS	Water Reuse	Sammamish River, 2001-2003	Conventional parameters[a], metals, organics, bacteria
		WDOE	Washington State Pesticide Monitoring Program	Select Streams in Lake Washington watershed, 1999	Pesticides
Chemistry	Sediment	King County	Major Lakes	Lakes Sammamish, Washington, Union, 1999-2001	Metals, organics
		King County	Stream Sediment Ambient Monitoring Program	Small streams of Lake Washington watershed, 1998-2003	Metals, organics
Chemistry	Fish and Invertebrate Tissue	King County	WTD CSO Study (Houck and Crawford, 2003)	Lake Union, 1999	Metals, organics

Data Type	Media	Source	Program Name/Report	Water Body	Parameter Categories
		King County	Major Lakes	Lake Union, 1997	Metals, organics
		King County/UW	J. McIntyre Master's Thesis (2004)	Lakes Washington and Sammamish, 2001-2003	Metals, organics
Human exposures	Human use survey	King County	Parametrix, 2003	Lakes Union, Washington, and Sammamish, 2002 - 2003	Human recreational exposure parameters

[a]Conventional parameters included nitrate-nitrite, ortho-phosphorus, ammonia-nitrogen, and phosphorus
"Organics" includes over 90 semi-volatile and volatile organic compounds.
USGS – United States Geological Survey
WDOE – Washington State Department of Ecology
UW – University of Washington

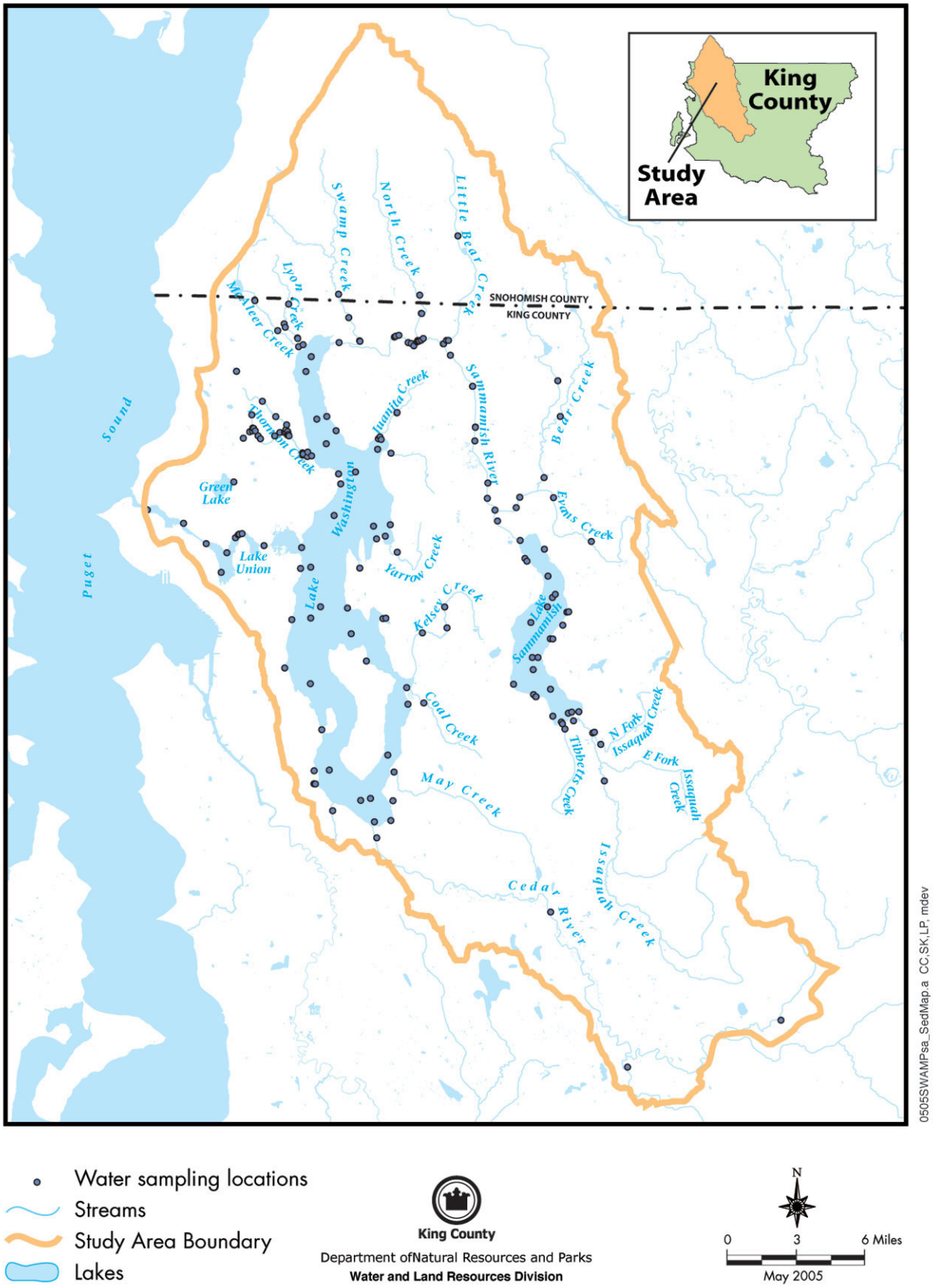

Figure 3. Greater Lake Washington Water Sampling Locations.

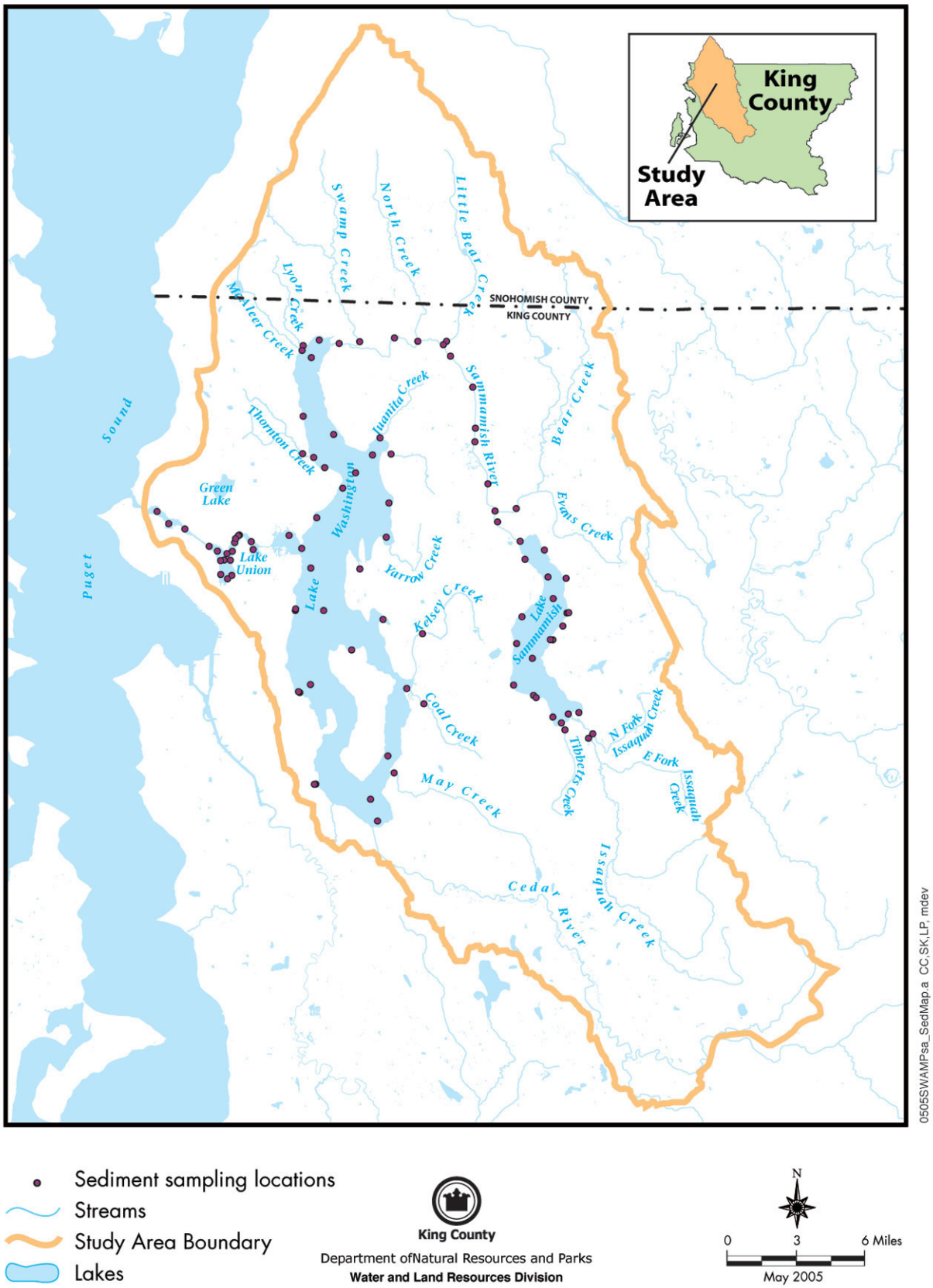

Figure 4. Greater Lake Washington Sediment Sampling Locations.

3.1.6.3 Exposure data sources

Exposure data for Tier 1 was principally adapted from EPA Region 3 "risk based concentrations". In some cases, the available exposure values used were oriented towards contaminated property assessment, e.g. CERCLA or Superfund projects. This project has followed the general CERCLA risks assessment guidance and process, and predominantly used national exposure assumptions from EPA's Exposure Factors Handbook (EFH) SEPA, 1997). However, in some cases the default or national exposure values did not adequately describe the potential exposures to Greater Lake Washington aquatic resources. The principle data sources used for site-specific exposure assumptions were: Washington Department of Health, Office of Vital Statistics and the human use survey conducted for this project (Parametrix, 2003).

3.1.6.4 Toxicity data sources

Screening Concentrations were derived from conservative exposure assumptions and EPA-established toxicity values. Toxicity associated with exposure to non-carcinogens is expressed as RfDs, carcinogen toxicity is quantified by EPA using CSFs.

Chemicals without an Rfd or CSF, and thus lacking SCs, were eliminated from further evaluation in Tier 1 and are discussed in the Tier 1 uncertainty section. For chemicals which were never detected, the maximum method detection limit (MDL) or reporting detection limit (RDL) was compared with SCs. Chemicals with an MDL/RDL less than the SC (and no detections) were also eliminated from further consideration. Those chemicals with MDLs/RDLs greater than the SC are also excluded from further evaluation in Tier 2 and instead are considered only in the Tier 1 uncertainty section. Ultimately, chemicals with a maximum concentration exceeding the SC are retained for Tier 2 analysis and those with maximum detected concentrations below the SC are eliminated from Tier 2 consideration.

4.0. TIER 1 ASSESSMENT

The Tier 1 HHRA process is to identify COPCs and exposure routes with the greatest influence on health risk early on in the RA process. Traditional baseline risk assessment initially requires intensive contaminant-specific data evaluation efforts that may ultimately be wasted due to later determinations that many of the chemicals and exposure routes evaluated had minimal influence on the overall health risk. In contrast, screening level assessments such as conducted in Tier 1 seek to make the baseline process "more efficient by focusing on dominant chemicals and routes of exposure at the earliest feasible stage" (USEPA, 1989).

4.1 Tier 1 Chemical Screening Assessment Approach

The chemical screening approach used in Tier 1 was based on technical guidance developed by USEPA Region III (USEPA 1993) for selecting exposure routes and COPCs by risk-based screening. This guidance is patterned after RAGS(a) (USEPA, 1989). In general, most risk assessments are conducted to support the cleanup of contaminated properties and this watershed-wide evaluation has been conducted similarly due to a lack of other suitable guidance. The sole purpose of Tier 1 is to generate a refined list of chemicals for more detailed evaluation in Tier 2.

The screening approach involves four steps summarized as follows: (1) data quality evaluation; (2) reduce data set using risk-based concentration screen; (3) consider re-including eliminated chemicals and routes; and (4) make further specific reductions in data set (optional). Each of these steps is described below.

4.1.1 Step 1: Data Quality Evaluation

According to RAGS(a), data used to assess potential human health risks associated with a particular site or study area should be representative of the study area and "of acceptable quality for use in the quantitative risk assessment" (USEPA, 1989). Data quality for this assessment was principally evaluated through the data qualifiers added to individual records by the various analysts. Because this assessment is a metadata analysis of data collected for various other purposes, a detailed review of accuracy, bias and precision was not conducted. Also, as discussed above, these data are assumed to represent the central tendencies of ambient conditions. The most highly contaminated areas subject to Model Toxics Control Act cleanup (MTCA, RCW 173.340) and pristine "background" areas outside of the study area boundaries were not sampled.

When chemicals in the data set and the USEPA Region III RBC table did not share the same nomenclature, synonyms based on name or CAS number were identified.

4.1.2 Step 2: Reduce data set using risk-based concentration screen

Reduction of the data set was accomplished using the risk-based concentration (RBC) screening approach delineated by USEPA (1989) to select chemicals and exposure routes with the greatest influence on overall health risk posed by the study area. This approach, which was originally adapted based on EPA methodologies, utilized a dataset of RBC values developed by Region III for 400-500 chemicals in water, fish tissue, soil, and air (USEPA, 2005). The RBCs were modified into screening concentrations (SCs) using the Region III approach with some additional modified site-specific exposure parameters. These modifications are described in the following section. The SCs were then compared to corresponding site-specific chemical concentration data.

For Tier 1, a "maximum chemical concentration" was derived using the larger of the detected concentration, or the MDL. When MDLs were not available, RDLs were used instead. For detected chemicals, the maximum concentration in water, sediment, and fish tissue was compared to SCs. When chemical concentrations were less than their respective SCs, this served as the initial basis for eliminating chemicals of potential concern from further evaluation.

Where toxicity information was not available for a particular study area chemical, and thus a SC could not be derived, the chemical was moved to the uncertainty section of this report for consideration. When contaminant detection limits exceeded the SC values, these chemicals were also considered in the uncertainty section.

4.1.2.1 Description of RBC Dataset and Derived Tier 1 SCs

The USEPA Region III RBCs used as the basis for this assessment incorporate currently available reference doses (RfDs) and cancer slope factors (CSFs) for each chemical in the dataset. According to RAGS(a) (USEPA, 1989), "A chronic RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." A cancer slope factor is a "plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen" (USEPA, 1989).

These toxicity values have been combined with typical exposure scenarios to calculate chemical- and media-specific concentrations that correspond to fixed levels of risk. However, because this evaluation occurred across an entire watershed instead of at the more typical scale of a hazardous waste site, some of the assumptions in the RBC table have been modified. These modifications also considered the "reasonable maximum exposures" (RME) to account for subpopulations which may be highly exposed (e.g. Tribal and/or Asian-Pacific Islander fishermen). The modified RBC for a particular media is based on the lower of the cancer or non-cancer chemical-specific derived concentrations. The formulas and default exposure assumptions used to calculate RBCs are as shown in EPA (2005a). Where a specific exposure assumption was modified, the original and revised values have been shown in Table 5. The modified RBCs are termed SCs.

Table 5. Revised values for calculation of Tier 1 screening concentrations

Variable	Region III default	This HHRA value
Exposure duration, total	30 years	78 years
Averaging time (days), carcinogens	25550 (70 yrs x 365 days)	28470 (78 years x 365 days)
Averaging time (days), non-carcinogens	10950 (30 yrs x 365 days)	28470 (78 years x 365 days)

For non-cancer effects, the accepted risk level is a HQ of 1 or less (an HQ is the ratio of an exposure concentration to a "safe" concentration). However, an RfD is derived assuming that a threshold exists below which exposure does not produce an adverse effect, where the adverse effect represents the "critical toxic effect" for that chemical of concern based on experimental study. In deriving the RfD, the EPA assumed that prevention of the critical toxic effect will also prevent the occurrence of other, less critical effects. Therefore, due to the potential uncertainty associated with this assumption, and the potential for multiple toxicants to act by the same mode of action, non-cancer SCs were conservatively adjusted down to a target HQ of 0.1 (by dividing the non-cancer SC by 10) in order to reduce uncertainty and ensure protection by not prematurely eliminating chemicals during the Tier 1 screening process.

This approach is consistent with EPA risk assessment guidance utilized for contaminated site cleanups (RAGS(a) USEPA, 1989) where simultaneous sub-threshold exposures to multiple chemicals are assumed to result in adverse health effects. This approach also assumes that potential adverse effects are proportional to the sum of these HQs.

For cancer effects, the risk level defining an "excess" over background is a lifetime cancer risk of $1x10^{-6}$. In HHRAs, relevant differences in risk typically have one or more orders of magnitude between them, thus in the notation $1x10^{-6}$ the most important number is presented in the smallest text. To simplify notation and to ensure that the relevant magnitude of risks are easy to read and compare, these logarithmic values are presented as 1E-6. For example, $5x10^{-4}$ would be reported as 5E-4 and so forth.

A CSF is based on the presumption that when evaluating cancer risk, no dose is thought to be risk-free. It is derived to be conservatively protective of public health at low doses and a range of variation in human susceptibility. SCs corresponding to cancer effects at a fixed risk level of 1E-6 were thought to be sufficiently conservative for screening purposes and were not adjusted.

For this assessment, the available RBCs for water, residential soil (as a surrogate for sediments), and fish tissue were modified to include more conservative RMEs by incorporating modifying exposure factors and assumptions based on typical domestic water supply with backyard wading use-type exposure as described in RAGS(a) methodologies (USEPA, 1989). For carcinogenic chemicals, water and sediment exposures incorporate age-adjusted exposure durations, intakes, and body weight factors to address carcinogenic risks during the first 30 years of life. EPA

Region 3 RBCs use an exposure duration of 30 years, which is based on the nationwide average time a person lives at a single home. The duration of residence in the study area is not known, but could range upwards to a whole lifetime. Thus, the exposure duration input to the SCs was revised upwards to 78.4 years. This value is based on the infant life expectancy for Washington State in 2000 (DOH, 2003).

The CSFs used in the RBCs are based on a lifetime of 70 years. Because this differs from the expected Washington State lifetime, the RBC formulas were modified by multiplying by 78.4/70 (x1.12). This adjustment to the CSFs used in the SCs is conservative.

For non-carcinogens, RBCs for exposure via water were based on adult-only exposures. The RBC table cover memo (EPA, 2005) discusses the potential that a non-cancer screening concentration for a child might be lower than for an adult; however, in cases where this is true, the difference has been determined to be well below an order of magnitude (i.e., a factor of 1.2-2.3) (USEPA, 2005a). Given that all non-cancer-based HQs >0.1 were retained for further analysis in Tier 2 of the evaluation, the use of adult-based non-cancer screening levels was expected to be sufficiently protective of both adults and children and SCs were not modified to incorporate childhood water exposures. The SCs combine the exposure of oral ingestion with the doses of volatile chemicals inhaled through the use of water during showering.

Risk-based concentrations for exposures to residential soil were used as surrogates for recreational exposure to sediments within the study area. Children were assumed to be more susceptible to this exposure medium than adults due to activity patterns and more significant hand-to-mouth behaviors. Consequently, the RBCs for non-carcinogens in soil contained within were based on childhood (age 0 to 6) exposures only. For carcinogens, the soil SCs used a longer exposure time to account for the fact that King County residents may be exposed to study area media for their entire lifetime.

For exposure via fish consumption, only adult exposures were represented by the RBCs within the Region III dataset. The default consumption rate used in the Region III RBCs is 54 grams/day. This rate is probably higher for freshwater fish than what some highly exposed local populations may consume. For instance, a rate of 31 g/day for all finfish was used by the Lower Duwamish Working Group (LDWG) Phase 1 RA in their tribal/subsistence reasonable maximum scenario (Windward 2003). However, the Phase 2 Draft HHRA for the Lower Duwamish Superfund site uses larger tribal values based on Tulalip tribal consumption survey (Windward 2007). Additionally, the Seattle-King County Asian Pacific Islander (API) community was surveyed by EPA (1999a). A 90th percentile rate of 19 g/day was found for freshwater fish in this population. As part of the Lower Duwamish HHRA, EPA recalculated and population weighted the values in earlier EPA (1999a) study. The revised freshwater fish consumption rate was approximately 8.3% of the total seafood consumption (95th percentile) or 4.7 gm/day.

These rates bracket the national average of 17.5 g/day used in the calculation of water quality criteria (USEPA, 2002) and the national rate of 4.7 g/day calculated by Jacobs et al. (1998), they are below the default Region III rate of 54 g/day. However, 54 g/day was retained as a screening value, to represent a reasonable maximum consumption rate of freshwater fish from the study area for potentially sensitive recreational, tribal or API subpopulations.

The conservative consumption rate, along with the increased exposure time of 78 years used in the SCs, makes evaluation of the adult receptor sufficiently protective of children as well. In addition, in a manner similar to that conducted for the water consumption pathway discussed above, USEPA has evaluated the differences between child and adult fish consumption exposures and the effects that these differences have on the relative protection of children by using RBCs based on adult only exposures. For fish consumption, some of the chemicals for which RBCs (at the HQ = 1 risk level) have been developed would result in lower RBCs for children, however, the factor difference is low, ranging from 1.1-2.3. Given that all non-cancer-based HQs >0.1 were retained for further evaluation in the Tier 2 risk assessment, the use of adult-based non-cancer SCs for this pathway should be sufficiently protective of both adults and children.

4.1.2.2 Modified Screening Concentrations

Modified chemical-specific SCs for each media were compared to media-specific maximum concentrations of these chemicals to assess relative risk and determine which chemicals and media have the greatest influence on the overall human health risk posed by aquatic resources in the study area. Because data quality varied, a conservative approach was used to generate chemical concentrations for screening.

For Tier 1, a "maximum chemical concentration" was derived using the larger of the detected concentration or the MDL. Since MDLs varied across sample batches, methods, and matrices, choosing the larger of the highest detected concentration or the highest MDL is conservative. When MDLs were not available, RDLs were used instead. Chemicals with maximum chemical concentrations or MDLs below the SC were eliminated from consideration.

Another group of chemicals segregated in the Tier 1 process were those chemicals without SCs. The most common rationale for the absence of a SC was the lack of suitable toxicity data in either the Integrated Risk Information System (IRIS) or the Health Effects Summary Tables (HEAST). Chemicals without SCs were discussed in the Tier 1 uncertainty section.

For chemicals which were never detected, the maximum MDL or RDL was compared with SCs. Those chemicals with MDLs/RDLs greater than the SC were also eliminated from further consideration and discussed in the uncertainty section.

If the maximum concentration for a given chemical was greater than the SC for any of the three media evaluated (i.e., sediment, water, or fish tissue), the chemical was retained for evaluation of multiple exposure pathways relevant to a particular receptor in Tier 2. If the maximum concentration for the chemical was less than the SC for all media evaluated in Tier 1 (and was not re-included for other reasons discussed below), the chemical was excluded from further evaluation in the Tier 2 evaluation.

For metals, the data often contained multiple results to accommodate different forms (e.g., total vs. dissolved) and different analytical methods (e.g., ICP vs. ICP-MS). In each medium, only the maximum concentration for each metal was included in Tier 1 regardless of analytical method.

For chromium, cadmium, and manganese, results were compared to two SCs, these multiple SCs were derived using all the different toxicity values (as shown in IRIS or HEAST) for the

different media (food vs. nonfood exposures). Cadmium results were compared to cadmium-water and cadmium-food SCs. Manganese results were compared to manganese-food and manganese-nonfood SCs. IRIS utilizes multiple RfDs for these compounds because they are differentially absorbed during digestion from water and food. Thus, surface water and tissue were compared to SCs using their respective RfDs.

Similarly, chromium data were not speciated, but were compared to SCs for both chromium (III) and chromium (VI). In each case, the chemical was retained for Tier 2 evaluation if at least one of the comparative SCs were exceeded. This was done to be conservative because the Tier 2 evaluation would consider both intentional ingestion (domestic water supply) and incidental ingestion of water and sediment. This ensured the screening did not prematurely eliminate these metals.

4.1.3 Step 3: Consider re-including eliminated chemicals and routes

All chemicals and routes of exposure that were screened out based on SCs were considered for possible re-inclusion based on special properties or concerns. According to USEPA Region III guidance, chemicals eliminated during the RBC screening process can be considered for further evaluation in Tier 2 based on the following:

- Historical information.
- Exceptional toxicity, mobility, persistence, or bioaccumulation.
- Special exposure routes.
- Special treatability problems.
- Applicable or relevant and appropriate requirements (ARARs) exceedance.
- Toxicity equivalence of chemical class (e.g., chlorinated dibenzo-dioxins (CDDs)/ chlorinated dibenzo-furans (CDFs), PAHs).

For this step, two USEPA chemical lists were used to identify chemicals for possible re-inclusion. These lists are: (1) Waste Minimization Priority Chemicals (WMPCs) and (2) Toxics Release Inventory Persistent Bioaccumulative, and Toxic (TRI PBTs) chemicals (USEPA, 2004a,b). WMPCs are 30 chemicals identified by USEPA to serve as the highest priorities for waste minimization. Twenty-seven of the 30 chemicals on the list are persistent, bioaccumulative, and toxic (PBTs). Even when released in small amounts, they can accumulate and cause environmental problems. Many are difficult to clean up once they are released into the environment, resulting in costly clean up efforts. The remaining 3 metals are also PBTs. They are high priority for international pollution minimization treaties and the United States has commitments to those efforts. TRI PBTs are a PBT subset of 16 chemicals and 4 chemical compound categories in the TRI program, in which EPA and the States annually collect data on releases and transfers of certain toxic chemicals from industrial facilities, and make the data available to the public. Many of these compounds have never been detected in King County

ambient waters, sediment, fish tissues, or in any wastewater treatment plant influent or effluent. Thus, only a subset of these priority chemicals were chosen for re-inclusion. The PBTs re-included for water based on bioaccumulative properties are: lead, mercury, PCBs, and all PAHs.

4.1.4 Step 4: Make further specific reductions in data set (optional)

Following RBC screening and assessment for re-inclusion within the dataset, USEPA Region III presents further dataset reduction steps that are optional. Specifically, on the basis of a retained chemical's (a) essentiality as a nutrient; (b) frequency of detection (FOD) within the study area samples; and/or (c) comparison to background (as available) levels, further reduction of the dataset for evaluation in Tier 2 can be considered. Determining essential nutrient concentrations and relevant background levels can be difficult and labor-intensive. Frequency of detection data were not part of the Tier 1 analysis. For the above reasons, these data reduction were not performed in Tier 1.

4.2 Tier 1 Chemical Screening Assessment Results

In summary, all chemicals for which water, fish tissue, and/or sediment data from the study area were evaluated in Tier 1 using the risk-based screening approach described above. For those chemicals quantitatively evaluated, screening ratios with HQs greater than 0.1 or a cancer risk greater than 1E-6 in any one of the three environmental media (water, sediment, or fish tissue) included in Tier 1 indicated that they be carried forward to Tier 2. Tier 2 presents a more detailed evaluation of specific study area receptor types including a domestic water supply scenario with backyard wading use and scenarios based one the SWAMP human use survey report (Parametrix, 2003). Special case chemicals were also carried forward to Tier 2, while chemicals with no RBC and those with elevated MDLs were forwarded to the uncertainty section. A summary of the Tier 1 screening results are shown in Tables 4 and 5. The tables used for Tier 1 screening may be found in Appendix A. Assessment of potential human health risks in Tier 2 will include consideration of the risk from multiple exposure routes and environmental media relevant to a particular receptor.

Table 6. Summary of Tier 1 screening results.

	Number of Chemicals		
	Water	**Sediment**	**Fish Tissue**
Number of unique chemicals for which data were available	382	141	119
Number of detected chemicals	115	74	21
Number of chemicals retained for Tier 2 evaluation	50 (13%)	47 (33%)	42 (35%)

Table continued

Basis for inclusion:			
Max concentration exceeded SC	25	14	8
Max concentration exceeded 1/10th SC for non-carcinogens	11	0	1
Re-included as special case	6	13	15
Re-included because of exceedances in different medium	8	20	18
Uncertainty section:			
No SC available	36	13	33
MDL > SC	42	1	7

SC = screening concentration
MDL = method detection limit

Table 7. Summary of Tier 1 Parameters further evaluated in Tier 2.

1. 2-Methylnaphthalene
2. 4,4'-DDD
3. 4,4'-DDE
4. 4,4'-DDT
5. 4,6-Dinitro-O-Cresol
6. Acenaphthene
7. Acenaphthylene
8. Aldrin
9. Anthracene
10. Antimony
11. Aroclor 1248
12. Aroclor 1254
13. Aroclor 1260
14. Arsenic
15. Barium
16. Benzo(a)anthracene
17. Benzo(a)pyrene
18. Benzo(b)fluoranthene
19. Benzo(k)fluoranthene
20. Bis(2-Ethylhexyl)Phthalate
21. Cadmium
22. Chromium
23. Chrysene
24. Copper
25. Dibenzo(a,h)anthracene
26. Disulfoton (Di-Syston
27. Fluoranthene
28. Fluorene
29. Hexachlorobenzene
30. Indeno(1,2,3-cd)pyrene
31. Iron
32. Lead
33. Manganese
34. Mercury
35. Methyl Mercury
36. Naphthalene
37. N-Nitrosodimethylamine
38. Pentachlorophenol
39. Phenanthrene
40. Pyrene
41. Simazine
42. Thallium
43. Total DDT
44. Total PAHs
45. Total PCB
46. Vanadium
47. Zinc

The following discussion applies to the "maximum concentrations" which may have been detections or may have been a MDL depending on the specific chemical and matrix. For instance, some of these chemicals were only detected at low levels, but also had other samples had detection limits exceeding the SCs and are thus included.

4.2.1 Tier 1 Water Results

A comparison of maximum chemical concentrations in surface water to SCs is shown in Appendix A. Of the 382 chemicals measured in water, 48 (12%) were retained for consideration in Tier 2. The basis for including these chemicals for further analysis is as follows: 25 chemicals had maximum concentrations greater than corresponding SC; 11 non-carcinogenic chemicals exceeded 1/10th of SC; 6 chemicals were re-included as a special case; and 8 chemicals were included because of exceedances in another medium.

4.2.2 Tier 1 Sediment Results

A comparison of maximum chemical concentrations in sediment to SCs for residential soil is also shown in Appendix A. Of the 141 chemicals measured in sediment, 47 (33%) were retained for consideration in Tier 2. The basis for including these chemicals for further analysis is as follows: 14 chemicals had maximum concentrations greater than the derived SCs; 13 chemicals were re-included based on their classification as a PBT, or other special cases; and 20 chemicals were re-included because they were retained for Tier 2 analysis in a different medium.

4.2.3 Tier 1 Fish Tissue Results

A comparison of maximum chemical concentrations in fish tissue to SCs for tissue is shown in Appendix A. Of the 119 chemicals measured in tissue, 42 (35%) were retained for potential consideration in Tier 2. The basis for including these chemicals for further analysis is as follows: 8 chemicals had maximum concentrations greater than their SCs; 1 chemical exceeded 1/10th its SC; 15 chemicals were re-included based on USEPA priority, PBT classification, or other special cases; and 18 chemicals were re-included because they were retained for Tier 2 analysis in a different medium. However, fish tissues were not further analyzed in this document, because the available data were insufficient to develop a more detailed analysis than what was already completed by DOH (2004a).

4.3 Tier 1 Bacteriogical Screening Assessment

The USEPA has established a maximum contaminant limit (MCL) for bacteria in drinking water. For fecal coliforms, no more than five percent of the samples collected during a month may have detectable fecal coliforms or *Escherichia coli* (*E. coli*) bacteria. The number of samples public water supply systems are required to collect varies from 1 to 480 depending on the service population.

For recreational water uses, USEPA established guidelines for fecal bacteria in the 1986 document "Ambient Water Quality Criteria (AWQC) for Bacteria" (USEPA, 1986). In this document, USEPA recommended using *E. coli* as the primary indicator for fecal contamination and established a standard of 126 colony forming units (cfu)/100 ml as the geometric mean for

recreational waters. USEPA also established a single sample maximum allowable concentration for *E. coli* that is dependent on water body use. The most conservative use is as a designated bathing beach, for which the maximum allowable *E. coli* concentration is the upper 75% confidence limit (75% C.L.) of the standard based on a site-specific log standard deviation.

The geometric mean of *E. coli* data calculated from the entire study area was 50.5 cfu/100 ml, which is less than half of the AWQC standard, indicating that *E. coli* levels, within the study area as a whole, are within acceptable limits. However, the maximum reported *E. coli* concentration of 31,000 cfu/100ml far exceeds the calculated 75% C.L. of the 126 cfu/100 ml standard (208 cfu/100 ml), indicating that *E. coli* will need to be considered further in Tier 2.

USEPA's Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters) Status Report (USEPA, 2003) updates the 1986 document by listing bacteria standards established by states and tribes. For Washington State, a fecal coliform standard of 50 cfu/100 ml as a geometric mean was established for "extraordinary primary contact" waters, with no more than 10% of samples to exceed 100 cfu/100 ml (WAC 173-201A-200-2(b)). The standard for primary contact recreation is a geometric mean of 100 cfu/100 mL with no more than 10% of the samples exceeding 200 cfu/100 mL. Most of the waterbodies in the study area are classified as either extraordinary primary contact or primary contact recreation. Primary contact recreation means, "activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing" (WAC 173-201A-020).

The calculated geometric mean for the fecal coliform data from the study area is 54.4 cfu/100 ml, which is slightly more than the Washington State extraordinary primary contact standard. Of the 6,718 independent water samples analyzed for fecal coliform, 2,355 (35%) exceed the 100 cfu/100 ml standard, indicating that fecal bacteria will need to be considered further in Tier 2.

King County has collected a limited amount of cyanobacteria data in the past. However, no dose response relationships were available to evaluate these data. Microcystin-LR is one of a family of cyanotoxins with high levels of toxicity, although animal and human toxicity data are incomplete. Available data were reviewed by Chorus and Bartram (1999) and the data only allowed derivation of a provisional tolerable daily intake (TDI) for microcystin-LR. This should not imply that only microcystin-LR is toxic, or that other cyanotoxins are less harmful. It is solely due to a lack of toxicological data. For the data period used in this report (1/1995 through 12/2003, Table 4), only 7 samples were analyzed for microcystin-LR. The MDL for these data was 0.05 µg/L and the provisional TDI is 1.0 µg/L. This suggests that for the existing data, no toxic cyanobacteria blooms were of concern.

4.4 Tier 1 Uncertainties

As with any risk evaluation, uncertainties inherent in the approach must be considered in the interpretation of results. Uncertainty can result in both under and over-estimates of risk. A large source of uncertainty is inherent in the evaluated dataset due to the fact that available chemistry data were not specifically collected for risk assessment purposes. For instance, the available data were not collected using risk assessment data quality objectives, and have not documented the complete range of human exposures to both natural background levels in pristine areas nor highly contaminated areas. The analyte list has not documented some of the more toxic potential

contaminants (e.g. dioxins) nor the more toxic forms of some chemicals (e.g. methyl mercury, chromium VI, and inorganic arsenic). Lastly, their spatial scale is generally too coarse relative to the exposure areas in the study area (e.g. domestic water supply with backyard wading use occurs on a residential lot sized scale). Thus, there is knowledge uncertainty associated with the water exposure estimates. The screening process and drinking water exposure assumptions used in Tier 1 suggest that undocumented water risks for more common recreational users are very unlikely.

For toxic cyanobacteria, an insufficient number of samples were available to thoroughly evaluate the episodic risks from toxic algae blooms. Additional microcystin-LR data are required, as well as published dose response relationships, to quantify the risks of algal blooms. Fecal coliforms and *E. coli* bacteria have been forwarded to Tier 2 for more refined analysis. While they may not warrant detailed risk evaluation at all locations, this approach is conservative and Tier 2 will address the uncertainties with bacteria in more detail.

For sediment, samples were generally collected from lakes, streams, and rivers. These areas are not consistently exposed/dry and accessible to children or adults. Thus, most uncertainties associated with sediment risks are probably addressed by the very conservative exposure assumptions used.

A very large level of knowledge uncertainty exists regarding the tissue results. The number of aquatic species was limited, and the sample sizes were small. One of the parameters of greatest concern, PCBs, were not analyzed by the ideal method for HHRAs. Use of the Aroclor® based methods of PCB analysis is reasonably accurate for contaminated areas with on-going, fresh sources. In areas with older, more weathered contamination, Aroclor® analysis may be less appropriate since the congener patterns in fish tissue typically become less and less similar to the Aroclor® parent materials over time. Since the majority of PCB sources in Lake Washington are presumably historic and/or atmospheric, the lack of PCB congener data provides a high level of uncertainty. Because the relationships between Aroclors® and congeners varies in fish tissues based on both the age of the accumulated PCBs and the food web through which they have accumulated, other Aroclor® to congener relationships developed by King County for the Duwamish Waterway cleanup are not necessarily appropriate for use in Lake Washington.

The greatest uncertainty may be associated with the tissue assessment. The tissue exposure assumptions were selected to include some of the very highest possible consumers of fish and shellfish, including tribal consumers and Asian Pacific Islanders. Based on a recreational use survey (Parametrix, 2003) most people fishing in Lakes Union, Washington, or Sammamish consume substantially less than 54 g/day of fish. Thus, any uncertainty generated by the high consumption rate used in the SCs is in a conservative direction.

The available fish tissue data are generally whole body results. While the consumption of whole fish is common in some cultures, the recreational use survey suggests that most consumers utilize only fillet/muscle tissue. Because most of the chemicals found in fish tissue are long-lived organic compounds, which are preferentially found in fat, the use of whole body concentrations is conservative. The exception is methyl mercury, which preferentially partitions to muscle tissues. The use of whole body samples could have diluted methyl mercury concentrations by including non-muscle tissues in the sample. This dilution is likely to be well within the range of variability between and within fish size and age classes. Thus, the

uncertainty associated with the use of maximum methyl mercury concentrations for screening is believed to counterbalance the use of whole body fish data.

Examples of uncertainties pertaining to the Tier 1 screening approach include limitations on receptor-specific input assumptions, such as body weight and ingestion rates, and lack of consideration of chemical bioavailability in the various environmental media. These issues are elaborated on below, although many are inherent in all risk assessments and are not necessarily deficiencies with the particular approach used in Tier 1 of this assessment.

Several limitations with the Region III RBC/derived SC dataset that may be relevant to the Tier 1 assessment should also be considered. Specifically, the following were not considered in development of the RBCs/SCs used in Tier 1: (1) transfers from water/soil to air, (2) cumulative risk from multiple chemicals or media; and (3) dermal exposure risk. These exposure routes were not evaluated because screening and/or measured values were not available and/or they represent issue better addressed at the Tier 2 level. Most of the analyzed chemicals are only moderately volatile and other industrial or ambient sources to air likely exceed the potential transfer of volatiles initially released in water to air. Additionally, cumulative risks are rarely evaluated at the screening level. The intent of the screening is to focus future risk analysis on those chemicals mostly likely to present a significant proportion of total risk. Thus, by design, minor contributors to risk are omitted. Due to the conservative nature of Tier 1 screening, eliminated chemicals are believed to represent less than 1% of total risk. Lastly, dermal exposures are a generally a minor contributor to total risk, thus this exposure pathway is better evaluated at the Tier 2 level.

In some cases, MDLs exceeded the screening values as shown in Appendix A, Table 2. There are 55 chemicals with at least one MDL greater than the screening concentration. Some of these chemicals were included in the Tier 2 assessment as special cases, e.g. all of the PAHs and PCBs. These special cases do not present screening uncertainty since they are evaluated in detail in Tier 2. Thirteen of these chemicals are volatile organics. The elevated MDLs of these volatile chemicals introduce little uncertainty to Tier 1, since they are not expected to be present in ambient surface waters or sediments. The greatest amount of Tier 1 uncertainty is likely due to the elevated MDLs for pesticides like chlordane and dieldrin. These chemicals are known to bioaccumulate and the DOH's fish consumption advisory considered chlordane. Thus, these persistent chemicals have already been detected in some study area media and may deserve additional evaluation in all media to reduce uncertainty.

A number of chemicals had no screening concentrations. Generally, the absence of a SC is due to the lack of an EPA established toxicity value. These chemicals may or may not pose a human health issue. Some chemicals in this group are similar to chemicals with established toxicity values, e.g. methylated PAHs, nitrophenols, benzo(e)pyrene, and phenanthrene. However, deriving a toxicity value based on structure activity relationships or other inferences is beyond the scope of this project. The majority of the other chemicals lacking human health toxicity values are pesticides or herbicides. These include bromacil, decalin, dichlobenil, MCPP, and tebuthiuron, among others. Attempting to derive a human health toxicity value for these chemicals, from occupational exposure (NIOSH) or other published limits is outside the scope of this project.

Lead in particular, has not been evaluated in Tier 1 due to the specialized models and spatial data needed to assess childhood (and/or adult) lead risks at the appropriate scale. Tier 2 discusses lead further as a special case. Discussion of lead exposure and toxicity issues will be presented in that section of the document.

5.0. TIER 2 ASSESSMENT

As previously discussed, this risk assessment utilized existing data and these data pose limitations for further analysis in Tier 2. These limitations are related to either chemical concentrations or exposure assumptions. Overall, the existing exposure and concentration data are insufficient to develop definitive metrics of human health risk in study area. However, for the purposes of understanding important pathways and chemicals, quantitative calculations of risk were conducted for three exposure scenarios:

1. Year-round use of surface waters as a domestic water supply with childhood play and adult contact (wading) to water and sediment in a backyard stream or lake;

2. Year-round wading in near-shore lake waters or streams, with sediment contact;

3. Summertime swimming in lakes without sediment contact.

In addition to these scenarios, *E. coli* bacteria were evaluated as if the waters were swimming beaches. This is because all of the water bodies in WRIA 8 are considered suitable for water recreation. Fecal coliforms cannot be further evaluated in Tier 2. King County routinely collects fecal coliform, *E. coli*, and periodically collects cyanobacteria data. For fecal coliforms, these bacteria are not definitively related with illness. USEPA (1986) states that, "The freshwater studies confirmed the findings of the marine studies with respect to Enterococci and fecal coliforms in that the densities of the former in bathing water showed strong correlation with swimming associated gastroenteritis rates and densities of the latter showed no correlation at all." Only 4 samples of other bacteria were collected (yielding 4 total coliform results and 4 *Enterococci* sp. results) and these limited data cannot be evaluated further. Dose response relationships for toxic cyanobacteria and human illness were also not available from either regulatory agencies or public health agencies like the Centers for Disease Control or the World Health Organization. Thus, only *E. coli* results were further evaluated in Tier 2.

When possible, the Tier 2 human health risk assessment process incorporated site-specific exposure information and chemical species-specific toxicity data to characterize the potential risks posed to receptors at a location. Tier 2 was comprised of three components: (1) an exposure assessment; (2) a toxicity assessment; and (3) risk characterization, which combines the outputs of the first two components (USEPA, 1989).

The remainder of this section will discuss the details of the exposure scenarios, exposure parameters, the exposure point concentrations (EPCs), intake calculations, and chemical toxicity. The section ends with the calculation method combining these variables into a risk characterization.

5.1 Exposure Evaluation

According to RAGS(a), "An exposure assessment is conducted to estimate the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the

pathways by which humans are potentially exposed." (USEPA, 1989). Several elements are included in the exposure assessment process:

- analysis of contaminant releases;
- identification of exposed populations;
- identification of potential pathways of exposure;
- estimation of exposure point concentrations for specific pathways; and
- estimation of contaminant intakes for specific pathways.

The first three of these elements represent the critical first step in evaluating potential impacts in the study area -- identifying the people potentially at risk and the pathways through which they can be exposed to chemicals carried forward from the Tier 1 screening. No known contaminant releases (e.g. oil spills) were included in the sampling regime and the human use survey (Parametrix, 2003) documented that approximately 1% of the recreational users of the three major lakes resided outside the study area. Thus, the exposed population potentially includes approximately 1 million study area residents (US Census Bureau, 2005).

However, the specific ways in which these people use the study area waters determines the degree to which they can be exposed to various chemicals, the time of year during which these exposures can take place, and the manner by which the exposure occurs (e.g., skin absorption versus ingestion). The human use survey (Parametrix, 2003) conducted to support this assessment was used to estimate local recreational exposures. For the domestic water supply with backyard wading use exposure scenario, local or state data were used when possible, otherwise national average exposure parameters were utilized.

Sediment samples were generally not collected from areas where human exposure occurs (e.g., the shorelines of parks or residential parcels). The human use survey defined exposures for: walking, sunbathing, picnics, playing games, biking, digging in sand away from water, digging in sand in-water, nature observation, wading, swimming, scuba diving, surfing, and boating. Only one of these activities, "digging in sand in water," is related to potential sediment exposure. The human use survey was conducted at public access points and parks surrounding Lakes Union, Washington, and Sammamish. Thus, the frequency and duration of "digging in sand, in water" is generally a reflection of beach exposures. Some of the beaches may use imported sand and in all cases exposure is to sediments in shallow waters. The human use survey did not estimate exposures to stream sediments or to lake or river shoreline sediments which might be part of a backyard wading use exposure route.

King County has only occasionally sampled the shallow beach sediments most closely related to the exposures documented in the human use survey. Additionally, an assessment of the exact water depth at each sediment sampling location was not always possible. This is because depth was only intermittently recorded in LIMS by KCEL when sampling sediments. Thus, the connection between the available exposure data and the environmental concentrations is weak. This issue is also present for stream and river sediments, since the human use survey did not evaluate exposures along these waterbody types. To address this, all of the available sediment

sampling locations were mapped onto bathymetric charts. All stream, along with lake and river sediment sampling locations landward of the 15-foot depth contour, were retained as shallow enough for human exposure. Deeper lake and river sediment locations were eliminated from further evaluation.

There were more data for sediment metals than for organic compounds. No specific location was sampled more than 10 times, thus a 95% UCL estimate of the daily average exposure to each chemical was not possible. Thus, the maximum concentration of each chemical was used to conservatively estimate exposure. The use of point maxima for sediment exposure concentrations means the Tier 2 RA is not significantly more refined than Tier 1. The use of maximum detected concentrations, by definition, omits consideration of non-detect values.

The Tier 1 screen included all of the data using an inhalation pathway for volatiles liberated from showering. None of the chemicals selected as COCs are volatile; therefore this pathway was eliminated from further consideration (Table 6).

The DOH has issued a fish consumption advisory for Lake Washington. The tissue data used in their assessment were provided by King County and the scientific basis for this advisory is described in "Evaluation of Contaminants in Fish from Lake Washington King County, Washington" (DOH, 2004a). It addresses chlordane, DDT, mercury and PCBs. Based on the human use survey (Parametrix, 2003), the preponderance of fishing activity in the study area occurs in Lake Washington. The available tissue and exposure data are too limited to evaluate the other study area waterbodies in a similar manner, although preliminary comparisons with Lake Washington results suggest Lake Union fish are comparable and Lake Sammamish fish have much lower concentrations of chemicals. Because DOH's fish evaluation (2004a) is a risk assessment of the primary risk drivers in fish tissue utilizing all available data and no new King County data are available, Tier 2 has not considered this exposure pathway further. The Tier 2 uncertainty section discusses the consequences of this decision.

Because some exposure routes were uncharacterized (e.g. residential soil) and others that were documented in the human use survey (Parametrix, 2003) did not necessarily match well with the existing data (e.g. shoreline bicycling), some exposure pathways defined in Tier 1 were not included in Tier 2. The pathways and exposure scenarios shown in Table 8 were evaluated in Tier 2. A "locator" for the purposes of this assessment is a single monitoring or environmental sampling point.

Table 8. Summary of Tier 2 exposure pathway/data combinations evaluated.

Intake Scenario	**Drinking water consumption**	**Dermal water contact**	**Incidental water consumption while swimming/wading**	**Incidental Sediment Ingestion**	**Dermal sediment contact**	**Fish Tissue Consumption**
Domestic water supply with Backyard Wading Use	Yes, by locator	Yes, locator average when N>10. Maximum detection by locator when N<10	No	Yes, for locations shallower than 15' No, for deeper locations	Yes, for locations shallower than 15' No, for deeper locations	No, see DOH advisory
Wading, all locations	No	Yes, locator average when N>10. Maximum detection by locator when N<10	Yes, locator average when N>10. Maximum detection by locator when N<10	Yes, maximum detection for locations shallower than 15' No, for deeper locations	Yes, maximum detection for locations shallower than 15' No, for deeper locations	No
Swimming, lake locators only	No	Yes, locator average when N>10. Maximum detection by locator when N<10	Yes, locator average when N>10. Maximum detection by locator when N<10	No	No	No

Note: The term "average" equals the 95% UCL of the arithmetic mean. Discussion of the data utilized to calculate averages is in Section 4.1.1.1, Exposure Point Concentrations below.

5.1.1 Human exposure variables

The values utilized to estimate exposure are listed in Tables 9 and 10. These values have been derived from four sources using the following priorities: (1) the human use survey (Parametrix, 2003); (2) DOH statistics; (3) Dermal Risk Assessment Guidance (RAGS(e); USEPA, 2004); and 4) the US EPA's EFH (USEPA, 1997). Values that have not changed between scenarios have only been presented once in Table 9 (e.g. adult average body weight).

Table 9. Summary of Tier 2 water exposure variables.

Variable	Value	Units	Citation/source
Drinking water consumption rate	2	Liter/day	EFH/ customary default
Drinking water consumption frequency	365	Days/year	Assumed to be year round
Exposure duration	78	Years	DOH (2004b) life expectancy statistics for a WA State infant in 2000
Weight, lifetime average	70	Kilograms	EFH/ customary default
Exposure averaging time (all scenarios)	28470	Days	365 x duration
Swimming and wading incidental water consumption rates	50	Milliliter/hour	RAGS(a) (1989)
Swimming time	4	Hours/event	human use survey (95th percentile for all 3 lakes)
Swimming frequency	58	Events/year	human use survey (95th percentile for all 3 lakes)
Showering time	0.5833	Hours/event	RAGS(e) (1989)
Showering frequency	1	Event/day	EFH/ customary default
Thickness of the stratum corneum (skin)	10E-3	Cm	RAGS(e) (1989)
Swimming/shower adult skin surface area	18,000	Cm2	RAGS(e) (1989)
Wading skin surface area	633	Cm2	Age weighted average, for children 0-6 the whole body, for adults the lower

Variable	Value	Units	Citation/source
			extremities. RAGS(e) and EFH
Wading time	2	Hours/event	human use survey (adult 95th percentile, digging in sand, in water)
Wading frequency	81	Days/year	human use survey (95th percentile for all 3 lakes)

EFH = Exposure Factors Handbook
RAGS(a) = Risk Assessment Guidance for Superfund, Part A
RAGS(e) = Risk Assessment Guidance for Superfund, Part E
human use survey = Parametrix, 2003

One sediment exposure parameter has been estimated via professional judgment. For adult sediment exposures, only 25% of the soil exposure was assumed to come from sediment (e.g. from backyard waterbody or wading use). The remainder of the soil exposure is assumed to come from upland soils. For children, all of the soil exposure was assumed to be shallow sediment. This is a conservative assumption because it assumes children do not play in soils in their yards or at parks but only in sediments. These values are reported as "fraction of contaminated soil exposed" below. Values have not changed between scenarios or from the water exposure pathway have only been presented once above in Table 9 (e.g. adult average body weight).

Table 10. Summary of Tier 2 sediment exposure variables.

Variable	Value	Units	Citation/source
Adult incidental ingestion	20	Milligram/hour	EFH (1997), adult gardening rate
Child incidental ingestion	15	Milligram/hour	EFH (1997), outdoor play average of 2.5 and 6 year old child rates
Adult skin surface area	2800	Cm2	RAGS(e) (1984)
Child skin surface area	5700	Cm2	RAGS(e) (1984)
Adult duration	72	Years	DOH (2004b) life expectancy statistics for a WA State infant in 2000 minus childhood
Child duration	6	Years	By definition / convention

Variable	Value	Units	Citation/source
Child body weight	15	Kilograms	EFH (1997)
Adult exposure hours	550	Hours/year	human use survey (adult 95th percentile, digging in sand, in water) multiplied by days/year with a high temperature greater than 50F, SeaTac weather data
Child exposure hours	850	Hours/year	EFH (1997)
Adult fraction of contaminated soil exposed	0.25	--	Professional judgment
Child fraction of contaminated soil exposed	1	--	Professional judgment
Exposure frequency	81	Days/year	human use survey (95th percentile for all 3 lakes)
Adult adherence factor	0.07	mg/cm^2-event	RAGS(e) (1984)
Child adherence factor	21	mg/cm^2-event	RAGS(e) (1984)

EFH = Exposure Factors Handbook
RAGS(a) = Risk Assessment Guidance for Superfund, Part A
RAGS(e) = Risk Assessment Guidance for Superfund, Part E
Human use survey = Parametrix, 2003

Adherence factors are the amount of soil adhering to the skin during and after an exposure event. These values determine the amount of chemical available to be dermally absorbed.

5.1.1.1 Exposure point concentrations

When assessing the risk of disease over an entire lifetime, average daily intakes of a contaminant are used with cancer slope factors or reference doses to estimate the risk of a toxic effects. In general, the existing chemical data were insufficient to precisely estimate average daily intakes of COCs with any degree of certainty. People live and recreate throughout the study area and chemical data were only available from a few select points. Temporally, the data were limited to a 5 year period assumed to represent current conditions. The number of samples collected at a specific location within this time period varied considerably, from as few as 1 to as many as 50. A large degree of uncertainty exists both spatially and where numbers of samples are limited.

For both sediment and water data, metals analysis was conducted more frequently than analysis of organic compounds. When more than 10 samples were available for a particular location,

estimates of the daily average exposure to each chemical were possible. When less than 10 samples were available at a location, the maximum concentration was used to conservatively estimate exposure. The use of point maxima for many (particularly organic and those in sediment) chemicals means the Tier 2 RA is not significantly more refined than Tier 1.

For those chemicals with greater than 10 detections, the 95% UCL of the arithmetic average was used to estimate an average daily exposure concentration. Most of these chemicals were metals with high detection frequencies, although some locations had sufficient data for organic compounds to calculate 95% UCLs of the mean. At each specific locator, when the FOD was less than 100%, one-half the MDL was used in these calculations as a surrogate value for non-detects.

Exposure point concentrations were developed from existing data using the following guidelines:

- For locations with less than 10 sampling events for the respective chemical, the maximum detected concentration was selected. Locations where samples were analyzed but where a chemical was never detected or where all samples were blank qualified were excluded from further consideration. There were less than 10 sampling events for all of the sediment data; as a result all sediment exposure concentrations are represented as maxima.

- For locations with more than 10 sampling events and at least one detection, the 95% UCL of the arithmetic mean was calculated using detected concentrations and one-half the MDL for non-detect samples.

EPA risk assessment guidance (EPA, 1992) recommends use of the 95%UCL on the mean as a "conservative estimate of the average concentration". This guidance also states that data sets with less than 10 samples in a spatial unit for Superfund sites have been shown to poorly represent the mean concentration. 95%UCL values for data with small sample sizes can result in values higher than the maximum concentration. For these reasons, the maximum concentration was used as a conservative estimate of the mean where sample sizes were less than 10.

The exposure point guidelines disregarded blank qualified samples and they were not used in Tier 2. There were significant uncertainties inherent in this assessment even using the more robust, unqualified laboratory data (discussed further in Sections 6 and 7). The use of blank qualified data was considered unnecessary to meet the assessment's objectives (Section 2.1.1). Spatial averages were not calculated because they were also not necessary to achieve the risk assessment objectives; to describe the parameters, locations, and exposure associated with the greatest risks.

Appendix B (Tables 5 and 6) lists all of the chemicals included in the Tier 2 assessment by locator. The total number of non-blank qualified samples, the FOD, and the concentrations used in the risk calculations for that locator are shown for both water and sediment.

5.1.2 Chemical Intake

Chemical intakes for each location/chemical were calculated by following the generic equation as shown below in Equation 1.

$$I = \frac{C \times CR \times EF \times ED}{BW} \times \frac{1}{AT} \quad (1)$$

Where:

- I = intake of chemical in mg/kg-body weight-day
- C = chemical concentration, either an estimate of the central tendency (95% UCL of the arithmetic mean) or the maximum
- CR = contact or ingestion rate (IR), amount of contaminated media contacted per unit time (e.g. liters/day)
- EF = Exposure frequency (days/year)
- ED = exposure duration (years)
- BW = average body weight over the exposure period (kg)
- AT = averaging time, period over which the dose is averaged

(RAGS (a) 1989)

The different exposure pathways shown in Table 8 each have media or unit specific modifications of this generic equation. Ingestion intakes, for water and sediment, are found in RAGS(a) (USEPA, 1989). Dermal water and sediment formulas may be found in RAGS(e) (USEPA, 2004). The chemical intake via different pathways will be combined with the exposure point concentrations as described in Appendix B Tables 5 and 6 to characterize the risk of the three selected exposure scenarios.

5.2 Tier 2 Toxicity Assessment

As defined by USEPA in RAGS(a), a toxicity assessment "considers: (1) the types of adverse health effects associated with chemical exposures; (2) the relationship between magnitude of exposure and adverse effects; and (3) related uncertainties such as the weight of evidence of a particular chemical's carcinogenicity in humans." To the extent possible, the HHRA Tier 2 risk assessment incorporated up-to-date chemical specific toxicity information that was publicly available from established government sources. Current and readily available chemical-specific toxicity data for each of the water and sediment COPC from Tier 1 were obtained according to the hierarchy of sources recommended by USEPA in its RAGS(a) (USEPA, 1989). The primary and secondary sources of toxicological data were USEPA's Integrated Risk Information System (IRIS) and USEPA's Health Effects Assessment Summary Tables (HEAST), respectively. The Superfund Technical Support Center's peer-reviewed provisional values were also used as a secondary source. Developing toxicity values for lesser-studied chemicals is beyond the scope of this assessment.

This assessment incorporated currently available reference doses (RfDs) and cancer slope factors (CSFs) for each chemical in the dataset. According to RAGS(a) (USEPA, 1989), "A chronic RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." A cancer slope factor is a "plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of

an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen" (USEPA, 1989).

5.2.1 Oral to Dermal Adjustments

For each COPC evaluated for direct contact, dermal toxicity factors were calculated. Specifically, adjustment of oral toxicity factors to account for absorbed, rather than administered doses, was conducted according to USEPA RAGS(e) (2004) guidance using gastrointestinal absorption efficiencies. Adjusted dermal reference doses and slope factors, respectively, were calculated as follows:

$$RfDd = RfDo \times ABSgi$$

and

$$CSFd = CSFo \div ABSgi$$

Where,

RfDd = Adjusted dermal reference dose (milligrams/kilogram-day)

RfDo = Oral reference dose obtained from IRIS, HEAST, or ATSDR (milligrams/kilogram-day)

CSFd = Adjusted dermal cancer slope factor (per milligram/kilogram-day)

CSFo = Oral cancer slope factor obtained from IRIS, HEAST, or ATSDR (per milligram/kilogram-day)

ABSgi = Chemical-specific gastrointestinal absorption efficiency (unitless) Table 11

RAGS(e) states that only chemicals with gastrointestinal absorption efficiencies of less than 50% shall have their oral CSFs and RfDs adjusted. This is due to the inherent uncertainties surrounding this adjustment. Of the Tier 2 parameters, only 6 non-carcinogenic metals had gastrointestinal absorption efficiencies of less than 50%. They are listed in Table 11, with their oral to dermal ABSgi values. The remaining COPCs all had ABGSgi values greater than 50% and thus were not adjusted.

Table 11. Gastrointestinal absorption efficiency values (unitless fraction).

Compound	ABSgi
Antimony	0.15
Barium	0.07

Compound	ABSgi
Cadmium	0.05
Chromium	0.025
Manganese	0.04
Vanadium	0.026

5.2.2 Chemicals with toxicity values via TEFs

A number of Tier 2 COPCs were chemicals without established toxicity values. These include: PCBs like Aroclor® 1248, PAHs such as acenaphthylene and metals such as lead. For Aroclors® 1248 and 1260, no RfD values were available. Thus, these parameters have been assessed as a constituent of "Total PCBs" only. A CSF is available for "Total PCBs" and these chemical mixtures are best evaluated using this approach. "Total PCBs" were derived by eliminating those PCB Aroclors® which were never detected in any media. Next, the detected concentrations of Aroclors® 1016, 1248, 1254, and 1260 were summed. When one or all of these Aroclors® were not detected, one-half the MDL was used as a surrogate value. For the non-cancer endpoint, the RfD for Aroclor® 1254 was used to conservatively estimate the risk of non-cancer effects from total PCBs.

Many of the PAHs also did not have individual toxicity values. Thus, toxicity equivalent factors (TEFs) were used to estimate potency based on the toxicity of benzo(a)pyrene. These are reiterated in Table 12 for review. The risk assessment utilized the average TEF as reported by USEPA (1993).

Table 12. Potencies of PAHs relative to benzo(a)pyrene.

Compound	Low potency TEF	High potency TEF	Average TEF used in Tier 2
Benz(a)anthracene	0.1	0.145	0.1225
Benzo(b)fluoranthene	0.1	0.167	0.1335
Benzo(k)fluoranthene	0.01	0.02	0.015
Chrysene	0.001	0.001	0.0027
Dibenz(a,h)anthracene	1	1.11	1.055
Indeno(1,2,3-cd)pyrene	0.1	0.055	0.0775

All the chemical specific toxicity values used in the HHRA are reported in Appendix C.

5.2.3 Other chemicals without toxicity values

Three PAHs lacked either a quantitative toxicity factor (in IRIS, HEAST), and/or a TEF. They were 4,6-dinitro-O-cresol, acenaphthylene, and lead. The EPA Region III RBC table includes a "peer-reviewed provisional" RfD for 4,6-dinitro-O-cresol. The EPA Superfund Technical Support Center (STSC) in Cincinnati, OH, provided the supporting documentation for the provisional peer-reviewed chronic oral RfD to WLR scientists (STSC, 2005). This RfD was developed by two EPA scientists and has been externally reviewed by three independent scientific experts for use in EPA's Superfund program. This value was deemed suitable for use in the RA. No toxicity values were available from other sources for acenaphthylene.

For lead, EPA has a bio-kinetic model which uses a variety of media to estimate blood lead concentrations. These parameters include: indoor dust, outdoor soil, air, water, and home-grown produce. Because water and sediment are minor components of an individual's overall lead intake and generic inputs are not available for the majority of the non-aquatic resource lead sources, the risks of lead ingestion via surface water and sediment cannot be assessed.

5.3 Tier 2 Chemical Risk Characterization

Risk characterization is the combination of exposure data with toxicity information. The sections below describe this process, while the results are presented in Section 5.0. Evaluation of the potential for medium-specific constituents to impact human health within the study area was conducted in accordance with USEPA's RAGS(a) (1989) guidance on characterizing risks. Thus, for each exposure scenario evaluated, the potential for cancer risks and non-cancer hazards were assessed for the intake of each COPC according to the following equations:

Cancer Risk = Chemical-Specific CSF x Chemical-Specific Exposure Dose

Non-cancer Hazard = Chemical-Specific Exposure Dose ÷ Chemical-Specific RfD

That is, for each receptor, pathway exposures were combined to obtain a scenario-specific total estimate of intake and corresponding risk. Using the USEPA's recommended guidelines for assessing impacts to human health, cancer risk estimates are compared to a target probability of 1 in one million, or 1E-6. Non-cancer hazards were added together based on target organ or mode of action and compared to a hazard level of 1.

The individual chemical cancer risk and the hazard level for each scenario are summarized by locator in Appendix E.

5.4 Bacteria Assessment

Escherichia coli are the only type of bacteria routinely analyzed by King County for which there is a published dose-response relationship. These bacteria predominantly cause gastrointestinal illness (fever, vomiting, diarrhea), although they can also cause meningitis and other even more serious disease (USEPA, 2002a).

The US EPA and the US Public Health Service began studying the relationships between fecal coliform, *E. coli*, and *Enterococus* spp. bacteria and human health in the 1950s. In August, 1984, the USEPA published "Health Effects Criteria for Fresh Recreational Waters" (Dufour, 1984) and this information was incorporated into the ambient water quality criteria for bacteria (EPA, 1986).

Dufour (1984) was able to document the relationship between *E. coli* and human illness and this relationship was reaffirmed in the 2002 "Implementation Guidance for Ambient Water Quality Criteria for Bacteria" (EPA, 2002). Dufour reviewed five studies conducted on Lake Erie and Keystone Lake, PA from 1979 to 1980. Each study used two beaches, one with human derived sewage inputs nearby and one without. *E. coli* concentrations were measured and compared with swimmer survey results over the swimming season to correlate gastrointestinal illness with *E. coli* levels.

The dose-response relationship in Dufour (1984) has been incorporated into a quantitative probabilistic evaluation of the risks of gastrointestinal illness from water activities on a random day as described further below.

While the dose-response relationship was reaffirmed by EPA in the 2002 Implementation Guidance for Ambient Water Quality Criteria for Bacteria (USEPA, 2002), the dose response relationship in Figure 4 of Dufour (1984) only describes the lower-middle range values in the database, 20 to 500 cfus/100mL. The lack of a defined dose-response at the high end of potential human exposure (thousands of CFUs/100mL) is not unexpected; as it would be unethical to allow swimming in highly contaminated waters for scientific purposes. This shortcoming in the Dufour (1984) relationship prevents accurate description of the illness rates potentially experienced from the complete range of *E. coli* concentrations (0 to tens of thousands of CFUs/100mL) found in King County waters. However, just as priority pollutant toxicity dose-response relationships are extrapolated downwards to human exposure levels, this relationship will be log-linearly extrapolated upwards to fit the range of potential exposures in King County.

5.4.1 Bacterial/pathogen Data Suitability Evaluation

While this assessment is occurring at the Tier 2 level of the risk assessment, many study area sampling locations never exceed water quality standards or there were insufficient data to evaluate. Thus, the bacteria assessment begins with data screening to narrow the focus to locations and results amenable to quantitative analysis. This screening process is discussed below.

5.4.1.1 Season

The bacteriological assessment began by removing *E. coli* sample results which were collected outside the summer season. The summer season was defined as beginning on June 1st and extending until September 15. The human use survey (Parametrix, 2003) did not include questions about the calendar period of exposure and thus the period used in the HHRA was established based on professional judgment. This exposure timeframe intends to represent the period of greatest human exposure. Most municipalities in the study area provide lifeguards from approximately June 15 until the first week of September (Labor Day).

5.4.1.2 Data manipulations

Samples were segregated from the database by sampling location and date. Samples collected at the same location and on the same date were considered replicates and they were converted to single values by taking their arithmetic average. Values flagged as "H" for holding time violations, were retained in the database. Values flagged as "E" were used as reported. The KCEL Quality Assurance manual (KCEL, 2006) defines an "E" as "applied to microbiological data when a standard method for estimation of the number of microorganisms has been employed during analysis rather than an actual count."

5.4.1.3 Location/data screening

The bacteria results were then examined by sampling location. Those locations which never exceeded the ambient water quality standard of 126 colony forming units per 100 mL were removed from further evaluation. The following list of locations (Table 13) never exceeded 126 cfu/100mL and were therefore considered to present an *acceptable* risk of human illness during the swimming season (USEPA, 1986).

Table 13. Number of samples, minimum and maximum *E. coli* values for locations with maximum *E. coli* results less than 126 cfu/100mL.

Location	Waterbody Name	N	*E. Coli* Minimum Value (cfu/100ml)	*E. coli* Maximum Value (cfu/100ml)
0540	Lake Union	44	0	120
0611	Lake Sammamish	43	0	4
0612	Lake Sammamish	43	0	5
0614	Lake Sammamish	43	0	35
0617	Lake Sammamish	43	0	45
0622	Lake Sammamish	43	0	12
0804	Lake Washington	44	0	33
0807	Lake Washington	44	0	65
0814	Lake Washington	44	0	21
0817	Lake Washington	44	0	22
0826	Lake Washington	44	0	10
0831	Lake Washington	44	0	90

Location	Waterbody Name	N	*E. Coli* Minimum Value (cfu/100ml)	*E. coli* Maximum Value (cfu/100ml)
0832	Lake Washington	44	0	38
0840	Lake Washington	44	0	74
0852	Lake Washington	44	0	13.5
0890	Lake Washington	44	0	8
C432	McAleer Creek	3	17	25
E434	Thornton Creek	3	1	100
K434	Maple Leaf Creek	3	4.5	24
M621	Lake Sammamish	43	0	14
SAMM_BRIDGE_116	Sammamish River	3	68	100
SAMM_BRIDGE_145	Sammamish River	3	40	78
SAMM_IRR_RETURN_145	Tributary to Sammamish River	3	2	25
SAMM_LITTLEBEAR_MOUTH	Sammamish River	3	77	110
SMT4.26	Sammamish River	1	48	48
SMT4.38	Sammamish River	1	37	37
SMT4.43	Sammamish River	1	74	74
SMT4.58	Sammamish River	1	52	52
X434	Thornton Creek	3	10	80

A number of locations may exceed ambient water quality criteria, but insufficient data (N<20) were available to quantitatively assess the risks of illness at these locations. The following locations (Table 14) were sampled for *E. coli* less than 20 times, but exceeded the standard of 126 cfu/100mL at least once. A minimum of 20 samples were considered necessary for Monte Carlo analysis because bacteria data rarely follow statistically normal distributions. The subsequent analysis steps required the data to be best fit to a distribution.

Table 14. Number of samples, minimum values, and maximum values for locations with maximum *E. coli* results greater than 126 cfu/100mL.

Locator	Waterbody	N	*E. coli* Minimum Value (cfu/100ml)	*E. coli* Maximum Value (cfu/100 ml)
0450B	SAMMAMISH RIVER	13	9	310
0450BB	SAMMAMISH RIVER	13	32	200
0450D	SAMMAMISH RIVER	12	23	340
A430	LYON CREEK	3	90	440
BB434	MAPLE LEAF CREEK	2	100	200
C430	LYON CREEK	4	23	15000
CC434	VICTORY CREEK	2	150	1600
D430	LYON CREEK	3	45	150
DD434	MAPLE LEAF CREEK	3	300	7300
E432	MCALEER CREEK	1	800	800
EE432	MCALEER CREEK	3	6	430
G434	THORNTON CREEK	3	150	230
HH434	MAPLE LEAF CREEK	5	460	1200
I434	MAPLE LEAF CREEK	3	530	2000
J434	THORNTON CREEK	4	50	6000
KK434	VICTORY CREEK	3	30	2000
LCW434	THORNTON CREEK	2	250	300
M434	MAPLE LEAF CREEK	5	80	470
PP434	MAPLE LEAF CREEK	4	160	7700
Q434	MAPLE LEAF CREEK	6	41	17000
R434	MAPLE LEAF CREEK	5	59	640
S434	THORNTON CREEK	3	20	230
S478	LITTLE BEAR CREEK	16	22	1500
SAMM_BEAR_MOUTH	BEAR CREEK	3	50	150
SAMM_BRIDGE_90	SAMMAMISH RIVER	3	70	170
SAMM_IRR_RETURN_124	Un-named Tributary (Sammamish River)	3	120	260
SAMM_WOODIN_MOUTH	SAMMAMISH RIVER	3	57	160
SMT3.21	SAMMAMISH RIVER	1	210	210
SMT3.40	SAMMAMISH RIVER	1	560	560
SMT3.66	SAMMAMISH RIVER	1	650	650
SMT3.86	SAMMAMISH RIVER	1	550	550
SMT4.01	SAMMAMISH RIVER	1	260	260
T434	THORNTON CREEK	5	15	367
V434	VICTORY CREEK	4	710	18000
W434	MAPLE LEAF CREEK	3	5	230
Y434	THORNTON CREEK	2	133.33	260
Z434	THORNTON CREEK	2	175	330

The locations with insufficient data for further quantitative analysis and those never exceeding the water quality standard (WQS) are presented in Figure 6.

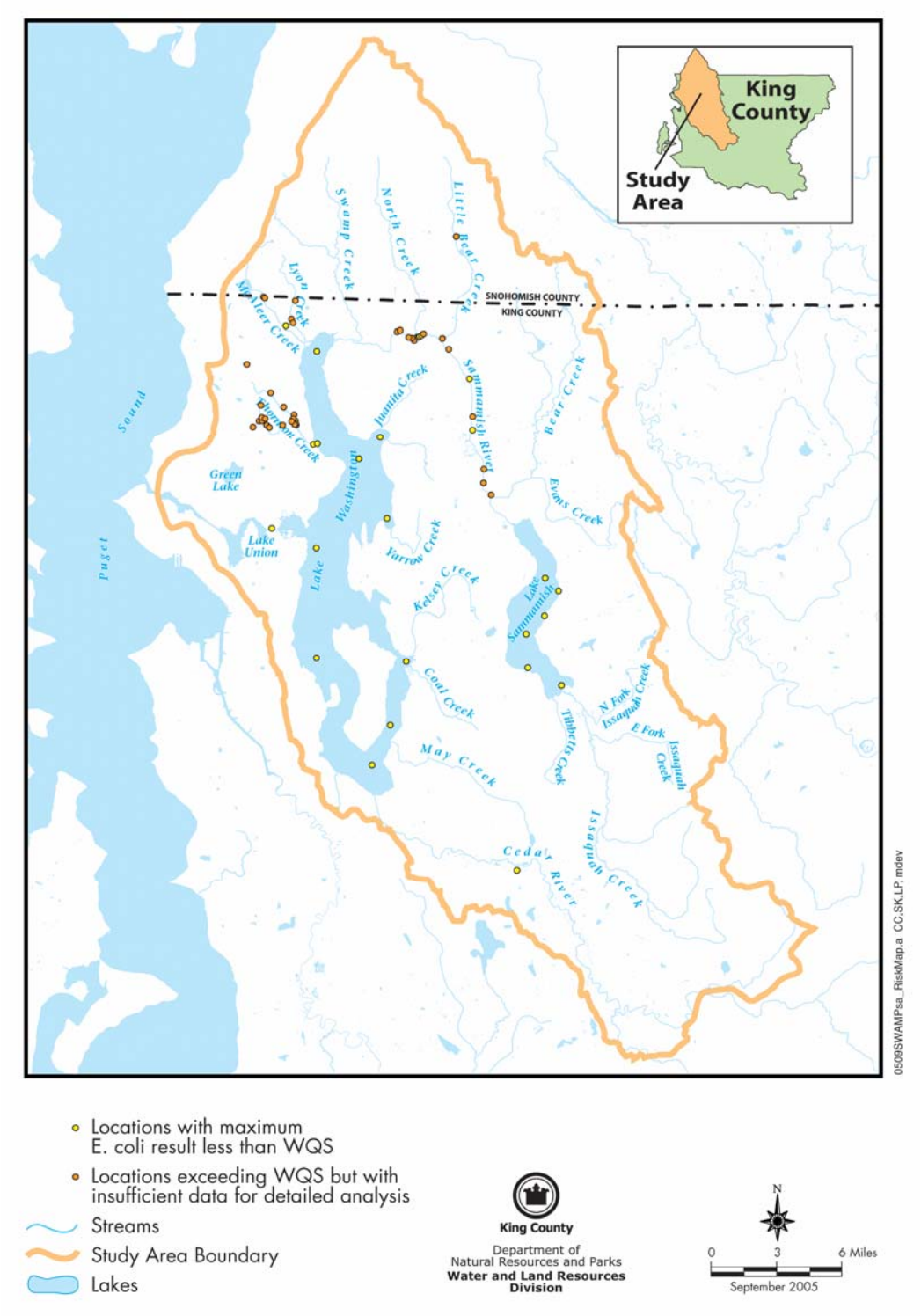

Figure 5. Sampling locations where *E. coli* levels do not exceed standards or where data is insufficient.

5.4.2 Bacteria Probabilistic Assessment Methods

The bacteria data were reduced to those locations with sufficient sampling effort to develop site-specific statistical distributions of *E. coli* concentrations. These distributions were then incorporated into the dose-response relationship for *E. coli* using Monte Carlo re-sampling techniques. The resulting distributions of illness rates were used to rank locations by the frequency of "excess" illness relative to USEPA (1986) guidelines.

5.4.2.1 Location specific assumptions

The remaining *E. coli* results were evaluated individually by locator. The bacteria concentrations were utilized to generate a probability distribution for each location. This assumes that all measurements were independent of one another. This assumption is not likely to always be met since King County's bacteria monitoring program uses previous results to guide future sampling.

King County monitors bacteria at swimming beaches throughout the summer on behalf of a number of municipalities. The DNRP is responsible for sample collection and analysis, while Seattle-King County Dept. of Public Health is responsible for beach closures. In general, sampling takes place on Tuesdays. This allows 24 hours to process the samples and report results. If the result elevates the geometric mean of the last 5 fecal coliform (not *E. coli*) samples over 200 cfu/100 mL or the individual sample exceeds 1,000 cfu/mL, the beach is re-sampled on the following Thursday. If this sample is lower, the beach remains open; if not, the beach is closed by Public Health in time for the influx of weekend users to be directed elsewhere.

The sampling strategy has theoretically populated the historical data with higher value results, since exceedances lead to re-sampling. However, bacteria counts are known to vary over short temporal and spatial scales. Thus, the degree to which statistical assumptions of independence were violated is unknown. The goal of answering the question, "what is the probability of getting sick from swimming" requires random sampling. Since the consequences of a biased sampling program designed to protect human health during weekends of high use are unclear, sample results may over or under-represent periods of higher contamination. Because the direction of possible sampling bias is unclear, this probabilistic analysis assumed samples were independent.

Monte Carlo analysis uses random re-sampling of a dataset to extrapolate a small data set to the larger, unknown population from which the samples were drawn. For this analysis, each location's results were compared to a variety of potential distributions using Decisioneering's Crystal Ball® software application. Each location's sample results were re-sampled 10,000 times to estimate the probability distribution characteristics of the location from which the samples were collected.

In many cases, a location's samples fit log-normal distributions although about 15% of the locations had other distribution types. Most other distribution types, the gamma and Weibull are similar in shape to the log-normal distribution. One location's data best fit a pareto distribution. The Anderson-Darling (A-D) test was used to fit data to distributions. Generally A-D values below 1.5 indicate a good fit. At two locations, A-D values exceeded 1.5, however these data

sets fit all known distributions poorly and the distribution with the lowest A-D value was selected as the "best-fit". Appendix D shows A-D values and other *E. coli* distribution specific data.

5.4.2.2 Monte-Carlo Analysis methods

Each location's distributions were then combined with the linear relationship between swimming associated gastrointestinal (GI) symptoms and mean *E. coli* density as given in Figure 4 of Dufour (1984). Swimming associated gastrointestinal symptoms such as nausea, diarrhea, and vomiting were more clearly associated with human fecal waste than "other" symptoms of illness such as fever or respiratory symptoms. The GI illness' algebraic formula is shown in equation 2 below.

$$I = 11.74 + 9.397 (\log B) \qquad (2)$$

Where:

I = illness rate per 1,000 swimmers
B = *E. coli*, CFU/100mL

The dose-response relationship in Dufour (1984) has confidence limits around it, although it is unclear what the limits represent (e.g. quartiles or 5%/95% limits). And thus, it is difficult to understand how those limits impact this analysis. However, RAGs(3A) (EPA, 2001), the guidance document for conducting probabilistic risk assessment for Superfund sites, explicitly states, "this guidance does not propose probabilistic approaches for dose-response in human health assessment and, further, *discourages undertaking such activities on a site-by-site basis.*" Because EPA discourages the incorporation of variability in dose-response relationships into probabilistic risk assessment, the uncertainty around Dufour's (1984) dose-response relationship between gastrointestinal illness and *E. coli* density has not been incorporated into this analysis. This probabilistic analysis uses the mean dose-response relationship shown in equation 2 with the sampling location-specific distribution of fecal coliform results to generate a probability of illness at each location.

The dose-response relationship in Dufour (1984) ends at approximately 17.75 CFUs/100mL. Below this concentration, theoretical negative illness rates are generated. To avoid this biologically implausible scenario, all *E. coli* concentrations generating negative illness rates were reported as zero illnesses.

This one-dimensional Monte-Carlo analysis generates a probability of illness per 1000 swimmers. These distributions were then ranked using the following methodology. Those locations where the 25th percentile of the distribution exceeded the maximum allowable illness rate of 8 per 1,000 swimmers (USEPA, 1986) were ranked highest. Those where the median concentration exceeded 8 per 1,000 swimmer illness were second. Locations where the 75th percentile exceeded 8 illnesses/1,000 swimmers were third, while those locations where the 75th percentile did not produce excess risk were ranked 4th. Lastly, locations where the 75th percentile yielded no illnesses at all, due to the nature of the dose response relationship, were ranked 5th. Note that due to the non-random nature of the sampling program, these distributions only loosely define the percentage of time a waterbody exceeds the water quality criteria and their relative risks.

6.0. TIER 2 RESULTS AND DISCUSSION

Results have initially been segregated by relative data quality. Then results by parameter and number of locations with excess risk have been presented by scenario. This section concludes with a presentation of the risks of illness at the bacteria sampling locations.

6.1 Higher vs. lower confidence data issues

Three exposure scenarios were included in this assessment, domestic water supply with backyard wading use, swimming, and wading alone. Within these scenarios, chemical data availability and statistical variability fluctuated widely. At some locations, higher confidence may be placed in the resulting risk estimates from robust exposure point concentration estimates. For instance, given equal exposures and toxicity values, higher confidence may be placed in results from locations with high frequencies of detection and many sampling events. Conversely, some locations had very little data, sometimes as few as one or two detections. Because this assessment used existing data that varied widely by location and parameter, risk results with higher and lower confidence have been differentiated. These distinctions are independent of the other sources of uncertainty in risk calculations, namely toxicological and exposure uncertainty. These latter two sources of uncertainty are discussed in Sections 6.0 and 7.0

The following section has distinguished results derived from higher confidence analytical data from those with lower confidence analytical data. Analytical results were defined as high or low confidence by a combination of professional judgment and the following general rules:

1. Chemicals for which a 95% UCL could be calculated were considered high confidence results (i.e. greater than 10 sampling results).

2. Location/parameter combinations with high FODs (>50%) were considered high confidence.

3. Lower confidence was placed in location/parameter combinations if few samples were collected (<10) or FODs were low (<50%), except when the results were consistent with other locations with large numbers of samples (>10) and high frequencies of detection.

4. Chemicals which were not frequently sampled and/or where laboratory blanks were contaminated were considered low confidence results.

From a practical perspective, these rules established a stark dichotomy between the higher confidence metals data and the lower confidence organic chemical data. There were 13 sampling stations with exceptions, mostly the less toxic low molecular weight PAHs detected in water. The purpose of this categorization is to clarify how analytical data precision and heterogeneity can influence exposure point concentrations, and thereby influence the discussion of risk - and the resulting management recommendations.

Analytical data quality is distinct from overall risk uncertainty, which is a composite of analytical data issues, exposure assumption variability, and toxicological uncertainty. The

sensitivity analysis attempts to understand some of these issues, while the uncertainty section discusses them in more depth.

6.2 Risk additivity and management thresholds

Risk is a relative term, as there are risks associated with the exposure/use of most everything in daily life and for carcinogens, there is some risk, no matter how small the dose. EPA has rejected the notion that a level of acceptable risk can be universally defined. Acceptable risks have been defined in agency decisions and through litigation, but not at a policy level. From a practical perspective, EPA has almost always regulated carcinogenic risks at hazardous waste sites greater than excess cancer risk of 1E-4 and almost never regulated excess cancer risks below 1E-6. These risk management thresholds have not been applied for drinking water purveyors, and many times EPA has set MCLs with much higher risks (e.g. arsenic and benzene MCLs).

In most EPA environmental/CERCLA risk assessments, "background" or non-site related risks are excluded. Chemical analysis and assessment occurs on site-related contaminants only and where naturally occurring metals are co-mingled with releases of extra metals, the "excess risk" is defined as that portion greater than background. However, for the purposes of this assessment and prioritization, "excess risk" is defined as a cancer probability exceeding 1E-6 *including background*. For non-carcinogens, excess risk is defined as a HQ greater or equal to 1.0 (also including background). Because of the thresholds exhibited by non-carcinogens, there is no concept of acceptable risk in non-carcinogenic risk management. Concentrations below an acceptable HQ of 1 pose no risk and concentrations above HQ of 1 are "significant" risks. As discussed in Tier 1, an HQ is the ratio of an exposure concentration to a "safe" concentration.

In this assessment, both the 1E-6 and the HQ of one threshold include both background and potentially human derived contaminants. Developing background risk levels was outside the scope of this document and the existing data used for this assessment were not adequate for this purpose. Thus, the risk levels presented here are not directly comparable with other assessments and should only be used as a relative metric.

Carcinogenic risks are presumed to be additive for all chemicals. Non-carcinogens are considered to be additive, typically based the target organ or mode-of-action. Target organs and/or mode of action were identified in IRIS for the non-carcinogens evaluated in Tier 2 as shown in Table 15.

Table 15. Target organs for Tier 2 non-carcinogens.

Chemical Name	Target organ/Mode of Action
2-Methylnaphthalene	Lung
4,4'-DDT	Liver
4,6-Dinitro-O-Cresol	Eye
Acenaphthalene	Liver
Acenaphthene	Liver
Aldrin	Liver
Anthracene	Other

Chemical Name	Target organ/Mode of Action
Antimony	Blood
Aroclor 1254	Blood
Arsenic	Skin
Atrazine	Heart
Barium	Kidney
Bis(2-Ethylhexyl)Phthalate	Liver
Cadmium	Kidney
Chromium	Other
Copper	Other
Disulfoton (Di-Syston)	Eye
Fluoranthene	Kidney
Fluorene	Blood
Hexachlorobenzene	Liver
Iron	Other
Manganese	CNS
Mercury	CNS
Methyl Mercury	CNS
Molybdenum	Kidney
Naphthalene	Body weight
Nitrate nitrogen (as NO3)	Methemoglobinemia
Nitrite nitrogen (as NO2)	Methemoglobinemia
Pentachlorophenol	Liver
Pyrene	Other
Selenium	Liver
Simazine	Liver
Thallium	Other
Vanadium	Hair
Zinc	Blood

"Other" is the information as reported in IRIS, no other information is available.
CNS = Central Nervous System

Readers should recognize that all of the risk values presented are "potential risks." Carcinogenic risks are expressed as a lifetime probability of getting cancer from a particular chemical or suite of chemicals. Non-cancer risks are expressed as an order of magnitude estimate of the adverse impacts associated with a chemical or chemicals acting on a target organ. Section 7.4 below discusses the uncertainty and probabilistic nature of both carcinogenic and non-carcinogenic risk estimates.

6.3 Risk Characterization

For review, the HHRA has evaluated 3 scenarios in Tier 2 with the following pathways.

1. Year-round use of surface waters as a domestic water supply with childhood play and adult contact in a backyard stream or lake (water and sediment);
    a. Ingestion of water and sediment, dermal contact with sediment

2. Year-round wading in near-shore lake waters or streams, with sediment contact;
    a. Ingestion of water and sediment, dermal contact with sediment
3. Summertime swimming in lakes without sediment contact.
    a. Ingestion of water

The following sections present the results for each of these scenarios by chemical group.

6.3.1 Domestic Water Supply with Backyard Wading Use Scenario

Because the domestic water supply with backyard wading use scenario has the most conservative exposure assumptions, the resulting risk estimates are also the highest. Based on the available data, these risk estimates present an upper-bound and are the maximum risks likely to occur. Because estimates of natural background metals concentrations such as barium, arsenic and vanadium were not available, the risks of anthropogenically derived and background levels of these constituents cannot be differentiated.

This presentation provides some perspective on the degree of treatment which would be needed to utilize Lake Washington or other water bodies as a commercial drinking water source. It also illustrates the increased risks to those, presumably few, residents using local waterbodies for drinking water purposes.

6.3.1.1 Metals

Eight different metals presented risks either greater than 1E-6 for cancer or with a non-carcinogenic endpoint HQ greater than 1. The number of locators where available data indicate a problem for use of water for domestic water supply with backyard wading use is shown in Table 16. Arsenic has been included with other metals, although this element is generally described as a metalloid. High confidence has been placed in the exposure point concentrations used to derive these risks because these elements are comparatively easy to measure with high analytical precision, generally have many sampling events throughout the 5-year existing data period, and have high FODs, often 100%.

Table 16. Number of locations with excess risks from metals in the domestic water supply with backyard wading use scenario.

Chemical Name	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Antimony	98	NA[a]	8	High
Arsenic	105	103	103	High
Barium	92	NA[a]	8	High
Cadmium	105	NA[a]	5	High
Iron	83	NA[a]	17	High
Manganese	43	NA[a]	4	High
Thallium	99	NA[a]	1	High
Vanadium	90	NA[a]	38	High

NA[a] = Not applicable this chemical is only considered non-carcinogenic

Table 16 illustrates that arsenic is the predominant metal risk driver for domestic water supply with backyard wading use receptors of study area aquatic resources. With numerous natural geologic sources, several historic smelters in Everett and Tacoma, and a relatively high IRIS cancer slope factor (toxicity), this outcome is not unexpected.

The arsenic cancer slope factor is based on inorganic arsenic, however only total arsenic concentrations are available for surface water and sediment. Since some percentage of the total arsenic is likely found as relatively non-toxic, organic arsenic, the arsenic risks are likely over-estimates. Other statewide surface water data suggest that approximately 80% of the total arsenic is inorganic (Johnson and Golding, 2002; Jack, 2003). While King County has not speciated arsenic in the past, because arsenic in water is found predominantly in the inorganic form, speciation of arsenic is not likely to revise the risk estimates substantially.

The other metals shown in Table 16 are also found in many geologic deposits (as well as anthropogenic sources) and further understanding of their natural background concentrations in surface waters and sediments is required before discussing their excess risk. Background concentrations of metals cannot, by definition, present excess risk above and beyond natural conditions. Because background data are limited and/or nonexistent, this issue will be elaborated on in the uncertainty section.

6.3.1.2 Polycyclic aromatic hydrocarbons

Nine individual PAHs had at least one location with excess risk in the domestic water supply with backyard wading use scenario (Table 17). The majority of these chemicals are by-products of combustion and are some of the most frequently found urban pollutants. The exposure point concentrations for these chemicals have a low level of certainty. This is due to infrequent sampling (generally 8 or 9 events per location) and low FOD; 10 to 20% is typical.

Table 17. Number of locations with excess risks from PAHs in the domestic water supply with backyard wading use scenario.

Chemical Name	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Benzo(a)anthracene	91	13	NA[b]	Low
Benzo(a)pyrene	91	22	NA[b]	Low
Benzo(b)fluoranthene	89	22	NA[b]	Low
Benzo(k)fluoranthene	89	14	NA[b]	Low
Chrysene	91	11	NA[b]	Low
Dibenzo(a,h)anthracene	91	4	NA[b]	Low
Indeno(1,2,3-cd)pyrene	91	5	NA[b]	Low
Pyrene	91	NA[a]	2	Low

NA[a] = Not applicable this chemical is only considered non-carcinogenic
NA[b] = Not applicable this chemical is only considered carcinogenic

Generally, King County analyzed PAHs by GC-MS in full scan mode, not selective ion mode (GC-MS/SIM), which is a more sensitive method that typically results in lower detection limits.

While sufficient data were collected at some locators to develop relatively robust 95% UCLs, even these data have 2 major limitations; which are discussed in more detail below.

First, these data were analyzed by GC-MS and many of the results were "J" flagged or only estimated concentrations. When a given sample was non-detect, one-half the detection limit was used as a surrogate. While the large volume injector used lowered the detection limits of the full-scan results relative to standard GC injectors, the MDLs remain generally high (0.0047 to 0.5 µg/L) relative to levels of human health concern. Detections of, for instance, benzo(a)pyrene were in the hundredths of a microgram per liter. Thus, despite having moderate FODs (e.g. 20% at a given locator), most exposure point concentrations were not lowered substantively by the use of ½ the MDL for non-detect values. This is because detection limits by full scan GC-MS often exceeded the detections by GC-MS/SIM one or more orders of magnitude.

For locations with fewer than 10 sampling events, UCLs were not calculated; per USEPA risk assessment guidance (USEPA, 1992). Thus, maximum detected concentrations were used to derive an exposure point concentration. These maxima may or may not represent lifetime average exposure point concentrations.

6.3.1.3 Pesticides

Four pesticides were detected in study area water or sediments at levels with greater than 1E-6 cancer risk or HQs greater than 1 for non-carcinogens. Three of these pesticides are legacy pollutants which are no longer sold or used in the United States. DDT, DDD, and DDE are highly persistent, chlorinated pesticides (or degradates), which accumulate in both sediment and fish tissue. However, in this case these compounds were detected in water during high flow events. While all of these results were estimated ("J" flagged), they appear to be detected with some regularity at specific locations. Except for one location with more than 10 pentachlorophenol sampling events and a FOD greater than 50%, the exposure point concentrations used to derive these risks have low confidence. This is due to their infrequent sampling (generally 8 or 9 times per location) and low FODs; 10 to 20% is typical.

Table 18. Number of locations with excess risks from pesticides in the domestic water supply with backyard wading use scenario.

Chemical Name	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Pentachlorophenol	97	17	17	Low, except for two locations with adequate data
4,4'-DDT	98	2	2	Low
4,4'-DDE	98	2	NA[a]	Low
4,4'-DDD	98	2	NA[a]	Low

NA[a] = Not applicable this chemical is only considered carcinogenic

Pentachlorophenol was historically one of the most widely used pesticides in the United States. It was used as both an insecticide and a herbicide (ATSDR, 2001). Current use is restricted to use as a wood preservative in utility poles, railroad ties, and wharf pilings (ATSDR, 2001). The

detections of pentachlorophenol were predominantly in water where it was detected at 17 locations at concentrations high enough to lead to excess risk. There is no apparent pattern to the pesticide excess risk locations which include Lake Union, Swamp Creek, North Creek, Mercer Slough, and Thornton Creek and the Sammamish River.

6.3.1.4 Other organics

Only three additional organic compounds from the Tier 2 COPC list (Table 7) pose a risk in the domestic water supply with backyard wading use scenario. The most common, bis(2-ethylhexyl)phthalate is a ubiquitous laboratory contaminant, as it is used as a plasticizer in many products. This is the reason for the small number of locations with at least one valid sample (50 locations) relative to the other semi-volatile organics (89 to 98 locations). While blank qualified data were removed from the database prior to Tier 2 analysis, the likelihood that some of the bis(2-ethylhexyl)phthalate is derived from sampling and/or laboratory contamination is high.

Total PCBs were never detected in water, although the sampling and analytical methods and detection limits are generally inadequate for evaluating human health via water exposure. PCBs were detected at several shallow sediment locations. Most sediment deposition areas are deeper than the wadeable areas where people can be readily exposed to sediment. As a consequence, the exposure point concentrations used to derive these risk estimates all have low confidence. This is due to their infrequent sampling (generally 8 or 9 times per location) and low FOD; 10% is typical. Because PCBs are highly bioaccumulative, the preponderance of human exposure occurs through food, e.g. fish consumption. Therefore, the use of refined methods to calculate PCB concentrations in water would be unlikely to revise their risks substantively.

Table 19. Number of locations with excess risks from other organics in the domestic water supply with backyard wading use scenario.

Chemical Name	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Bis(2-Ethylhexyl)Phthalate	50	39	39	Low
Hexachlorobenzene	94	1	1	Low
N-Nitrosodimethylamine	87	1	NA[a]	Low
Total PCBs	29	5	NA[a]	Low

NA[a] = Not applicable this chemical is only considered carcinogenic

PCBs are a contaminant of concern in fish tissue and the DOH human health advisory discusses the risks of PCBs in tissue further (DOH, 2004c). Contaminated sediment is likely a prominent bioaccumulation pathway into fish tissue.

Hexachlorobenzene was widely used as pesticide up until the 1960s (ATSDR, 2002) and its presence in Juanita Creek is possibly related to the DDT, DDD, and DDE detections in other reaches in this watershed. Its prevalence here is unknown since the sole detection was at a unique location near the mouth which was only sampled once. Its risk of 3.5E-5 is only slightly elevated above USEPA target level of 1E-6.

N-Nitrosodimethylamine (NDMA) was detected once in Lake Sammamish although this chemical, "…is produced in the U.S. only for use as a research chemical. NDMA was used to

make rocket fuel" (ATSDR, 1989). NDMA is unintentionally formed during various manufacturing processes and in air, water and soil by reaction with other chemicals called alkylamines. Alkylamines are both natural and man-made compounds which are found widely distributed throughout the environment (ATSDR, 1989). NDMA may form directly in sewage as a result of the biological and chemical transformation of alkylamines in the presence of nitrate or nitrite (Ayanaba & Alexander, 1974; ATSDR, 1989). It may also be released into the environment as the result of application of sewage sludge to soils rich in nitrate or nitrite.

NDMA may also be formed during the treatment of drinking water (OME, 1994). Water treatment plants incorporating a chlorination process (e.g., sodium hypochlorite) will produce NDMA from these nitrate or nitrite precursors (Jobb et al., 1993; Graham et al., 1996). NDMA may be released into the environment as a result of use of certain pesticides contaminated with this compound (Pancholy, 1978). NDMA is present in various technical and commercial pesticides used in agriculture, hospitals, and homes as the result of its formation during the manufacturing process and during storage. The following DMA formulation pesticides may contain NDMA as a microcontaminant: bromacil, benazolin, 2,4-D, dicamba, MCPA, and mecoprop (as cited in WHO, 2002). These pesticides have been detected in King County streams, although not at levels sufficient to pose a significant human health risk themselves.

Despite the varied processes by which NDMA may be formed, its FOD was very low, 1 of 770 samples or about 0.001% (Appendix B).

6.3.2 Wading Scenario

The wading scenario has transitional exposure assumptions: (1) the ingestion rates for water are similar to those in the Swimming scenario; and (2) incidental sediment ingestion is included similar to the backyard wading pathway. Therefore, the resulting risk estimates are typically lower than the domestic water supply with backyard wading but higher than the swimming scenario. As with the domestic water supply with backyard wading use scenario, these risk estimates present an upper-bound and are the maximum risks likely to occur.

6.3.2.1 Metals

Only two metals presented risks either greater the 1E-6 for cancer or with a non-carcinogenic endpoint hazard index greater than 1. The number of locators posing an excess risk to people wading is shown in Table 20.

Table 20. Number of locations with excess risks from metals in the wading scenario.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Arsenic	79	77	77	High
Thallium	78	NA[a]	1	High

NA[a] = Not applicable this chemical is only considered non-carcinogenic

Table 20 illustrates that, as with the domestic water supply with backyard wading use scenario, arsenic is the predominant metal risk driver for the Wading scenario. With numerous natural

geologic sources, several historic smelters in Everett and Tacoma, and a relatively high IRIS cancer slope factor (toxicity), this outcome is not unexpected. As discussed above, the lack of speciated arsenic data, particularly for water, has probably biased these results high by a small amount (estimated at 10-30%).

6.3.2.2 Polycyclic aromatic hydrocarbons

Seven different PAHs had at least one location with excess cancer risk greater than 1E-6 under the wading scenario. The majority of these chemicals are by-products of combustion and are some of the most frequently found urban pollutants (Table 21). The exposure point concentrations for these chemicals have a low level of certainty, due to their low FODs.

Table 21. Number of locations with excess risks from PAHs in the Wading scenario.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Benzo(a)anthracene	73	13	NA[a]	Low
Benzo(a)pyrene	73	21	NA[a]	Low
Benzo(b)fluoranthene	71	20	NA[a]	Low
Benzo(k)fluoranthene	71	12	NA[a]	Low
Chrysene	73	10	NA[a]	Low
Dibenzo(a,h)anthracene	73	3	NA[a]	Low
Indeno(1,2,3-cd)pyrene	73	3	NA[a]	Low

NA[a] = Not applicable this chemical is only considered carcinogenic

As discussed above, King County has not analyzed PAHs by the most sensitive methods with the lowest detection limits. While sufficient sample numbers were collected at many locators to develop relatively robust upper confidence limits of arithmetic means, these data have 2 major limitations; high detection limits for GC-MS full scan results and use of one-half the MDL which are discussed under the domestic water supply scenario above (Section 5.3.1.2).

6.3.2.3 Pesticides

Four pesticides were detected in study area waters or sediments at levels yielding greater than the 1E-6 cancer risk or HQs greater than 1 for non-carcinogens (Table 22). Except for one location with more than 10 pentachlorophenol sampling events and FODs greater than 50%, the exposure point concentrations used to derive these risks have low confidence.

Table 22. Number of locations with excess risks from pesticides in the wading scenario.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
4,4'-DDD	80	2	NA[a]	Low
4,4'-DDE	80	2	NA[a]	Low
4,4'-DDT	80	2	2	Low
Pentachlorophenol	79	17	17	Low, except for two locations with adequate data

NA[a] = Not applicable this chemical is only considered carcinogenic

6.3.2.4 Other organics

Only three additional organic compounds (Table 23) from the original Tier 2 COPC list (Table 7) pose a risk based on the wading scenario. The most common, bis(2-ethylhexyl)phthalate, is a common laboratory contaminant, and the issues discussed under the domestic water supply scenario also apply to these data when used in the wading and swimming scenarios.

Table 23. Number of locations with excess risks from other organics in the wading scenario.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Bis(2-Ethylhexyl)Phthalate	38	27	27	Low
Hexachlorobenzene	76	1	1	Low
Total PCB	29	5	NA[a]	Low

NA[a] = Not applicable this chemical is only considered carcinogenic

6.3.3 Swimming

The swimming scenario has the lowest overall exposures. The ingestion rates for water are similar to those in the wading scenario; however, incidental sediment ingestion was not included in this exposure scenario. Thus, the resulting risk estimates are relatively low compared to the other scenarios. As with the other scenarios, these risk estimates present an upper-bound and are the maximum risks likely to occur.

6.3.3.1 Metals

Only two metals presented risks either greater than 1E-6 cancer risk or a non-carcinogenic endpoint hazard index greater than 1. The number of locators posing a these risks based on the swimming scenario is shown in Table 24.

Table 24. Number of locations with excess risks from metals in the Swimming scenario.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 cancer HQ	Relative data confidence
Arsenic	42	42	42	High
Manganese	13	NA[a]	2	High

NA[a] = Not applicable this chemical is only considered non-carcinogenic

Table 24 illustrates that, as with the domestic water supply with backyard wading use and wading scenarios, arsenic is the predominant metal risk driver for swimming receptors using study area aquatic resources. With numerous natural geologic sources, several historic smelters in Everett and Tacoma, and a relatively high IRIS cancer slope factor (toxicity), this outcome is not unexpected. As discussed above, King County has not speciated arsenic in the past. However because arsenic is found predominantly in the inorganic form, speciation of arsenic is not likely to revise the risk estimates substantially. The domestic water supply with backyard wading use discussion elaborates on this issue and its expected magnitude.

6.3.3.2 Polycyclic aromatic hydrocarbons

Seven different PAHs had at least one location with excess cancer risk of 1 E-6 under the swimming scenario. The majority of these chemicals are by-products of combustion and they are frequently found in urban areas, although these risk estimates have a low level of certainty due to generally low FODs (10 to 20%).

Table 25. Number of locations with excess risks from PAHs in the swimming scenario.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of non-cancer HQ	Relative data confidence
Benzo(a)pyrene	34	1	NA[a]	Low
Benzo(b)fluoranthene	34	2	NA[a]	Low
Benzo(k)fluoranthene	34	1	NA[a]	Low
Chrysene	34	1	NA[a]	Low
Indeno(1,2,3-cd)pyrene	34	1	NA[a]	Low

NA[a] = Not applicable this chemical is only considered carcinogenic

Generally, King County has not analyzed PAHs by the most sensitive methods with the lowest detection limits. While sufficient sample numbers were collected at many locators to develop relatively robust upper confidence limits of arithmetic means, for locations with fewer than 10 sampling events, UCLs were not calculated; per USEPA risk assessment guidance. Thus, maximum detected concentrations were used to derive an exposure point concentration. These maxima are assumed to very conservatively represent lifetime average exposure point concentrations.

6.3.3.3 Pesticides

Only one pesticide was detected in surface waters at levels yielding greater the 1E-6 cancer risk or HQs greater than 1 for non-carcinogens. Pentachlorophenol was sampled at 34 locations and

only two locations had risks greater the 1E-6 via the Swimming scenario. Despite the 28 and 34 sampling events at the two locations, the pentachlorophenol FODs are very low. The maximum pentachlorophenol FOD was 3.6%, thus the exposure point concentration confidence is low.

6.3.3.4 Other organics

Only two additional organic compounds from the original Tier 2 COPC list (Table 7) pose a risk in the swimming scenario. The most common, bis(2-ethylhexyl)phthalate, is a common laboratory contaminant, as it is used as a plasticizer in many products. While blank qualified data were removed from the database prior to Tier 2 analysis, the likelihood that some of the bis(2-ethylhexyl)phthalate is derived from sampling and/or laboratory contamination is high.

Table 26. Number of locations presenting excess swimming risks for other organics.

Parameter	Number of locations in scenario sampled	Number of locations >1E-6 cancer risk	Number of locations >1 non-cancer HQ	Relative data confidence
Bis(2-Ethylhexyl)Phthalate	22	22	22	Low
N-Nitrosodimethylamine	33	1	NA[a]	Low

NA[a] = Not applicable this chemical is only considered carcinogenic

The exposure point concentrations used to derive these risk estimates all have low confidence. This is due to the limited sampling frequency (generally 8 or 9 times per location) and low FODs; 10% is typical.

6.4 Cumulative risks

RAGS(a) (USEPA, 1989), describes the protocols used to determine total risk. For carcinogens, individual chemical's cancer risks are added together. For non-carcinogens, the summation process occurs by target organ. A primary target organ for each COC was identified using IRIS (Table 15). Then, individual HQs for each chemical were summed based on common target organs; this summed value is referred to as a hazard index (HI). This assumes that two (or more) compounds acting on the same organ (e.g. the liver) act by the same mode of action and produce additive effects. RAGS(a) (1989) established this conservative approach to describing the total risk at a location or spatial area and this assessment has adopted this approach for individual locations. In reality, people are exposed to chemicals throughout their lives and in many areas. However spatial averaging was unnecessary to achieve this study's limited objectives (Section 2.1.1.)

The cumulative risk at each location is derived from a mixture of chemicals, some with higher exposure point confidence and some with lower confidence. For the cancer endpoint, the relative contribution of high and low confidence data has been shown. For the non-cancer endpoints, the presentation is less straightforward. Because non-carcinogens act on target organs, each target organ has a HI formed from the mixture of chemicals found at each location. Thus, in many cases each location has a different HI for different target organs and these HIs are formed from chemicals with varying confidence in their exposure point concentrations. Appendix E, Table 5 provides the detailed breakdown of the confidence level associated with the results by locator. For discussion purposes below, some of the confidence details have been omitted.

6.4.1 Domestic Water Supply with Backyard Wading Use Scenario

For the domestic water supply and backyard wading use scenario, Appendix E lists the total carcinogenic risks at each location when the sum of risks exceeded 1E-6, and lists the maximum non-carcinogenic target organ specific HI found at each location where the total non-cancer HI exceeded 1.0. The overall purpose of this discussion is to illustrate the variety of risk drivers and the general range of risks. Thus, 4 representative urban streams and the major lakes are the focus of the discussion below.

6.4.1.1 Risk Maps and Spatial Descriptions

Streams

Four sub-basins, Thornton, Taylor, Lyon, and Juanita Creeks are discussed further below. These sub-basins are densely populated areas with higher than median aggregate risks and are also distributed around the study area. For this exposure scenario, the median cancer probability for all locations was 7.3E-4. The median non-cancer HI across all target organs was 1.7. In addition to having higher than median risks these sub-basins were chosen for more detailed discussion because of their high population density, the higher quantity of data available in them than in other sub-basins, and the fact that they are distributed across the study area. Figure 6 is presented to orient the reader to the four sub-basins. Figure 7 shows the spatial distribution of the excess risks, i.e. that greater than 1E-6 or an HI greater than 1.0.

Location 0434, in Thornton Creek, has 4 principle carcinogenic risk drivers, which contribute the most to the excess risk shown on Figures 8 and 9 and listed in Appendix E, Table 5. Benzo(a)pyrene provides the most risk, 2.6E-1, while benzo(b)fluoranthene, benzo(k)fluoranthene, and pentachlorophenol in aggregate contribute a 1.27E-1 probability of cancer. For non-carcinogenic chemicals, bis(2-ethylhexyl)phthalate has the highest HQ of 11, and pentachlorophenol has an HQ of 5.5. These chemicals were generally detected infrequently with 11 to 22% FODs. Bis(2-ethylhexyl)phthalate was an exception with an FOD of 100%. As discussed earlier, some fraction of the bis(2-ethylhexyl)phthalate concentrations is likely due to field and/or laboratory contamination. Sediment was not analyzed at this station, thus water has contributed all of these risks in this scenario.

Hazard indices were calculated by target organ and the maximum HI value for each station has been shown in Figure 9. These HIs are the sum of the HQs by target organ and the map illustrates the range and general magnitude of the maximum non-cancer risks posed at each location. The calculation of HIs was necessary to accomplish this illustration. Other than providing the locations of the least and greatest non-cancer risks, HIs by target organ do not otherwise support the objectives of this HHRA to identify prominent chemicals and pathways of concern.

Figure 9 illustrates that the highest levels of non-cancer risk were found throughout the watershed, although they are concentrated around Lakes Union and Washington. Interspersed with the lower HIs are a variety of very low HIs just above the threshold of 1.0. This range is

probably indicative of varied analyte lists and sampling efforts in combination with non-constant chemical concentrations.

Because impervious area is implicated as a major contributor of pollutants to urban and suburban streams (USEPA, 2005b), and PAHs appear to be risk drivers in Thornton Creek and other sub-basins, cumulative PAH risk was correlated with effective impervious area. While the cumulative PAH risk was positively correlated with effective impervious area (Appendix F), the relationship was too weak to provide useful predictive power.

Figure 6 **Overview of Thornton, Lyon, Taylor, and Juanita Creeks, Subbasins Discussed in Text**

SWAMP Risk Assessment

Note:
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Data Sources:
King County Datasets,
2000 US Census, Appendix D

Produced by:
DNRP GIS and WLRD Visual Communications Unit

File:
0610Swamp_FOCUS.ai LPRE, wgab

Cancer Probability

- 1E-6 to 1E-5 - Lowest Probability
- 1E-5 to 1E-4
- 1E-4 to 1E-3
- 1E-3 to 1E-2
- 1E-2 to 1E-1
- 1E-1 to 0.99 - Highest Probability

E. coli Illness Rank

- 1 - Highest E. coli Illness Rank
- 2
- 3
- 4
- 5 - Lowest E. coli Illness Rank

Maximum Non-Cancer Hazard Quotient

- 1.1 - 3.0 - Lowest Risk
- 3.1 - 5.0
- 5.1 - 15.0
- 15.1 - 100.0
- 100.1 - 300.0 - Highest Risk

Population Density (per sq. mile)

- 2 - 1389
- 1389 - 3316
- 3316 - 5056
- 5056 - 6592
- 6592 - 9169
- 9169 - 87809

- Study Area Boundary
- Streams
- County Boundary
- Lakes
- Parks
- Swimming Beaches

Note:
Please note that symbols representing illness risk locations have been offset slightly in areas of overlap for greater map clarity.

Figure 7 **Common Cancer and Non-Cancer Risk Characterization Legend for Figures 8, 9, 10, 11, and 14**
SWAMP Risk Assessment

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File: 0712swampLEGEND.ai wgab

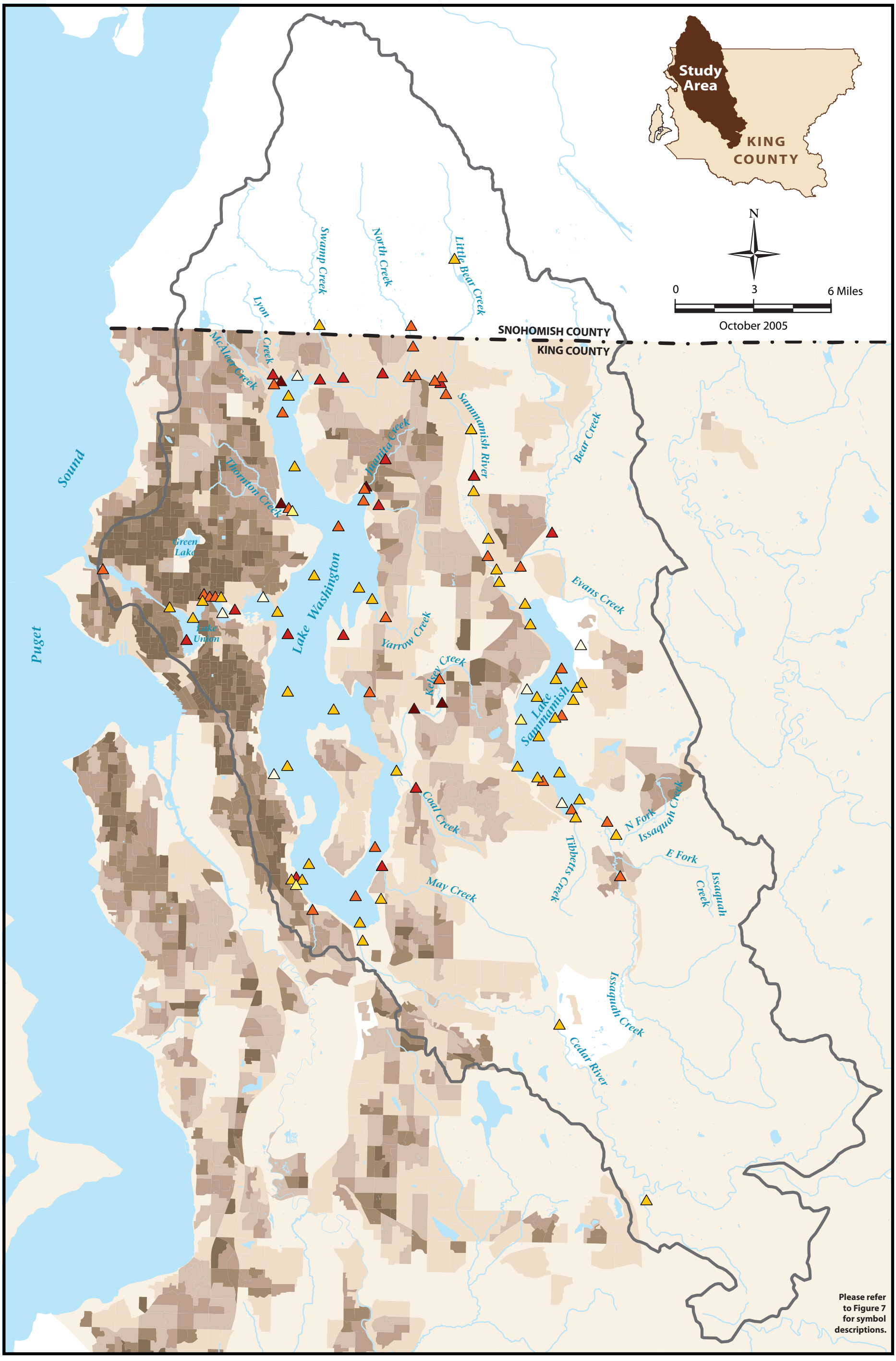

Figure 8 **Water Supply with Backyard Waterbody Use Cumulative Cancer Risks with Year 2000 Population Density**

SWAMP Risk Assessment

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Data Sources:
King County Datasets,
2000 US Census, Appendix D

Produced by:
DNRP GIS and WLRD Visual Communications Unit

File:
0712Swamp_REScan.ai LPRE, wgab

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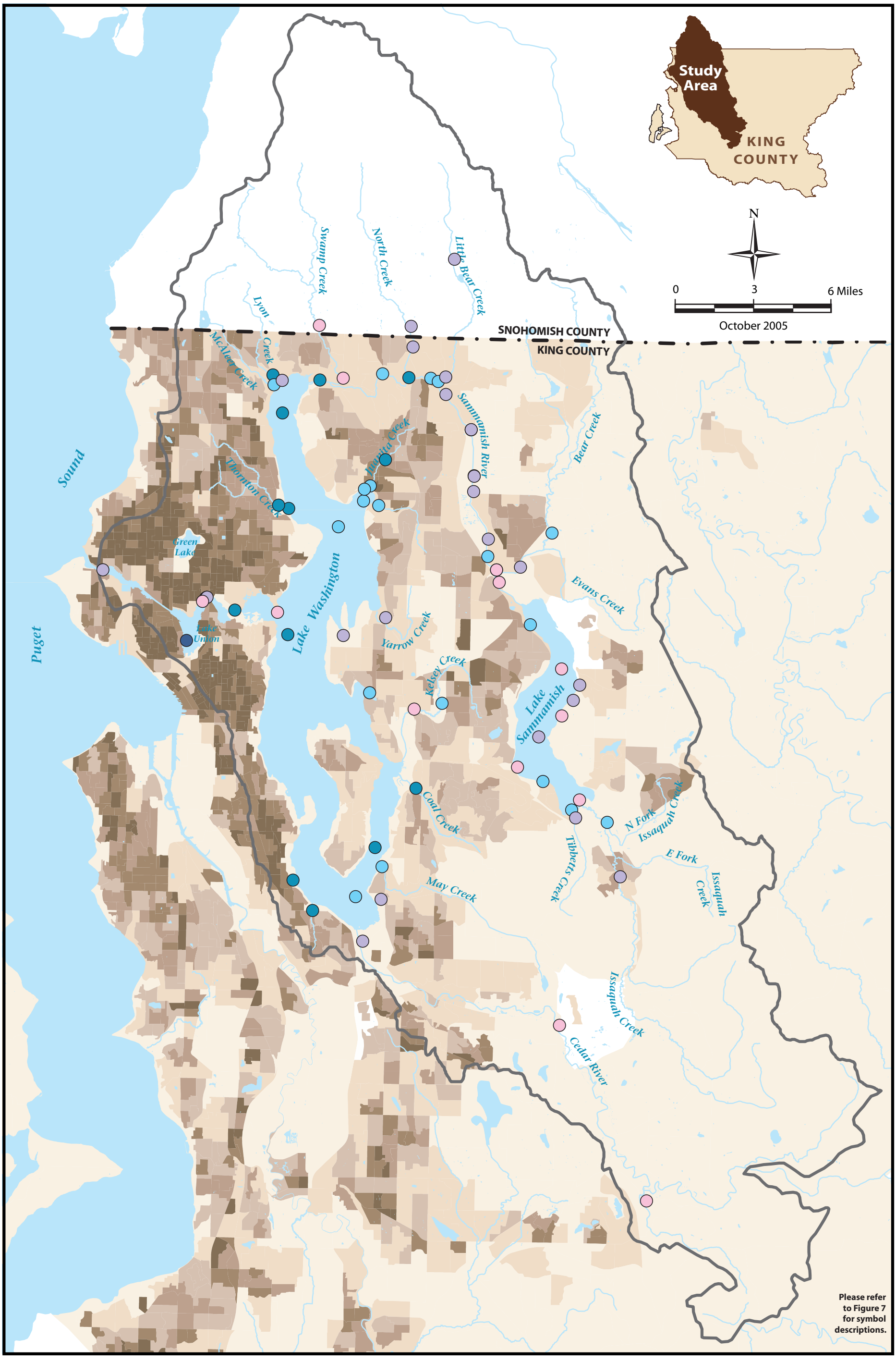

Figure 9 **Domestic Water Supply with Backyard Wading Use Non-Cancer Risks with Year 2000 Population Density**

SWAMP Risk Assessment

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Data Sources:
King County Datasets,
2000 US Census, Appendix D

Produced by:
DNRP GIS and WLRD Visual Communications Unit

File:
0712Swamp_RESnoncan.ai LPRE, wgab

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Taylor Creek, which drains to southwestern Lake Washington, has a large excess risk relative to some other sampling locations. Arsenic and pentachlorophenol are the only carcinogenic chemicals found at this location with cancer risk. Antimony, arsenic, barium, cadmium, pentachlorophenol, and vanadium all contribute to excess non-carcinogenic risks. Vanadium poses the highest non-carcinogenic risk with an HQ of 25.8. The target organ for vanadium is hair cystine levels. The implications for this impact are unknown. Other target organs with excess non-carcinogenic risk at this location include the liver and skin. The principle source of vanadium is through combustion of fuels oils (ASTDR, 1992). The widespread prevalence of vanadium, along with the prevalence of PAHs in the watershed suggests that they may be related. However, the current dataset cannot elucidate this relationship. Vanadium and PAHs were rarely sampled at the same places on the same days, and only three detections were common to both.

Lyon Creek, in the City of Lake Forest Park, has a similar suite of metals and sporadic detections of DDT, DDE, and DDD. Arsenic, pentachlorophenol and DDT are the greatest source of carcinogenic risk at this location, while DDT and vanadium present the greatest excess non-cancer hazard. While DDT, DDE, DDD, and pentachlorophenol are all chlorinated pesticide compounds, DDT and its breakdown products DDE and DDD have been banned from use in the US since 1972. More than 675,000 tons were applied across the US in the post-World War II period (USEPA, 1975). DDT concentrations in Lyon Creek were estimated ("J" flagged) at 0.041 µg/L. For DDE and DDD, estimated detections were found for these two chemicals. Under the established data manipulation rules, for locations with less than 10 samples, the larger of ½ the MDL or the detected values were used. For Lyon Creek, a MDL concentration of 0.008 µg/L was therefore used to generate the risk estimates for DDE and DDD, while the actual, single detected concentrations were both 0.0021 µg/L. Pentachlorophenol was commonly detected; its FOD was 73% in 11 samples. The 95% UCL of the mean for these data is 0.104 µg/L.

Juanita Creek has two sampling locations, 0446 and C446. The dataset for these two locations comprises 13 different water samples and 1 sediment sample. Carcinogenic risk drivers at location 0446 were benzo(a)pyrene, benzo(b)fluoranthene. Non-carcinogenic risk drivers were arsenic, iron, vanadium, and bis(2-ethylhexyl)phthalate. While the FODs for risk driver chemicals were 100% in sediment (N=1) they were 11 to 100% in water (N=13), only the water concentrations contributed to the excess risk at this location. For location C446, only water was analyzed and PAHs were not included in this analysis. Thus, the principal risk drivers at this location are metals, DDT, DDE, and DDD. DDT has the greatest potential risk, with a cancer probability of 9.4E-3 and a non-cancer HQ of 55.

These data suggest that risks at the Thornton Creek location are dominated by combustion by-products and phthalates, while other urban creeks may have chlorinated pesticides and metals such as arsenic and vanadium as significant risk drivers. Locations may potentially have a variety of toxicants adversely affecting human health and impervious area is a weak predictor of risk.

Major Lakes

Arsenic has high FODs in Lake Sammamish; arsenic data for water are much more robust (N=23 to 46) than for shallow sediment (N=1 to 3). Arsenic is the principal risk driver in Lake Sammamish with cancer probabilities up to 4.3E-4. However, of the three major lakes in the study area, Lake Sammamish generally exhibits the lowest risks to human health.

Lake Washington has some locations with high domestic water supply with backyard wading use risks and other locations with much lower risks under this scenario. Locations 0805A and 4903 (including 4903A, 4903B, and 4903C) are Lake Washington locations with high carcinogenic risks from bis(2-ethylhexyl)phthalates8 and 9. Minor risk contributors are arsenic and PAHs. Bis(2-ethylhexyl)phthalate was detected once during a single sampling event at both of these locations and risks thereof are 5.9E-3 and 1.3E-2 respectively. Site 0805A is near the north end of Lake Washington while 4903 is near Atlantic City Park. It is unknown if residents are withdrawing water at these locations and the data are very sparse. Nevertheless, they do illustrate the need for additional study of organic chemical concentrations and more refined exposure estimates, to better understand the need for risk management actions in these locations.

Water at location 0852 (Lake Washington) near Madison Park and the SR-520 bridge is periodically heavily contaminated, as shown by high PAH risks with low FODs (3.8% to 7.7%). Risks from benzo(a)pyrene and indeno(1,2,3-cd)pyrene are relatively elevated at 3.2E-2 and 1.2E-2 respectively. These values exceed management thresholds defining excess carcinogenic (1E-6) risk by four orders of magnitude.

Location 0840 is in Lake Washington near the southeast shore of Mercer Island. Cancer probabilities from arsenic are 2.1E-4 and 5.1E-3 from bis(2-ethylhexyl)phthalate. The arsenic data are relatively robust and higher confidence may be placed in them. Twenty-one samples were successfully analyzed with an FOD of 100%. As shown with other locations where the domestic water supply with backyard wading use scenario was evaluated, the arsenic data tends to be the most robust with the number of samples frequently exceeding 40, followed by a sparser dataset of PAHs with 8 to 11 samples. The least confidence is placed in the bis(2-ethylhexyl)phthalate data where frequently only one, non-blank qualified sample has driven significant risk.

6.4.2 Wading

The same addition process to evaluate cumulative risk discussed at the beginning of this section applies to the wading scenario. The spatial orientation of the cumulative risks is discussed below. The wading scenario included stream locations and lake locations shoreward of the 15 foot depth contour.

6.4.2.1 Risk Maps and Spatial Descriptions

As with the domestic water supply and backyard wading use scenario, four sub-basins, Thornton, Taylor, Lyon and Juanita Creeks are discussed further below. These sub-basins represent densely populated areas with higher than median aggregate risks. The shorelines of lakes follow. Figure 6 can be used to orient the reader to the streams discussed, while Figure 8 shows the

spatial distribution of excess risk, that greater than 1E-6 or a HI for a target organ greater than 1.0.

Location 0434 in Thornton Creek has 2 principle carcinogenic risk drivers that contribute the most to the excess cancer risk of 5.9E-3 (Figure 9 and Appendix E). As with the domestic water supply with backyard wading use scenario, benzo(a)pyrene is estimated to have the highest risk (3.8E-3) for the wading scenario, while benzo(b)fluoranthene contributes 1.3E-3 probability of cancer. For non-carcinogenic chemicals, bis(2-ethylhexyl)phthalate has the highest HQ of 0.16 suggesting little non-carcinogenic hazard in the wading scenario. As discussed earlier, some fraction of these detected concentrations is likely due to field and/or laboratory contamination. Sediment was not sampled at this station, thus water exposures have contributed all of these risks in this scenario.

Taylor Creek, in southwestern Lake Washington, has a large excess risk relative to some other sampling locations. Arsenic and pentachlorophenol are the only carcinogenic chemicals found at this location with excess risk. Both were frequently detected (FOD=100%), but sample sizes were small, 2 and 4 respectively. These chemicals present a sum cancer probability of 1.1E-4. For non-carcinogenic endpoints, no chemicals present a hazard at this location via the wading scenario.

Lyon Creek in the City of Lake Forest Park has a similar suite of metals and sporadic detections of DDT, DDE, and DDD. Arsenic, pentachlorophenol, and DDT are the greatest source of carcinogenic risk at this location, while no chemical presents an excess non-cancer hazard. Pentachlorophenol was commonly detected, with a FOD of 73% (N=11). The 95% UCL for these data is 0.104 µg/L. The sum cancer risk associated with the wading scenario at this location is low relative to the domestic water supply with backyard wading use scenario; total probability of these risk drivers is 1.9E-4.

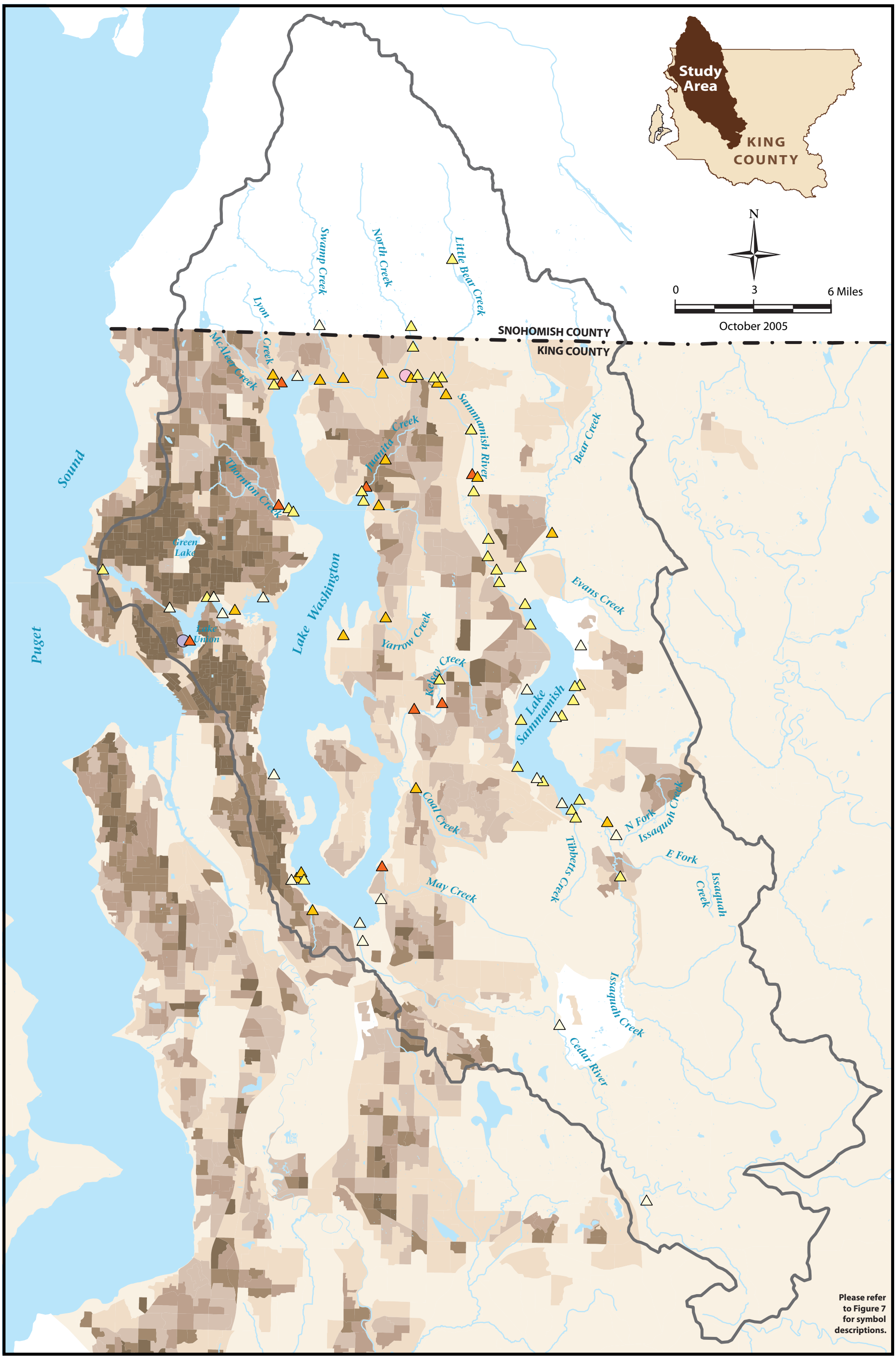

Figure 10 **Cumulative Wading Cancer and Maximum Non-Cancer Risks with Year 2000 Population Density**

SWAMP Risk Assessment

Note:
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Data Sources:
King County Datasets,
2000 US Census, Appendix D

Produced by:
DNRP GIS and WLRD Visual Communications Unit

File:
0712Swamp_WADE.ai LPRE, wgab

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Juanita Creek has two sampling locations, 0446 and C446. These two locations have different risk drivers. The principle risk at location 0446, near the mouth, is via benzo(a)pyrene and benzo(b)fluoranthene. The FODs for these chemicals were only 11% in water (N=9), and only the water concentrations contributed to their excess risks since no sediment data were available for these compounds. For C446, which is located at approximately stream mile 1.2, only waters were analyzed and PAHs were not included in this analysis. Thus, the principal risk drivers at this location are metals, DDT, DDE, and DDD. DDT has the greatest potential risk, with a cancer probability of 9.4E-3 and a non-cancer HQ of 55.

The data discussed above suggest that Thornton Creek risks are dominated by combustion by-products and phthalates, and other urban creeks may have chlorinated pesticides and metals such as arsenic and vanadium as significant risk drivers. Locations may potentially have a variety of toxicants adversely affecting human health via the wading scenario and aggregate risks from carcinogens and maximum non-carcinogenic hazards are much smaller than reported via the domestic water supply with backyard wading use scenario.

Of the three major lakes in the study area, Lake Sammamish generally has the lowest risks to human health via the wading scenario, paralleling the domestic water supply with backyard wading use scenario spatial pattern. The highest cancer risk in Lake Sammamish of 5.5E-5 is due to benzo(a)pyrene at location 0618 in sediment. Of the 27 water samples collected at this location, there was a 0% FOD and a 100% FOD in 3 sediment samples. Sum cancer probabilities in Lake Sammamish are relatively small with a maximum sum of 9.9E-5 at location 0618 and a minimum of 1.2E-5 at location 0623.

Lake Washington has some locations with high potential wading scenario risks and other locations with much lower wading risks, suggesting considerable spatial heterogeneity. Locations 4903 and 4903A near Atlantic City Park in the southwest portion of the lake are locations with the highest carcinogenic wading risks. These probabilities are relatively small, less than 2E-4 and arise from bis(2-ethylhexyl)phthalate and benzo(a)pyrene respectively. Other PAHs and arsenic are minor risk contributors around the shores of Lake Washington. All non-carcinogenic HQs are below 1 for the wading scenario in Lake Washington. Two locations had an excess HI via the wading scenario. Station A522 in Lake Union had a liver HI of 4.2 while North Creek had unspecified organs impacted by an HI of 1.5. This latter HI is predominantly due to thallium.

6.4.3 Swimming

The same addition process to evaluate cumulative risk discussed at the beginning of this section applies to the swimming scenario. The spatial orientation of the cumulative risks is discussed below. The swimming scenario was assumed to occur only at lake and near-shore locations. Stream locations were not included. Only the domestic water supply with backyard wading use and wading scenarios considered risks at stream locations.

6.4.3.1 Risk Maps and Spatial Descriptions

There were 12 sampling locations in Lake Sammamish with cancer risks greater than 1E-6 or a maximum hazard quotient greater than 1 (Figure 9). In Lake Sammamish, the greatest

carcinogenic risk and non-cancer hazard was from bis(2-ethylhexyl)phthalate; both at location 0615 near the mouth of Tibbetts Creek in Lake Sammamish State Park. For other locations, arsenic was the predominant carcinogenic risk driver, while one other location had non-carcinogenic HQs greater than 1; 0611, had an HQ of 1.1 also for bis(2-ethylhexyl)phthalate. Location 0611 is in the north central portion of Lake Sammamish. Arsenic risk at other locations in Lake Sammamish ranged from 2.8E-5 to 3.9E-4. Figure 9 shows these excess risks and hazards for Lake Sammamish as well as for the other major lakes.

In Lake Washington, station 0852 offshore from Madison Park, was sampled for PAHs 26 times; although at various depths, FODs varied from 3.8 to 7.7%. The detected values and ½ the MDLs were combined per the established decision rules to generate a 95% UCL. When this UCL is used to calculate risk, the total PAH risk at location 0852 is 2.1E-2, while the total probability of cancer at this location is 2.6E-2. This demonstrates that PAHs are the most significant risk driver for the location, although the collection of data with specific risk assessment data quality objectives would likely improve confidence in this estimate. The remaining risk is due to bis(2-ethylhexyl)phthalate.

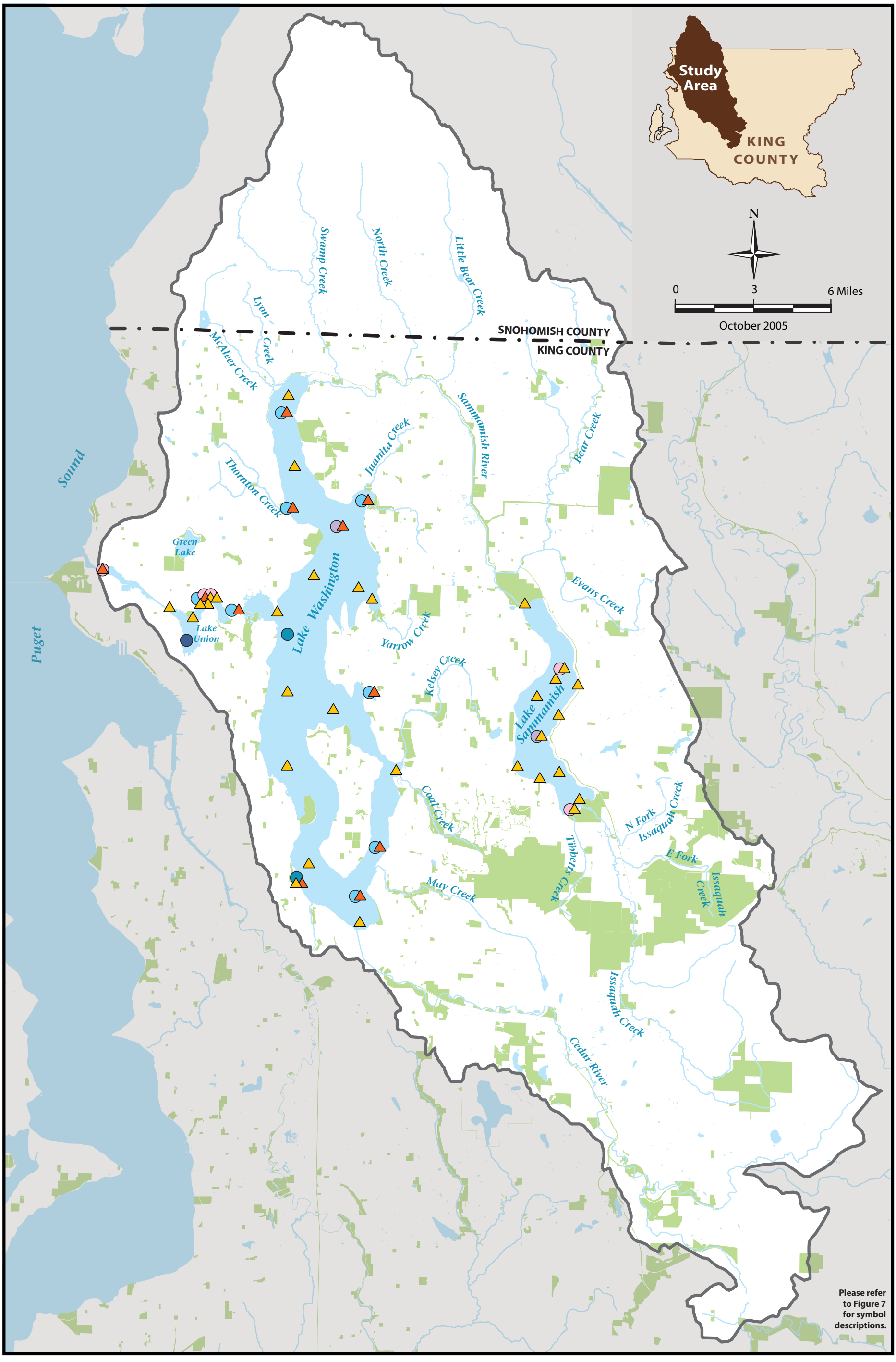

Figure 11 **Cumulative Swimming Cancer and Maximum Non-Cancer Risks with Public Parks**

SWAMP Risk Assessment

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Data Sources:
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Lake Union has slightly higher total cancer risks via swimming than Lake Washington, which on average is higher than Lake Sammamish. The highest cancer probabilities were calculated for location A522, along the southwest shore of Lake Union, at 3.7E-2. Other Lake Union locations range from a maximum of 4.5E-3 to 2.1E-4. For non-cancer endpoints, station A522, also has the highest HI of 121.8. This location had the highest domestic water supply with backyard wading use, wading and swimming non-cancer hazard index and this hazard is exclusively due to bis(2-ethylhexyl)phthalate. This plasticizer was detected in 100% of 4 samples at this location. Because less than 10 samples were available, a 95% UCL was not calculated as an exposure point concentration and the maximum detected concentration was used to estimate exposure.

Figure 11 illustrates the range of non-cancer HIs throughout the watershed. There are 18 locations with HIs in excess of 1. These were predominantly due to bis(2-ethylhexyl)phthalate (16 of 18 locations). Two locations also had arsenic and manganese HQs greater than 1 although these did not act on the same target organs as bis(2-ethylhexyl)phthalate. One location in Lake Sammamish had a fairly low HI due to manganese alone.

6.5 Comparisons with epidemiological results

As described in RAGS(a) (EPA, 1989), risk characterization should include comparisons with site-specific health or exposure studies when appropriate. For instance, an adequate site-specific Agency for Toxic Substances and Disease Registry (ATSDR) health assessment can strengthen the results of a risk characterization and serve as an additional line of evidence. To this end, epidemiological sources were searched and the only identified database of heath effects was obtained through the National Cancer Institute (NCI) of the National Institute of Health. The Surveillance, Epidemiology, and End Results (SEER) Program has collected data on cancer incidence in the Puget Sound region since 1978. There are no published epidemiological databases of non-cancer health effects using endpoints similar to those in the IRIS toxicology database. Therefore, this comparison with actual human health illness probabilities can only be conducted for carcinogens. The following compares SEER epidemiological cancer probabilities with the risk characterization results discussed above.

6.5.1 Domestic Water Supply with Backyard Wading Use

The results described in Section 5.4 and presented in Appendix E suggest that the risks to study area residents for drinking water with backyard wading use scenario are significantly greater than 1E-6. While the number of people using surface waters for drinking water purposes is unknown, King County has received anonymous phone calls from concerned citizens regarding water quality for drinking water purposes during algal blooms. Thus, some consumption of surface waters as drinking water is suspected, although withdrawal locations are unknown. In addition to water consumption, the domestic water supply with backyard wading use scenario has high rates of dermal contact with waters (from showering) and contact with sediments as if they were garden soil. Water and sediment sampling locations were only co-located about 5% of the time and thus each pathway is generally independent.

While both the water and sediment exposure assumptions likely represent a conservative exposure scenario not experienced by the majority of the population, it is useful to compare the

results of the domestic water supply with backyard wading use scenario and the wading scenario alone with epidemiological results. This assumes that individuals will drink, bath, and play/work in water and sediment from a particular location/waterbody for their lifetime. The swimming scenario was not compared with epidemiological results because of the difficulty in estimating the total population of interest associated with swimming beaches.

Therefore, the domestic water supply with backyard wading use and wading use alone scenario cancer probabilities were each multiplied by the year 2000 population in each sampling location's respective census block. A census block is typically between 600 and 1500 people; 941 census blocks are wholly or partially within the study area. These 941 blocks have approximately 1 million residents out of a total of 1580 King County census blocks with a population of 1.7 million. Thus, this multiplication yields a hypothetical number of cancer cases in each census block. The hypothetical cancer incidences were then summed across blocks and divided by the total population of the 941 study area blocks. Equation (3) provides the formula of these calculations:

$$\frac{\sum_{i=1}^{N} [(CAloc_i) \times (BLKpop_i)]}{\sum_{i=1}^{N} BLKpop_i} \qquad (3)$$

Where:

$CAloc_i$ = location specific cancer probability
$BLKpop_i$ = population of each census block

These calculations provide an estimated lifetime cancer risk weighted by the population in the vicinity of each sampling location. This population-weighted cancer probability was 1.4E-2.

The National Cancer Institute SEER*Stat (NCI, 2005) and DevCan (NCI, 2005) software packages were used to generate a lifetime probability of developing cancer using data from the Puget Sound SEER cancer registry. The cancer incidence and mortality data are from SEER, 2004 and these data include additional counties not part of the watershed. They are: Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom counties. However, these data provide the best epidemiological resource for calculating the actual cancer risks in the study area. .

The SEER*Stat and DevCan software packages work together using the methods described in Fay, et al. (2003, 2004) to produce an age-conditional probability of developing cancer from birth. To be comparable with the lifetime ages used in the risk calculations (Tables 7 and 8) a term of 78 years was used in DevCan. The cumulative lifetime probability of developing cancer for a Puget Sound resident from these counties is 3.4E-1 (34%). This probability is much larger than this risk assessments Tier 2 population weighted probability of 1.4E-2 (0.014%) for the domestic water and wading and 2.0E-4 (0.0002%) for wading alone. These disparities suggests that even considering the highly conservative scenario of using the study area aquatic resources for domestic water supply with backyard wading use represents a very small fraction of the

overall cancer risk documented via epidemiology. And wading alone is an even smaller fraction of the total lifetime risk. However, it is unknown how these scenarios' risks compare to other more documented cancer risk factors. The risks from cigarette smoke can be voluntary or involuntary (i.e. from secondhand smoke). These risks were also compared to the Puget Sound lifetime cancer risks and the carcinogenic risks enumerated in the domestic water supply with backyard wading use scenario (Table 27). For the smokers other health impacts are known, although only lung cancer risk is reported here (e.g. increased risk of heart disease, increased risk of oral cancer, etc.).

Table 27. Comparisons of Puget Sound lifetime cancer risk with smoking risks and domestic water supply with backyard wading use and wading use alone scenario cancer risks.

Scenario/Model	Carcinogenic Risk Probability
Average Puget Sound lifetime risk (NCI, 2005)	3.4E-1
Domestic water supply with backyard wading use (most conservative scenario in this study)	1.4E-2
Lung cancer risk in a 75 year old smoker who smoked 1 pack/day for 40 years (Bach et al. 2003)	8.0E-2
Lung cancer risk in a 75 year old smoker who smoked 2 packs/day for 50 years (Bach et al. 2003)	1.5E-1
Backyard or beach wading use alone	2.0E-4

As Table 27 illustrates, the risks of lung cancer from smoking alone are 6 to 11 times higher than the average risks posed by the use of study area surface waters *as drinking water* and for leisure activities.

6.5.2 Wading

Like with the domestic water supply with backyard wading use scenario, the wading scenario alone was compared to epidemiological results. While this scenario included public access locations and residential waterside lots, population weighted cumulative cancer risk from the wading scenario is a small fraction of the risk of cancer as described by epidemiological data as shown in Table 27. As examples, Table 28 shows the eight wading locations with the highest potential total risk.

Table 28. Eight highest wading total cancer risk locations.

Location	Waterbody	Sum Cancer Risk
SAMM_TRIB _124	SAMMAMISH Unnamed Trib. @ 124th St.	7.37E-03
0434	THORNTON CREEK	5.86E-03
D444	KELSEY CREEK	5.43E-03
0444	MERCER SLOUGH	2.79E-03
0446	JUANITA CREEK	1.74E-03
0430	LYON CREEK	1.70E-03
A522	LAKE UNION	1.29E-03
0440	MAY CREEK	1.14E-03

All of the excess cancer risk shown in Table 28 is due to the incidental water ingestion in the wading scenario. At three of these higher risk locations, sediment was not sampled (SAMM_TRIB _124, D444, and A522), the remainder had insignificant sediment risks relative to the water media and pathways. The preponderance of risk being derived from water exposures was typical for the majority of wading locations.

6.5.3 Swimming

Unlike with the drinking water with backyard wading and wading scenarios, no epidemiological results are available with which to directly compare these swimming results. This is because various citizens may use beaches and other areas extensively and the census blocks of those areas would not accurately represent population exposure. Parks and public beaches tend to skew the population of a particular census block downwards since there are no residents, while they attract a disproportionate fraction of the exposures.

Nevertheless, cumulative cancer risk from the swimming scenario ranges widely from a tiny fraction of the risk of cancer as described by epidemiological data to, at most, about 1% of the observed lifetime cancer frequency of 3.4E-1. Table 29 shows the swimming scenario total cancer risks.

Table 29. Cumulative Swimming scenario total cancer risk by location in lakes.

Location	Waterbody	Sum Cancer Risk
0615	LAKE SAMMAMISH	7.07E-04
0611	LAKE SAMMAMISH	6.16E-04
0612	LAKE SAMMAMISH	4.19E-04
0614	LAKE SAMMAMISH	3.86E-04
0604A	LAKE SAMMAMISH	3.22E-04
0607A	LAKE SAMMAMISH	3.01E-04
0603	LAKE SAMMAMISH	2.76E-04
M621	LAKE SAMMAMISH	2.24E-04
0617	LAKE SAMMAMISH	2.22E-04
0625	LAKE SAMMAMISH	2.22E-04

Location	Waterbody	Sum Cancer Risk
0622	LAKE SAMMAMISH	2.15E-04
0618	LAKE SAMMAMISH	1.92E-04
A522	LAKE UNION	3.70E-02
0540	LAKE UNION	4.49E-03
0512	LAKE UNION	2.54E-03
B535	LAKE UNION	1.77E-03
A535	LAKE UNION	7.88E-04
0535	LAKE UNION	5.70E-04
0544	LAKE UNION	3.77E-04
C535	LAKE UNION	3.20E-04
0527	LAKE UNION	2.64E-04
0518	LAKE UNION	2.55E-04
0536	LAKE UNION	2.05E-04
0852	LAKE WASHINGTON	2.61E-02
4903	LAKE WASHINGTON	5.59E-03
0805A	LAKE WASHINGTON	2.65E-03
0817	LAKE WASHINGTON	2.56E-03
0840	LAKE WASHINGTON	2.33E-03
0831	LAKE WASHINGTON	1.76E-03
0807	LAKE WASHINGTON	1.71E-03
0834	LAKE WASHINGTON	1.59E-03
0826	LAKE WASHINGTON	1.12E-03
4903C	LAKE WASHINGTON	2.31E-04
0804	LAKE WASHINGTON	2.15E-04
0832	LAKE WASHINGTON	1.91E-04
0890	LAKE WASHINGTON	1.87E-04
0814	LAKE WASHINGTON	1.85E-04
0848	LAKE WASHINGTON	1.81E-04
0845	LAKE WASHINGTON	1.79E-04
0805B	LAKE WASHINGTON	1.78E-04
0846	LAKE WASHINGTON	1.77E-04
0814A	LAKE WASHINGTON	1.76E-04
0847	LAKE WASHINGTON	1.75E-04
0829	LAKE WASHINGTON	1.68E-04

In all of these cases, swimming represents a relatively small proportion of the overall epidemiologically derived cancer risk. As described above, there are no known public access databases for non-cancer health endpoints.

6.6 Data comparisons with MCLs

EPA has established two different types of MCLs. MCL goals (MCLGs) are policy goals for drinking water without regard to implementation issues. MCLs are regulatory thresholds above

which water purveyors are expected to take action to reduce the contaminant. MCLs have been established using a variety of scientific information, practical and financial considerations, and other management decisions. Because this HHRA utilized a potable water use scenario the exposure concentrations used in the HHRA have been compared to MCLs to provide perspective on how these concentrations compare with these regulatory thresholds. Because MCLs were derived from a mix of objective and subjective information, the ratio of exposure concentrations with MCLs is not proportional to health risk.

Table 30. Maximum HHRA Tier 2 EPCs compared to MCL goals and regulatory limits.

COC	Max EPC, when N<10 (mg/L)	Max EPC, when N>10 (mg/L)	MCLG[1]	MCL[1]
2-Methylnaphthalene	Not detected in water		None	
4,4'-DDD	0.000008	None	None	
4,4'-DDE	0.000008	None	None	
4,4'-DDT	0.000084	None	None	
4,6-Dinitro-O-Cresol	Not detected in water		None	
Acenaphthene	0.00002	1.48E-04	None	
Acenaphthylene	0.000015	1.20E-05	None	
Aldrin	Not detected in water		None	
Anthracene	0.000016	1.05E-05	None	
Antimony	0.00079	6.74E-04	0.006	0.006
Aroclor 1248	Not detected in water		None	
Aroclor 1254	Not detected in water		None	
Aroclor 1260	Not detected in water		None	
Arsenic	**0.00853**	**7.84E-03**	0	0.01
Barium	0.15	7.55E-02	2	2
Benzo(a)anthracene	0.000049	1.86E-05	None	
Benzo(a)pyrene	**0.0000576**	**1.74E-05**	0	0.0002
Benzo(b)fluoranthene	0.000149	3.97E-05	None	
Benzo(k)fluoranthene	0.000136	3.74E-05	None	
Bis(2-Ethylhexyl)Phthalate	**0.148**	None	0	0.006
Cadmium	0.00047	2.34E-04	0.005	0.005
Chromium	0.03	7.51E-03	0.1	0.1
Chrysene	0.000122	4.17E-05	None	
Copper	0.03	1.30E-02	1.3	1.3[2]
Dibenzo(a,h)anthracene	Not detected in water		None	
Disulfoton (Di-Syston)	Not detected in water		None	
Fluoranthene	0.000162	3.61E-05	None	
Fluorene	0.0000277	8.27E-05	None	
Hexachlorobenzene	**0.000035**	None	0	0.001
Indeno(1,2,3-cd)pyrene		3.15E-05	None	
Iron	1.17	11.83	None	
Lead	**0.04**	**1.14E-02**	0	0.015[2]

COC	Max EPC, when N<10 (mg/L)	Max EPC, when N>10 (mg/L)	MCLG[1]	MCL[1]
Manganese	0.168	None	None	
Mercury	0.0001	1.20E-04	0.002	0.002
Methyl Mercury	Not detected in water		None	
Naphthalene	0.000135	4.92E-04	None	
N-Nitrosodimethylamine		1.15E-05	None	
Pentachlorophenol	**0.000475**	**2.04E-04**	0	0.001
Phenanthrene	0.0000802	8.50E-05	None	
Pyrene	0.000187	5.11E-05	None	
Simazine	0.00028	None	0.004	0.004
Thallium	0.000019	**1.23E-02**	0.0005	0.002
Total PCB	Not detected in water		0	0.0005
Vanadium	0.04	1.32E-02	None	
Zinc	0.11	4.17E-02	None	

[1]MCLG and MCLs from 40 CFR Subpart F § 141
[2]Copper and lead are not regulated at the supply but at the point of delivery, since they are principally derived from household pipes based on water corrosivity. Water purveyors are required to use corrosion control technology when the 90th percentile of tap concentrations for lead or copper exceed these action levels (56 FR 26460-26564, June 7, 1991)
EPC = exposure point concentration used in HHRA
MCLG = Maximum contaminant level goal
MCL= Maximum contaminant level
Bold = Exceeds MCLG, shaded = Exceeds MCL

Table 30 illustrates that many of the chemicals evaluated in Tier 2 also exceeded MCLGs, including arsenic, bezo(a)pyrene, bis(2-ethylhexyl)phthalate, hexachlorobenzene, lead, pentachlorophenol, and thallium. Three EPCs used in Tier 2 also exceeded MCLs, bis(2-ethylhexyl)phthalate, lead, and thallium. The majority of COCs had no MCLGs or MCLs: 30 of 45 (66%).

6.7 Data comparisons by water type

To examine potential sources and further describe the potential for risk to vary depending upon weather and other environmental conditions, chemical concentrations in the database were examined by matrix code. This analysis was limited to five chemicals of concern with some of the highest risks identified above, covering metals, PAHs, and chlorinated pesticides. For KCEL data, “matrix” is a term identified by the field and laboratory staff. In general, “storm” waters are samples that are collected during rain events and “fresh” waters are samples collected during dry weather. The definition of a storm event is variable, although most “storms” led to a visible rise in stream or river stage and an increase in turbidity.

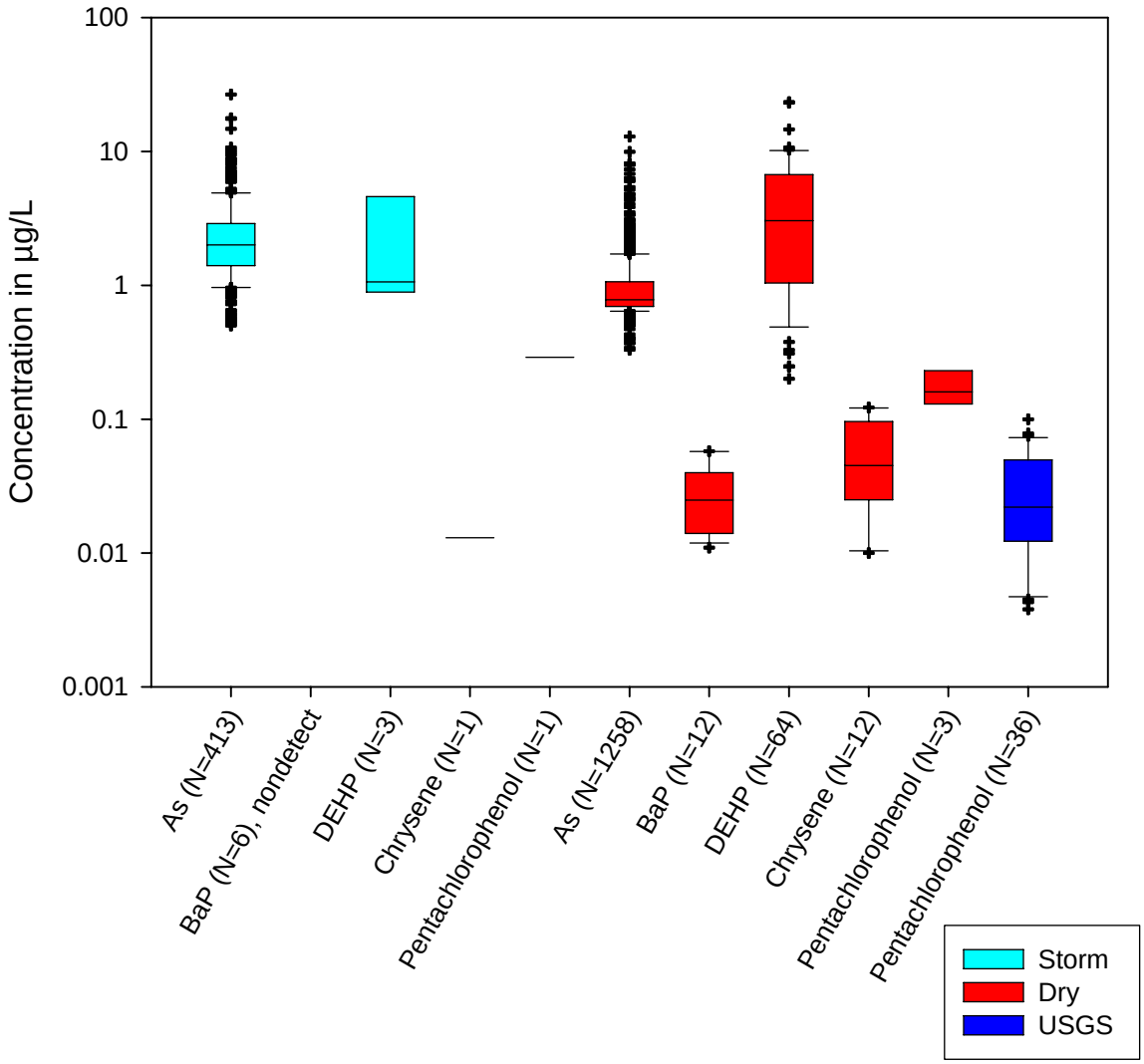

Figure 12. Box plots of 5 risk drivers' water quality detections by matrix code.
Note: Log scale is used for concentrations, +s are outliers
Values in parenthesis indicate number of detections
As = Arsenic, BaP = Benzo(a)pyrene, DEHP = Bis(2-ethylhexyl)phthalate, USGS = US Geological Survey data without a weather related matrix code.

The box plots in Figure 12 illustrate the differences between wet and dry weather arsenic concentrations. Average concentrations were approximately 150% lower during dry weather (*t*-test, p=<0.001). The mean wet weather concentration of total arsenic was 2.65 vs 1.04 µg/L in dry weather.

Benzo(a)pyrene was only detected 12 times; all detections occurred during dry weather (Figure 12). Examining the dataset's non-detects, the average MDL for wet weather samples of 0.0625 (N=6) was not statistically higher than the average MDL during dry weather conditions

0.013 (N=863) (*t*-test, p=0.24). However, the lack of sufficient numbers of wet weather samples likely limited the power of this test to detect differences and to find this common urban contaminant during rainy conditions.

For bis(2-ethylhexyl)phthalate, as noted earlier, only a few wet weather detections were available. The preponderance of the valid detections (i.e. non-"B" flagged) were collected during dry weather. This may be due to more frequent field or laboratory contamination of wet weather samples, as all of the remaining samples were blank qualified.

Chrysene and pentachlorophenol pose similar reasoning problems as benzo(a)pyrene, there are an insufficient number of wet weather detections to evaluate if stormwater runoff may be contributing to increased lifetime average chemical intakes. The dataset for this risk analysis included data sources outside King County DNRP (Table 4) and it is noteworthy that all of the pentachlorophenol detections reported by USGS are lower than those detected by KCEL. It is unknown whether these differences are due to field or laboratory methodological differences, or the environmental conditions targeted for sampling.

6.8 Data comparisons with Washington State urban regional data

To evaluate the uniqueness of the study area data and provide perspective on the relative magnitude of the chemical concentrations evaluated, data from other regions of Washington State were collated. Surface water data from five COCs identified above, covering both metals, PAHs, and chlorinated pesticides, were extracted from Ecology's "Environmental Information Management" system (EIM) (accessed August 9, 2006). Four regional areas with large metropolitan populations were selected: Clark, Pierce, Spokane, and Whatcom Counties. While these data do not necessarily cover a complete watershed, they likely encompass the range of chemical concentrations found in other urban and suburban regions of Washington.

These other regions of Washington likely have different exposure parameters based on their climate and local aquatic resource usage differences. Thus, risk calculations were not performed on these data. Instead, their chemistry results are compared with chemistry results from this risk assessment. Only freshwater results were used, but it remains difficult to ensure the regional dataset is directly comparable with the existing data used in this risk assessment. It is possible that the EIM data include studies and locations which are not directly comparable with ambient water conditions (e.g. stormwater effluents, hazard waste site investigations, or samples from pristine areas). Nevertheless, Figure 11 summarizes these data and compares them with data used in the risk analyses above.

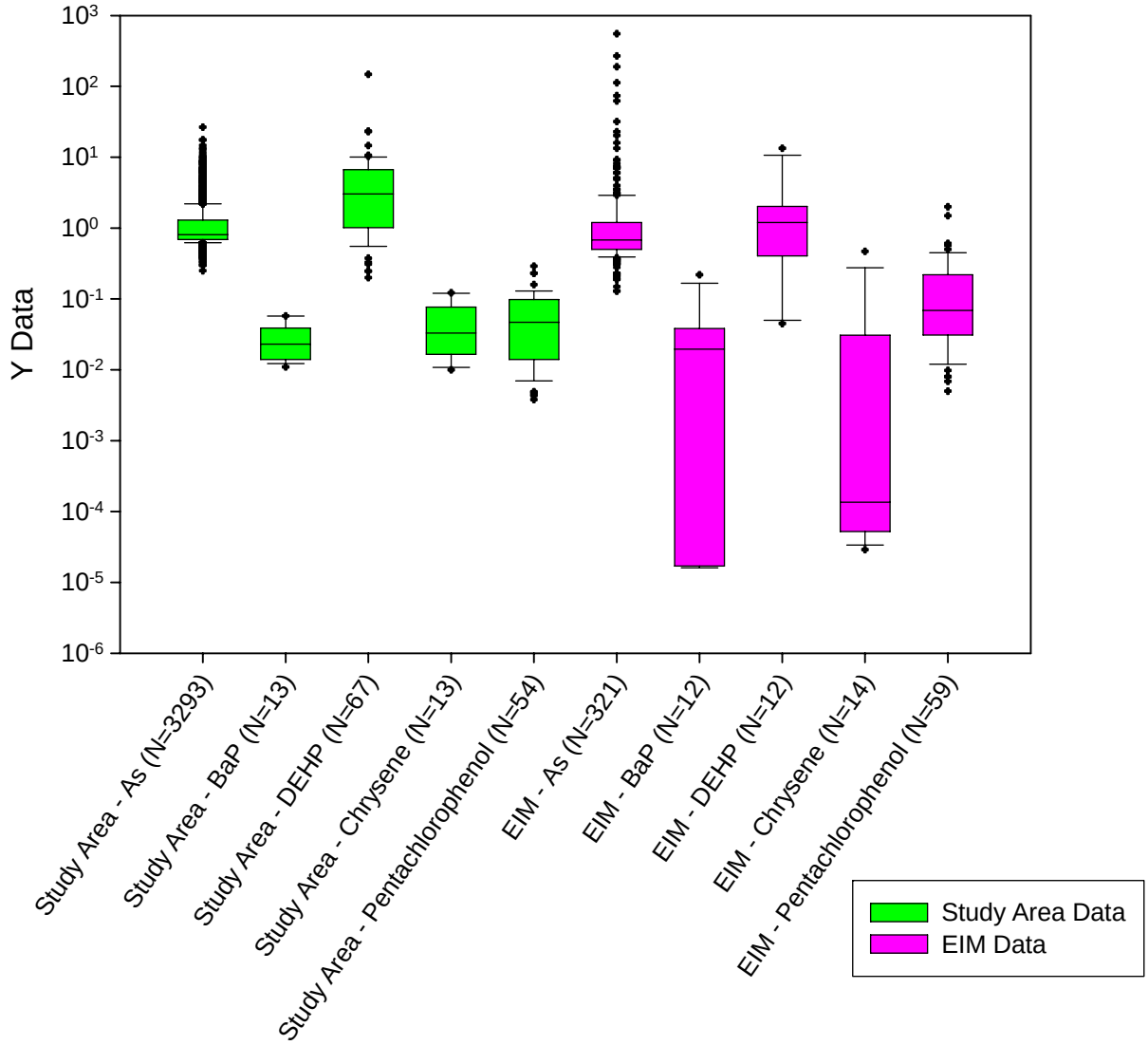

Figure 13. Box plots of Clark, Pierce, Spokane, and Whatcom County water quality detections compared to risk assessment detections for select chemicals of concern.
Note: Log scale is used for concentrations, +s are outliers
As = Arsenic, BaP = Benzo(a)pyrene, DEHP = Bis(2-ethylhexyl)phthalate, EIM = Environmental Information Management

Figure 13 illustrates that concentrations of the principle risk drivers for this risk assessment are detected throughout other Washington State counties with urban centers. Maximum detected EIM concentrations of these risk drivers are between 4 and 100 times higher. This is not unexpected, because Ecology has responsibility for many environmental issues and these data may have been collected to support MTCA or CERCLA cleanups or at other known contaminated properties. The minimum detected concentrations from EIM are sometimes

similar to those detected in this study's dataset. Although in the case of the PAHs benzo(a)pyrene and chrysene, the minimum detected concentrations in EIM are 3 orders of magnitude lower. These differences reflect the highly sensitive collection methods used for these particular data. These low detections are from a Johnson and Norton (2005) study which used semi-permeable membrane devices (SPMDs) to collect PAHs from the lower Columbia. These data reflect the fundamental method differences between SPMDs and the grab sample results used for the sampling efforts used in this HHRA (Table 4).

The average concentrations of all five chemicals selected for comparison are within a factor of four of the EIM data. In all cases, average concentrations of parameters used in this risk assessment were lower than those from EIM. The largest differences between the existing data used in this risk assessment and the EIM data pertain to the FOD percentages. For benzo(a)pyrene, chrysene, and pentachlorophenol, the study area risk assessment data had FODs ranging from below 1% to 4.3%. In contrast, the regional data in EIM had FODs ranging from 31% to 56%. This may be a reflection of the types of projects for which water samples were collected and analyzed

Overall, the chemical concentrations reflected in the data used in this risk assessment are much lower than the maximum concentrations found by Ecology in other counties with urban centers. Average concentrations are comparable, sometimes slightly higher (e.g. bis(2-ethylhexyl) phthalate) and sometimes slightly lower (e.g. pentachlorophenol). The box plots illustrate no significant differences between the regional Ecology data and the data used in this risk assessment. Available data from Ecology do have much higher FODs than in study area data, although this is believed due to differences in sampling and project design, not fundamental environmental differences between relatively urbanized areas of Washington.

6.9 Bacteria

As discussed above, only *E. coli* bacteria were assessed for human health risks. This is due to a lack of published quantitative dose-response relationships for fecal coliforms and toxic cyanobacteria.

6.9.1 Location-specific illness rates

The probabilistic simulations developed for this analysis were used to extrapolate from the datasets available to the larger populations of swim-able summertime days. The results of the Monte Carlo simulation, by location, were ranked according to the percentage of the distribution exceeding the allowable illness rate (8 per 1,000 swimmers) specified in the ambient water quality criteria. As discussed above, these illness rates are only for the GI illnesses most closely related with swimming water exposures (Dufour, 1984). When the 25th percentile exceeded 8 illnesses per 1,000 swimmers, the location was ranked highest (number 1). If only the 50th and higher percentiles exceeded the allowable rate, the location was ranked second. When only the 75th or higher percentile exceeded the allowable rate, the locations were ranked third. When some risk of illness was present at the 75th percentile, but below 8 per 1,000 swimmers, these locations were ranked fourth. The last category, lowest concern locations, represents those with

no measurable risks at the 75th percentile of their bacteria distributions. The 25th, 50th, and 75th percentile illness rates are presented below in Table 31, along with waterbody and locations rank.

Table 31. Bacteria sampling locations with Monte Carlo estimates of the 25th, 50th, and 75th percentile illness rates per 1,000 swimmers and relative ranks.

Location	Waterbody	Illness Rates			Relative Risk Rank
		25th%ile	50th%ile	75th%ile	
0434	Thornton Creek	**11.85**	**14.97**	**18.17**	1
A434	Tributary to Thornton Creek	**11.81**	**14.31**	**16.83**	1
C446	Juanita Creek	**10.17**	**13.35**	**16.45**	1
0446	Juanita Creek	**10.17**	**13.32**	**16.45**	1
A432	McAleer Creek	**9.23**	**12.67**	**15.95**	1
A620	Idylwood Creek	**9.11**	**12.92**	**16.65**	1
0430	Lyon Creek	**9.10**	**13.28**	**17.41**	1
0444	Mercer Slough	**8.70**	**12**	**15.47**	1
KSHZ06	Piper's Creek	**8.40**	**12.60**	**16.82**	1
0456	Forbes Creek	7.43	**11.31**	**15.40**	2
0498	Fairweather Creek	5.80	**11.14**	**16.63**	2
0440	May Creek	7.47	**11.02**	**14.53**	2
D444	Kelsey Creek	7.77	**11.01**	**14.49**	2
A617	Lewis Creek	5.53	**10.43**	**15.16**	2
0484	Bear Creek	6.84	**10.41**	**14.10**	2
0470	Swamp Creek	7.26	**10.24**	**13.33**	2
X630	Tibbets Creek	5.74	**9.82**	**13.98**	2
0442	Coal Creek	4.56	**9.54**	**14.55**	2
D474	North Creek	7.52	**9.50**	**11.42**	2
0478	Little Bear Creek	6.53	**9.28**	**14.03**	2
0474	North Creek	5.86	**9.28**	**12.69**	2
0806SB	Lake Washington – Juanita Beach	4.90	**9.26**	**13.55**	2
0631	Issaquah Creek	5.68	**9.25**	**12.83**	2
A680	Pine Lake Creek	4.78	**9.19**	**12.59**	2
X438	Cedar River	5.10	**8.83**	**12.64**	2
0834SB	Lake Washington – Meydenbauer Bay Beach	4.20	**8.75**	**13.24**	2
C484	Bear Creek	6.04	**8.58**	**10.78**	2
BB470	Swamp Creek	5.75	**8.18**	**10.45**	2
0450	Sammamish River	5.42	**8.07**	**10.68**	2
0818SB	Lake Washington – Matthews Beach	1.82	6.40	**10.90**	3
A632	Issaquah Creek	4.69	7.65	**10.60**	3
N484	Cottage Lake Creek	5.34	7.83	**10.34**	3
A499	Tributary to Yarrow Creek	0.67	5.47	**10.30**	3
0828SB	Lake Washington – Gene	0.15	5.01	**9.96**	3

Location	Waterbody	Illness Rates			Relative Risk Rank
		25th%ile	50th%ile	75th%ile	
	Coulon Beach				
0450A	**Sammamish River**	5.16	7.52	**9.93**	3
0860SB	**Lake Washington – Medina Beach**	0.62	4.81	**9.24**	3
A631	**Issaquah Creek**	2.84	6.07	**9.19**	3
B484	**Evans Creek**	3.45	6.63	**9.17**	3
0450C	**Sammamish River**	2.90	6.24	**8.90**	3
A438	**Cedar River**	0.30	4.49	**8.82**	3
A690	**Eden Creek**	0	4.94	**8.75**	3
J484	**Bear Creek**	3.68	6.16	**8.54**	3
A685	**Ebright Creek**	0.62	4.64	**8.53**	3
0852SB	**Lake Washington – Madison Park Beach**	0	3.23	7.84	4
0602SB	**Lake Sammamish – Idylwood Beach**	0	3.61	7.48	4
083930SB	**Lake Washington – Newcastle Beach**	0	2.75	7.12	4
A734SB	**Green Lake Beach**	0	3.20	6.97	4
4903SB	**Lake Washington – Pritchard Island Beach**	0	2.43	6.86	4
A422SB	**Lake Washington – Houghton Beach Park**	0	3.27	6.77	4
0512	**Lake Union**	0	3.08	6.57	4
0486	**Sammamish River**	0.02	3.45	6.17	4
0606SB	**Lake Sammamish – State Park Beach**	0	2.14	6.12	4
0826OLA	**Lake Washington – Magnuson Off Leash Area**	0	2.33	6	4
S484	**Evans Creek**	0	2.61	5.67	4
0826SB	**Lake Washington – Magnuson Beach**	0	0.89	5.14	4
4903	**Lake Washington**	0	0.88	4.62	4
SD007SB	**Lake Washington – Madrona Beach**	0	0.64	4.62	4
0820SB	**Lake Washington – Mount Baker Beach**	0	0.67	4.44	4
0615SB	**Lake Sammamish – State Park Beach**	0	0	4.32	4
SD017SB	**Lake Washington – Luther Burbank Beach**	0	0	3.67	4
0813SB	**Lake Washington – Seward Park Beach**	0	0	3.14	4
0825SB	**Yarrow Point**	0	0	2.62	4
0536	**Lake Union**	0	0	2.53	4
0518	**Lake Union**	0	0.02	2.44	4
A522	**Lake Union**	0	0	2.02	4
0805BSB	**Lake Washington**	0	0	1.83	4
0805ASB	**Lake Washington – Denny Park**	0	0	0.59	4

Location	Waterbody	Illness Rates			Relative Risk Rank
		25th%ile	50th%ile	75th%ile	
0625	**Lake Sammamish**	0	0	0	5
0829	**Lake Washington**	0	0	0	5
0834	**Lake Washington**	0	0	0	5

Note: Bold text exceeds allowable risk per 1,000 swimmers.

The ranking of bacteria risk by location has been mapped, along with public parks and annotations of swimming beaches in Figure 14 below. Swimming beach locations have been marked and shown on Figure 14, most of these locations rank low to moderately high relative to other bacteria sampling locations. This suggests that King County's swimming beach monitoring and closure program is important to minimizing beachgoers risks of waterborne illness.

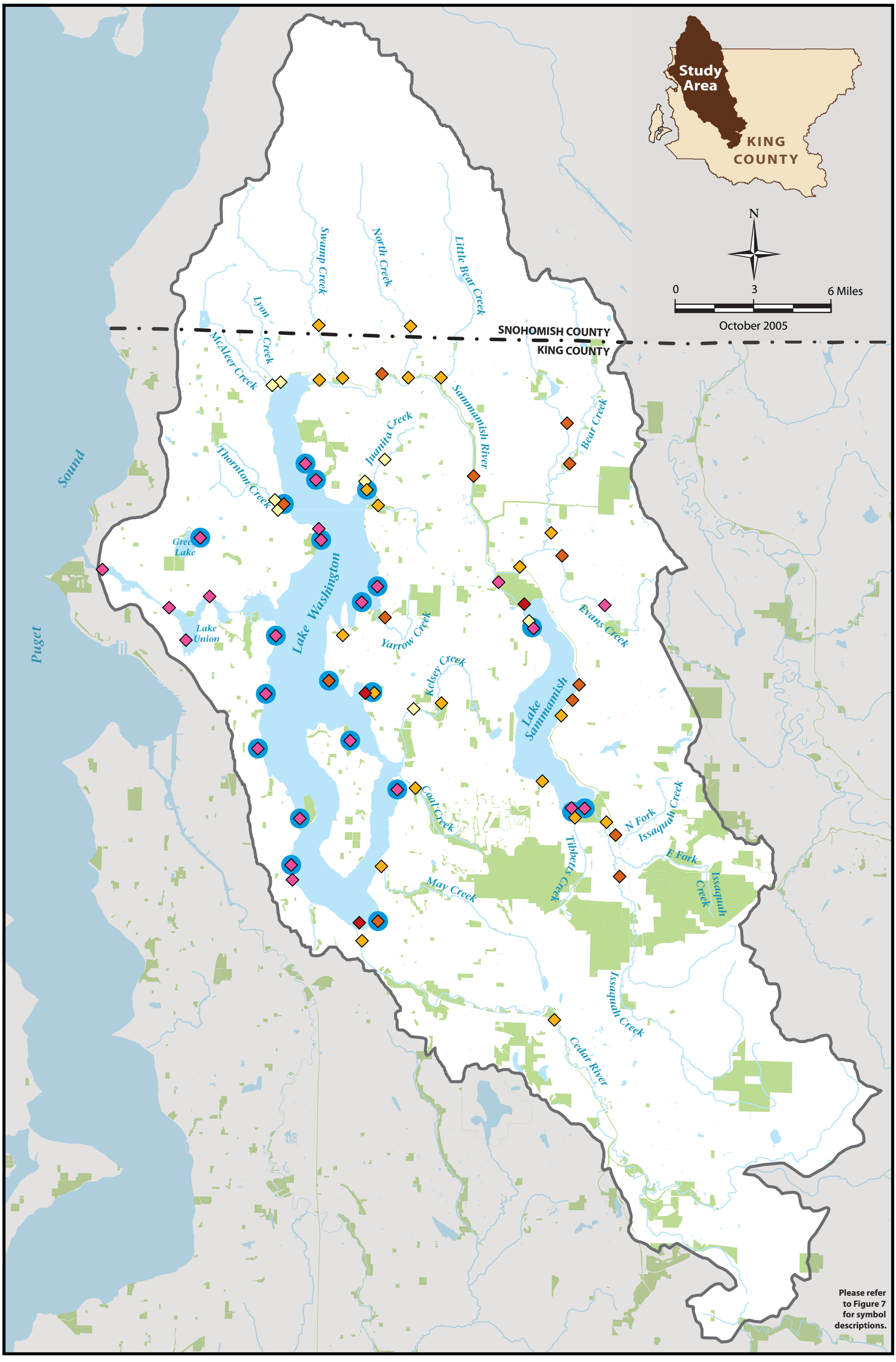

Figure 14 **Bacteria Sampling Locations with Illness Ranking, including Swimming Beaches and Public Parks**

SWAMP Risk Assessment

Note:
The information included on this map has been compiled by King County staff from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information. This document is not intended for use as a survey product. King County shall not be liable for any general, special, indirect, incidental, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.

Data Sources:
King County Datasets,
2000 US Census, Appendix D

Produced by:
DNRP GIS and WLRD Visual Communications Unit

File:
0712Swamp_BACT.ai LPRE, wgab

King County
Department of Natural Resources and Parks
Water and Land Resources Division

7.0. SENSITIVITY ANALYSIS

The consequences of many risk assessment assumptions are typically not fully understood without a sensitivity analysis. This section examines variation in some of the more uncertain parameters which, based on professional judgment, are likely to significantly affect the risk assessment outcome.

The following parameters were considered significant factors in the final risk numbers and thus were intentionally varied while holding the remaining variables static:

1. 78 year exposure duration to study area aquatic resources

2. Number of hours per swimming event, and number of swimming events per year

3. Chemical exposure point concentrations

4. Child soil ingestion rates

The 78 year exposure duration was selected based on an infant life expectancy as published by DOH (2004b). This value is more than twice the typical value used by EPA in CERCLA guidance. Typical CERCLA, RCRA and MTCA hazardous waste cleanups use an exposure duration of 30 years. This value is based on the 90th percentile of how long a person lives in a single house in the United States.

The risk assessment used the 78 year exposure duration because data on rates of immigration and emigration from the study area are unavailable. It is quite plausible that an individual may live in the 692 mi^2 (1,792 km^2) study area their entire life. To provide a better understanding of the likely range of adverse effects over shorter exposures, two additional durations were selected; 15 and 30 years. As shown in Equation 1, the relationship between exposure duration and human cancer risk is linear. For non-carcinogens, the exposure duration does not influence the results. This is because both the numerator and the denominator are multiplied by this value. Thus, reducing the exposure duration does not change the non-cancer risk estimates, which are based on an allowable dose per day (see definition of a Rfd in Section 3.1.2.1 above).

The cancer risk associated with a particular exposure duration linear to exposure duration and averaging time. Under the risk assessment assumptions presented in Tables 7 and 8, the exposure duration was 78 years and the averaging time was 78 years multiplied by 365 days/year. Using the alternative duration of 15 years of living in the study area and the EPA national default of a 70 year lifetime, revises both the duration and the averaging time. Thus, all of the cancer risk estimates would decline by 15 $\div$ 70. This is 21% of their original estimated value. The default averaging time of 70 years was selected instead of the Washington state lifetime of 78 years because citizens immigrating and emigrating from the study area do not necessarily remain within Washington State, which is the reference population for the DOH 78 year average lifespan.

Utilizing an exposure duration of 30 years, the same linear relationships apply. Thus, the 30 year duration is divided by the default averaging time of 70 years. Cancer risks therefore decline to 30 ÷ 70 or 43% of their original values. The fact that these assumptions influence the resulting risk calculations by less than an order of magnitude suggests that they have a moderate influence on the overall risk value.

The variability in the number of swimming hours and days per year was very high in the Human Use Survey (Parametirx, 2003). For instance, the minimum swimming duration per event was 30 minutes, while the maximum was 480 minutes. The risk assessment used a 95th percentile of 240 minutes consistent with EPA guidance recommendations to utilize a "reasonable maximum exposure" or RME. This wide range of values is reasonable and expected from a study area population of 1 million. However, for the purposes of discussion, an alternative swimming frequency and duration were chosen for comparison. Medians were chosen for both as they represent values that are not subject to much influence by the extremes of the distribution. Thus the sensitivity analysis utilized the median value of 60 minutes per event.

For the event frequency, the risk assessment used a 95th percentile of 58 days per year. This sensitivity analysis substituted the median value of 8 days per year. For dermal contact, the duration of exposure is an important, nonlinear variable in determining the chemical dose per event. Thus, all of the swimming risk calculations were re-run and the revised values compared to the initial values on a percent difference basis (RPD). The reduction in swimming frequency and duration reduced the resulting cancer risks between 174 and 187%. The average reduction in cancer risk was 181.7%. However, none of the locations with excess swimming risk were reduced below 1E-6 (Table 32)

Table 32. Comparison of 95th percentile and median swimming duration and frequency with respective cancer probabilities.

		Cancer probabilities		
Location	**Waterbody**	**95%ile swimming exposures**	**Median swimming exposures**	**RPD**
0615	LAKE SAMMAMISH	7.07E-04	4.88E-05	174.2%
0852	LAKE WASHINGTON	2.61E-02	1.79E-03	174.3%
A522	LAKE UNION	3.70E-02	2.53E-03	174.4%
4903	LAKE WASHINGTON	5.59E-03	3.78E-04	174.7%
0540	LAKE UNION	4.49E-03	3.03E-04	174.7%
0805A	LAKE WASHINGTON	2.65E-03	1.76E-04	175.0%
0817	LAKE WASHINGTON	2.56E-03	1.70E-04	175.1%

		Cancer probabilities		
Location	**Waterbody**	**95%ile swimming exposures**	**Median swimming exposures**	**RPD**
0840	LAKE WASHINGTON	2.33E-03	1.54E-04	175.2%
B535	LAKE UNION	1.77E-03	1.17E-04	175.3%
0831	LAKE WASHINGTON	1.76E-03	1.16E-04	175.4%
0807	LAKE WASHINGTON	1.71E-03	1.11E-04	175.5%
0512	LAKE UNION	2.54E-03	1.65E-04	175.6%
0834	LAKE WASHINGTON	1.59E-03	1.03E-04	175.6%
0826	LAKE WASHINGTON	1.12E-03	7.11E-05	176.2%
0535	LAKE UNION	5.70E-04	3.37E-05	177.7%
A535	LAKE UNION	7.88E-04	4.66E-05	177.7%
0544	LAKE UNION	3.77E-04	1.98E-05	180.0%
0611	LAKE SAMMAMISH	6.16E-04	3.19E-05	180.3%
C535	LAKE UNION	3.20E-04	1.65E-05	180.4%
0527	LAKE UNION	2.64E-04	1.21E-05	182.5%
0612	LAKE SAMMAMISH	4.19E-04	1.87E-05	182.9%
M621	LAKE SAMMAMISH	2.24E-04	9.51E-06	183.7%
0604A	LAKE SAMMAMISH	3.22E-04	1.32E-05	184.2%
0618	LAKE SAMMAMISH	1.92E-04	7.43E-06	185.1%
0614	LAKE SAMMAMISH	3.86E-04	1.48E-05	185.3%
0603	LAKE SAMMAMISH	2.76E-04	1.04E-05	185.5%
0607A	LAKE SAMMAMISH	3.01E-04	1.11E-05	185.8%

		Cancer probabilities		
Location	**Waterbody**	**95%ile swimming exposures**	**Median swimming exposures**	**RPD**
0622	LAKE SAMMAMISH	2.15E-04	7.65E-06	186.3%
0617	LAKE SAMMAMISH	2.22E-04	7.73E-06	186.5%
0625	LAKE SAMMAMISH	2.22E-04	7.65E-06	186.7%
0845	LAKE WASHINGTON	1.79E-04	6.16E-06	186.7%
0846	LAKE WASHINGTON	1.77E-04	6.12E-06	186.7%
0814A	LAKE WASHINGTON	1.76E-04	6.09E-06	186.7%
0829	LAKE WASHINGTON	1.68E-04	5.78E-06	186.7%
0518	LAKE UNION	2.55E-04	8.79E-06	186.7%
0536	LAKE UNION	2.05E-04	7.07E-06	186.67%
4903C	LAKE WASHINGTON	2.31E-04	7.96E-06	186.7%
0832	LAKE WASHINGTON	1.91E-04	6.60E-06	186.7%
0890	LAKE WASHINGTON	1.87E-04	6.44E-06	186.7%
0848	LAKE WASHINGTON	1.81E-04	6.23E-06	186.7%
0847	LAKE WASHINGTON	1.75E-04	6.02E-06	186.7%
0804	LAKE WASHINGTON	2.15E-04	7.41E-06	186.7%
0814	LAKE WASHINGTON	1.85E-04	6.38E-06	186.7%
0805B	LAKE WASHINGTON	1.78E-04	6.14E-06	186.7%
			Average Reduction =	181.7%

RPD= relative percent difference

The reduction in non-cancer hazard quotients through the use of median swimming exposure durations was pronounced. All but three of the 18 locations with HIs greater than 1 were reduced to less than this threshold (Table 33).

Table 33. Comparison of 95th percentile and median swimming durations with respective HIs

		Non-Cancer Hazard Quotients using:	
Location	**Waterbody**	**95%ile exposure assumptions**	**Median exposure assumptions**
A522	Lake Union	121.80	8.40
4903	Lake Washington	19.17	1.32
0852	Lake Washington	19.01	1.31
0805A	Lake Washington	8.81	<1
0540	Lake Union	8.51	<1
0817	Lake Washington	8.48	<1
0840	Lake Washington	7.63	<1
B535	Lake Union	5.78	<1
0831	Lake Washington	5.67	<1
0807	Lake Washington	5.43	<1
0834	Lake Washington	5	<1
0612	Lake Sammamish	4.35	<1
0826	Lake Washington	3.35	<1
0611	Lake Sammamish	2.76	<1
0615	Lake Sammamish	2.53	<1
A535	Lake Union	2.01	<1
0535	Lake Union	1.46	<1
0512	Lake Union	1.39	<1

This suggests that swimming frequency and duration are major factors in resulting risk calculations, particularly for non-carcinogens. The high sensitivity of these exposure parameters

and the wide range of swimming frequencies and durations reported by Parametrix (2003) is a source of considerable variation in non-carcinogenic risks across the study area population.

Another major assumption of the risk assessment is the accuracy and precision of the underlying chemistry data. To evaluate the effects of major errors in the accuracy and precision of the exposure point concentrations, each water and sediment concentration in the database was multiplied by 0.5 and again by 1.5. This 50% reduction and 50% increase in concentration is warranted by the sometimes limited confidence in the exposure point concentrations. For instance, PAHs are significant risk drivers and many locations had less than 10 sampling events, leading to the use of maximum detected values as exposure point concentrations. In other cases, increasing or decreasing the water and sediment concentrations by 50% is justified by a lack of understanding of the exact chemical form. Inorganic arsenic is toxic, while organic arsenic has a very low toxicity. King County has not speciated arsenic to date, and some fraction is suspected to be present in the organic form. Varying the exposure point concentration can illuminate the extent which this might influence the resulting risks.

The variability in resulting risk estimates was evaluated two ways. Initially, the number of locations with an excess risk above 1E-6 probability of cancer or a HQ greater than 1 were calculated by parameter (Section 5). This statistic (Tables 14 through 24) was useful to evaluate the spatial prevalence of each parameter with excess risk. Thus, the sensitivity analysis has compared the number of locations with excess risk by parameter using the minus 50% and plus 50% chemical concentration database adjustments. This intends to summarize the degree of sensitivity chemical concentrations play in the prevalence of excess risk by chemical. Table 34 lists these comparisons for the domestic water supply with backyard wading use scenario.

Table 34. Domestic Water Supply with Backyard Wading Use. Plus and minus 50% chemical concentration sensitivity scenarios relative to risk assessment results.

	Number of locations with >1E-6 cancer risk			Number of locations with a non-cancer HQ greater than 1		
Chemical	**Minus 50% chemical concentration**	**Exposure Point Concentration**	**Plus 50% chemical concentration**	**Minus 50% chemical concentration**	**Exposure Point Concentration**	**Plus 50% chemical concentration**
4,4'-DDD	NC	2	NC	NC	0	NC
4,4'-DDE	NC	2	NC	NC	0	NC
4,4'-DDT	NC	2	NC	NC	2	NC
Antimony	NC	0	NC	**1**	**8**	**39**
Arsenic	NC	103	NC	NC	103	NC
Barium	NC	0	NC	**3**	**8**	**27**
Benzo(a)anthracene	NC	13	NC	NC	0	NC
Benzo(a)pyrene	NC	22	NC	NC	0	NC
Benzo(b)fluoranthene	NC	22	NC	NC	0	NC
Benzo(k)fluoranthene	NC	14	NC	NC	0	NC
Bis(2-Ethylhexyl)Phthalate	NC	39	NC	NC	39	NC

	Number of locations with >1E-6 cancer risk			Number of locations with a non-cancer HQ greater than 1		
Chemical	**Minus 50% chemical concentration**	**Exposure Point Concentration**	**Plus 50% chemical concentration**	**Minus 50% chemical concentration**	**Exposure Point Concentration**	**Plus 50% chemical concentration**
Cadmium	NC	0	NC	**2**	**5**	**15**
Chrysene	NC	11	NC	NC	0	NC
Dibenzo(a,h)anthracene	NC	4	NC	NC	0	NC
Fluoranthene	NC	0	NC	**NC**	**0**	**2**
Hexachlorobenzene	NC	1	NC	NC	1	NC
Indeno(1,2,3-cd)pyrene	NC	5	NC	NC	0	NC
Iron	NC	0	NC	**8**	**17**	**26**
Manganese	NC	0	NC	**NC**	**4**	**5**
Naphthalene	NC	0	NC	**0**	**10**	**11**
N-Nitrosodimethylamine	NC	1	NC	NC	0	NC
Pentachlorophenol	NC	17	NC	NC	17	NC
Pyrene	NC	0	NC	**0**	**2**	**3**
Thallium	NC	0	NC	NC	1	NC
Total PCB	NC	5	NC	NC	0	NC

	Number of locations with >1E-6 cancer risk			Number of locations with a non-cancer HQ greater than 1		
Chemical	**Minus 50% chemical concentration**	**Exposure Point Concentration**	**Plus 50% chemical concentration**	**Minus 50% chemical concentration**	**Exposure Point Concentration**	**Plus 50% chemical concentration**
Vanadium	NC	0	NC	**27**	**38**	**49**

Shaded boxes = changes in frequency
NC = no change

Table 34 illustrates that even significant changes in chemical concentrations, plus and minus 50%, have no influence over the spatial prevalence of carcinogenic risk. In many cases, this appears due to the use of maximum detected concentrations as the exposure point concentration. Locations where a chemical was never detected were not deemed to present a risk based on detection limits alone. So, despite the apparent robustness of many carcinogenic organic chemicals to ±50% perturbations in concentration, FOD played the greatest role in their spatial prevalence.

For non-carcinogens, adjusting the chemical concentrations up and down by 50% played a significant role in their spatial prevalence. A 50% increase in antimony and barium concentrations increased the 8 locations with an HQ greater than one, to 39 and 27 locations with HQs greater than one respectively. Cadmium, iron, and vanadium also are highly sensitive to ±50% perturbations in exposure point concentrations.

The following example illustrates the sensitivity of a representative metal to changes in concentration. In the database, antimony was not analyzed at 26 of 148 locations. Of the remaining 116 sampling locations, antimony was analyzed between 2 and 56 times. Thus, complete uncertainty in the hazard quotient for antimony exists at 22 % (26/116) of the study area sampling locations. Other sampled locations have a variable degree of sensitivity in their HQs from analytical or sampling errors. Additionally, the magnitude of any individual deviation from the true exposure point concentration depends on the number of samples collected. For instance, at locations with just a few sampling results, the true exposure point concentration could be significantly skewed from the true value. At sampling locations with many sampling results, the 95% UCL of the mean is likely a robust, conservative indication of the exposure point concentration. For any individual contaminant, its contribution to the overall accuracy of the risk assessment appears highly dependent upon its sampling frequency. Those chemicals with a low sampling frequency contribute the most uncertainty and slight deviations in accuracy can influence their spatial prevalence considerably.

Child soil (sediment) ingestion rates were varied to consider the risks posed to a “pica” child. This is a child who intentionally ingests soil. The EFH (EPA, 1997) recommends 1000 mg/hr as an ingestion rate. Thus, this rate was substituted for the standard child play rate of 15mg/hr to evaluate the increased risks experienced by pica children. This analysis revealed that for the majority of locations evaluated for domestic water supply with backyard wading use, no measurable increased risks were posed to pica children. This is due to the dominant influence of water concentrations on risk. Because risk estimates are rounded to the nearest tenth, the effect of raising the child soil ingestion rate was not apparent at the 120 highest risk locations. Thus, it appears that child soil ingestion rate is a relatively insensitive parameter and population variability in this rate has little effect on total individual site risk.

8.0. UNCERTAINTIES

All risk assessments carry uncertainty. The goal of this section is to describe major sources of uncertainty to allow decision makers to prioritize future data and risk assessment needs. In general, USEPA guidance (1989) stresses the planned, appropriate collection of data for risk assessment purposes. The first step would be to define risk assessment questions of interest. Then, many of the uncertainties described below can be reduced by developing data quality objectives (DQOs) specific for those questions.

8.1 Sampling Design

This risk assessment used pre-existing data to calculate carcinogenic and non-carcinogenic risks at selected locations throughout King County. Because the available data were collected for a variety of other purposes (e.g. long-term ambient monitoring and special projects), they could not be extrapolated from single points to zones or areas. For instance, the data density is far too low and spatially heterogeneous relative to an average residential lot to interpolate chemical concentrations at this smaller scale. There are approximately 582,000 privately owned parcels with some type of residential zoning in the study area (e.g. single family, duplex, nursing home, mobile home, apartment, etc.). Of these parcels, 10,897 abut a waterbody. The existing data were collected systematically in most cases. In order to characterize conditions at each of these waterside properties, a randomized sampling design would be required. Such a sampling design may not meet other sampling objectives, e.g. understanding long term trends in water quality or identifying sewage leaks.

The existing data used for this risk assessment were not specifically collected for risk assessment purposes and were thus not stratified or randomized across the various waterbodies in the study area. Therefore, extrapolation of the existing data to this large number of waterbodies and their adjacent parcels is one of the largest sources of uncertainty in the risk assessment. This evaluation considered populations exposed to chemicals across 2-dimensions, while existing data are points representing specific locations only. Unfortunately, the use of systematically selected point data in lieu of random data was unavoidable.

At many sampling locations, either water or sediment was collected but not both. This led to about 95% of the locations having only one medium to evaluate. Thus, the calculated risks at each location are generally not representative of the total chemical exposure likely in that scenario. For instance, swimming locations were unable to account for sediment exposure because shallow area sediments, where the majority of exposure occurs, were not sampled.

Fish tissue sampling was limited. While DOH evaluated these results (DOH, 2004a), it is clear that use of whole body tissues in lieu of fillets, the limited number of species analyzed, and small sample sizes constrained their analysis. The lack of complete chemistry data for this exposure route presents a large degree of uncertainty in the overall assessment of aquatic resources.

Known contaminated properties were excluded from this assessment. Additionally, more pristine waterbodies and upland areas where people spend much of their lives were not

evaluated. Thus, while this assessment is believed to represent the central range of ambient, study area aquatic exposures, there are no data available to support this assumption. For instance there has not been a policy or technical effort to define the level of anthropogenic impact (e.g. aerial depositions) in "natural background" conditions (as described in WAC 173-340-200). So the degree to which the risks described herein are due to natural, localized, regional or global contaminate distributions is unknown. The aggregate and cumulative uncertainties of these knowledge gaps are significant, but of unknown magnitude.

8.2 Analytical

The analyte list for this project was not selected based on human health assessment needs, nor were all chemicals analyzed at every sampling location. This latter issue is a greater source of uncertainty, although the former is also significant in judging overall results. A total of 247 parameters were analyzed at least once in water, but never detected. In sediment, 74 parameters were analyzed but never detected. The Tier 1 screening tables (Appendix A, Tables 1 and 2) document which parameters exceeded their SCs, while Tables 3 and 4 of Appendix A list the number of times non-detected chemicals were analyzed. Those chemicals which were rarely analyzed (e.g. aldicarb in water, N=4) pose far greater uncertainty than those which were frequently analyzed (e.g. dibenzo(a,h)anthracene, N=863).

The available data at each location are generally comprised of either: (1) metals; or (2) metals and semi-volatile organic compounds. At a small number of locations, some, but not all semi-volatile organics were analyzed. Volatile organics were removed at the Tier 1 screening level as expected, since none of the sampling occurred during known oil spills or similar events. Without an immediate source such as a spill, volatiles by definition would be found in the gaseous, not the aqueous phase.

The analytical methods chosen for this project were not specifically selected with HHRA needs in mind; as a general rule they were chosen based on expediency or for a special project (non-human health risk assessment). Thus, for many of the risk drivers, a more refined method is available (more precise or with better detection limits). For some chemicals, the analytical methods are only coarse estimators of the analyte of interest, for example total arsenic in lieu of speciated arsenic. As described in the discussion, PAHs are major risk drivers for many scenarios and at a variety of locations. PAHs were a risk driver almost everywhere they were analyzed. The depth and breadth of high PAH risk locations suggest that PAHs are one of the most prominent risk drivers in the study area. This suggests that more refined PAH methods may reduce the uncertainty of the chemical concentration, but would not diminish their role as prominent risk drivers.

As discussed in the Tier 1 uncertainties section (Section 3.4), a very large level of knowledge uncertainty exists regarding the tissue results. One of the parameters of greatest concern, PCBs, were not analyzed by the ideal method for HHRAs. Use of Aroclor® based analytical methods for PCB analysis is reasonably accurate for contaminated areas with on-going, fresh sources. In areas with older, more weathered contamination, Aroclor® analysis becomes less appropriate since the congener patterns in fish tissue become less and less similar to the Aroclor® parent material over time. Since the majority of PCB sources in Lake Washington are presumably

historic or atmospheric, the lack of PCB congener data provides a high level of uncertainty. Relationships between Aroclors® and congeners can be developed to allow the use of Aroclors® in HHRAs. However these relationships vary based on the fish species, the accumulation food web, and the specific tissues. In general the sum of Aroclors® is conservative relative to the sum of PCB congeners, although this should be validated on a case-by-case basis. Thus, other Aroclor® to congener relationships developed by King County for the Duwamish Waterway cleanup are not necessarily appropriate for Lake Washington. The DOH (2004a) evaluation has addressed these concerns and the lack of additional data has prevented this risk assessment from evaluating these risks in any further detail.

Other, potentially highly toxic, parameters were not analyzed at all or available data were insufficient for further analysis in Tier 2. These include chlorinated dibenzo-*p*-dioxins and furans (CDDFs) and PCBs, although PCBs in fish tissue were preliminarily evaluated by DOH (2004a). These bioaccumulative compounds are highly toxic and likely to be present in sediment and fish tissues from urban areas. While dioxins and furans have no industrial uses, they are frequent co-contaminants of PCBs and also of some formulations of pentachlorophenol. CDDFs are also formed in combustion, predominantly when other chlorinated substances are burned. The frequent detections of pentachlorophenol in water, PCBs in sediment, and PAHs in both water and sediment suggests that CDDFs are probably present in study area aquatic resources as well. CCDFs are usually found at very low levels in the environment. These levels are measured in nanograms (one billionth of a gram) and picograms (one trillionth of a gram). Because these compounds are considered extremely toxic, small concentrations can have a marked influence on overall human health risk (ATSDR, 1998).

Bis(2-ethylhexyl)phthalate was frequently detected in blanks, as most of the available data were blank qualified. The remaining non-blank qualified data were used in Tier 2, although some fraction of the detected concentrations is likely from field or laboratory contamination. Because bis(2-ethylhexyl)phthalate is a significant risk driver when present, an accurate understanding of the levels of this contaminant is important to calculating precise risk estimates.

Sufficiently analyzing all of the potential study area contaminants to accurately calculate the total human health risk from study area aquatic resource exposures would be extremely costly. This is because the absence of a focused risk management question requires the use of highly precise analytical methods for every possible contaminant. Analytical uncertainties can be reduced by having specific risk management questions, and tailoring the analyte list and analytical methods to meet those questions. Examples have been provided in the management recommendations (Section 9.2).

8.3 Exposure Assumptions

King County collected information regarding recreational exposures via the human use survey (Parametrix, 2003). However, this survey was unable to describe the frequency and duration of study area aquatic resource use at areas other than public parks and access areas. For instance, residences abut the majority of study area waterbodies and no information was available about the frequency and duration of backyard wading use of these resources. Gathering this

information would require some type of house-to-house survey design rather than the public access based survey previously completed.

There are approximately 582,000 privately owned parcels with some type of residential zoning in the study area (e.g. single family, duplex, nursing home, mobile home, apartment, etc.). Of these parcels, 10,897 abut a waterbody. An exposure survey of a statistically valid subgroup of these properties would substantially reduce uncertainty about the use of privately accessed study area aquatic resources.

Another source of uncertainty arises from the unknown numbers of individuals using study area waterbodies for domestic water supply. Since the majority of the population is provided potable water via various public or private purveyors, on a population-wide basis this knowledge gap is not suspected to be a large source of uncertainty. However, given the large increases in risk between the domestic water supply with backyard wading use scenario and the swimming scenario, this lack of knowledge could have significant ramifications on an individual's health.

Many of the remaining exposure assumptions listed in Tables 7 and 8 are national default values derived from US EPA CERCLA risk assessment guidance. These assumptions are predominantly bounded by biological plausibility. For instance, body weight, body surface area, skin thickness are limited in their range and thus present only a limited amount of uncertainty to this assessment.

The largest source of uncertainty is the number of calendar days per year of waterbody use, the number of hours of contact per event, and the number of years of use. These exposure parameters multiply each other, and thus small changes in each can have a large influence on results as demonstrated in the sensitivity section. The human use survey reported a high degree of variability for these values (Parametrix, 2003). This is probably an accurate reflection of the large population with diverse interests living and recreating nearby. While a more expansive survey may increase the precision of some of these measures (e.g. number of days swimming each year), it would be unlikely to reduce the overall spread between low frequency, average and high frequency users. Thus, the "maximum likely" scenario is likely robust and unlikely to change significantly with a more comprehensive recreational exposure dataset. Despite this range of potential exposures, this HHRA still provides metrics of relative risk. The areas of higher risk or higher exposure worth of greater investigation would remain similar.

8.4 Methodological

The Tier 1 risk assessment followed a typical screening process and generated a list of chemicals for more robust Tier 2 analysis. Based on the very conservative assumptions used in Tier 1, it is unlikely that a parameter included in the initial analysis was prematurely eliminated.

In Tier 2, data were evaluated by location and an exposure point concentration was estimated. For locations with less than 10 sampling events, the maximum detected concentration was used; for locations with greater than 10 samples, the 95% UCL of the arithmetic mean was used as an exposure point estimate. However, residents, swimmers, and waders are exposed to a variety of locations throughout their lives, not just one location with a single exposure point concentration. Generating more robust exposure concentrations and recognizing the spatial movement of

receptors would require substantially more data on both day-to-day movement of exposed populations and the spatial and temporal distribution of chemicals in study area resources.

One additional source of risk was not included in the existing scenarios. All three scenarios evaluated may also have the risks of fish tissue consumption added to the cumulative risks presented. Since this is merely addition, this presents little additional uncertainty to that already present in the three scenarios evaluated in Tier 2 or to that in DOH (2004a). Of course, additional risks from environmental (air particulates and toxins) or lifestyle choices (smoking) were also not added to the scenarios. The separate characterization of fish consumption risks (DOH, 2004a) and subsequent fish advisories by DOH (2004c) satisfies the objective of identifying important pathways and chemicals in study area aquatic resources.

Many of the IRIS toxicity values utilize safety factors to account for knowledge uncertainty surrounding the use of animal toxicological data and to account for sensitive subpopulations. King County will continue to rely on IRIS to provide reasonably robust estimators of toxicity. King County also assumes that these toxicity adjustments avoid type II statistical errors; that is deciding that a location/chemical presents no risk, when it in fact presents a risk. These safety factors and associated knowledge uncertainty are inherent to the CERCLA risk assessment paradigm. These certainties are best described by the definitions of an RfD and a CSF (emphasis added):

1) "A chronic RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is *likely to be* without an appreciable risk of deleterious effects during a lifetime."

2) A cancer slope factor is a "plausible *upper-bound estimate* of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen" (USEPA, 1989).

Based on these definitions, the risk estimates presented herein are believed to represent an upper estimate of the range of health hazards. However, some chemicals could not be evaluated in Tier 2 due to methodological issues. The largest potential human health threat which was not evaluated in Tier 2 is probably lead.

Lead is a potent neurotoxin, particularly for developing children. Lead risk assessment requires the use of a pharmacokinetic model to estimate blood lead concentrations (USEPA, 2002). Data on potable water with residential soil, house and outdoor dust, air, and many other media are required inputs to this model. Because no King County data were available to run the model, and water/sediment exposures represent relatively insensitive values in the computations, lead risks were not calculated. The absence of understanding about lead risks presents a fairly large uncertainty in the overall human health risks in the study area, although aquatic resources probably contribute relatively little to this threat.

9.0. CONCLUSIONS

This document presents a problem formulation, Tier 1 screening, and Tier 2 detailed analysis of human health risks from exposure to aquatic resources in the Greater Lake Washington watershed. Tier 1 used conservative exposure assumptions to identify chemicals of potential concern (COPCs) in aquatic resources that are the focus for Tier 2 analysis.

Tier 2 used site-specific exposure estimates in the study area, to identify "chemicals of concern (COCs) in aquatic resources that likely pose unacceptable carcinogenic, non-carcinogenic, or pathogen risk to human health in the study area." From this analysis, lists of COCs posing the greatest risks to human health were developed. PAHs, pentachlorophenol, and arsenic appear to pose the greatest risk to human health. Chlorinated dioxins and furans, and PCBs are also likely of concern in either based on limited data available (PCBs) or because of the high toxicity associated with them and complete absence of data (dioxins/furans).

Many of these risk drivers were considered problematic from a human or ecological risk perspective prior to this analysis. Chaitin (2004) surveyed 5 King County programs, 2 non-profit agencies, the City of Seattle, Ecology, and the Puget Sound Clean Air Agency. Based on this survey, phthalates, PCBs, and PAHs were all identified by multiple stakeholders as of concern. Ecology identified arsenic as an area-wide COC. Many of these chemicals were identified as prevalent in regional data from Whatcom, Clark, Spokane and Pierce Counties as well. Thus, the presence of these chemicals in the relatively urbanized study area's aquatic resources is expected.

Results from the risk assessment, even under the most conservative domestic water supply and backyard wading use scenario, demonstrate that approximately 4% of the lifetime average Puget Sound cancer risk (NCI, 2005) can be attributed to exposure to aquatic resources. They are the same order of magnitude as the lung cancer risk posed by smoking for 40 years (Bach et al., 2003). Wading alone had risks several orders of magnitude lower, around 2/100ths of 1%. Maps by exposure scenario and location identified the study area waterbodies and sampling locations with the greatest risk. Areas with high population densities appear to have higher than median risks (Figures 8 and 10). Some areas/subbasins specifically discussed include Thornton, Junaita, Lyon and Taylor Creeks.

The bacteriological assessment evaluated a total of 136 sampling locations. Twenty-nine were found to have never exceeded a swimming beach water quality standard of 126 cfu/mL and thus posed an acceptable risk of illness through the data's period of record. There were 37 locations which may pose an unacceptable risk of illness from bacteria but where insufficient data prevented detailed analysis of their risks. The remaining 70 sampling locations were modeled using a Monte Carlo boot-strapping technique to generate probability distributions for their *E. coli* data. These probability distributions were used together with the dose-response relationship from Dufour (1984) to estimate the number of illnesses on a hypothetical day. These illness rates were used to rank the relative importance of each location. Nine locations posed the highest risks of illness, while three posed very low risks of illness. The highest nine were all creeks, while the lowest ranking three were in central portions of Lakes Washington and

Sammamish. The remainder of the 70 analyzed locations were of intermediate risk, with swimming beaches generally ranking low (Table 31).

The purpose of this evaluation was to identify, using a human health risk assessment paradigm and existing data, priorities for future investigations and management actions. Thus, the following recommendations section outlines some departmental priorities in these two areas. One of this document's objectives was to identify data gaps. One of the most important elements of any risk evaluation is having a clearly defined risk management objectives and goals in mind.

> "It is important to recognize that information should be developed *only* to help EPA [or other responsible agencies] determine what actions are necessary to reduce risks, and *not* to fully characterize site risks or eliminate uncertainty from the analysis." (USEPA, 1989. pg 3-1, emphasis added)

Thus, before any public health concerns can be addressed with the best available science, the KC DNRP needs to define specific risk management objectives consistent with its mission and goals prior to conducting further investigations. With risk management goals in mind, KC DNRP scientists can develop the sampling and analysis plans to evaluate and address the greatest risks and economic expertise could be utilized to direct source control efforts where the greatest risk reductions can occur. Thus, discussions of data gaps hinge significantly on the policy and risk management recommendations discussed in Section 9.

10.0. RECOMMENDATIONS

Two types of recommendations, for different audiences, have been developed from the results and conclusions of this HHRA. Scientific and technical recommendations are intended to guide staff when planning changes to various King County monitoring programs. The management recommendations are directed towards middle- to higher-level managers who must prioritize King County environmental programs and overall stewardship.

10.1 Scientific and Technical

From the risks and analysis presented in this HHRA, certain information and/or data gaps have been identified. The more prominent of these, which have limited this risk assessment's ability to fully characterize human health risks in the watershed are discussed below.

Limited analysis of differences between wet weather and dry weather chemical concentrations suggests that large differences in risk are unlikely. Chemical exposures are averaged over long timeframes for human health assessments as well. However, if stormwater management and associated source control is an important issue for King County DNRP, focused comparisons of stormwater, wet weather receiving waters, and dry weather receiving water concentrations are recommended.

Another area for recommended future data collection revolves around non-recreational uses. The Human Use Survey (Parametrix, 2003) has thoroughly characterized the ranges and central tendencies of recreational exposures on the three major lakes in the study area. Beyond occasional anecdotal information about possible surface water withdrawals for drinking water purposes, no robust information is available about the use of privately owned stream, river and lake shorelines and waterbodies. A statistically robust usage survey of these areas is merited to refine King County DNRP understanding of these potential exposures.

Urbanized areas with high population densities appear to have the highest levels of chemicals. While arsenic, PAHs, and chlorinated pesticides in water pose substantive risks, the media about which the least is known and understood are sediment and fish tissue. The current DOH fish advisory is based on very few whole body fish samples and data are insufficient to robustly evaluate recreational, tribal, and Asian Pacific islander risks. From a scientific perspective and human health perspective, further understanding of the spatial variability and impacts of sediment chemicals is warranted. This data gap is further supported by the results of the ecological risk assessment which is a (pending) companion to this document. The combination of the ecological risk assessment's findings of degraded benthic communities, toxicity, sediment quality quideline exceedances, and the HHRA's general insufficiency in evaluating nearshore sediments identifies this media in general as a data gap.

As presented in the discussion, chemicals and pathogens in urban creeks such as Thornton, Lyon, Juanita, and Taylor Creeks potentially pose a significant public health risk depending upon the exact exposure scenario. Locations 4903 and 0852 in Lake Washington and location A522 in Lake Union pose some of the highest human health risks in study area major lakes. Both streams

and lakes deserve more refined human health assessment to understand the frequency and duration at which people are exposed, what chemicals present a risk, when the risks are greatest, how to limit exposure in the near-term, and how to control their sources in the long-term.

The DOH (2004a) risk assessment of fish tissues in Lake Washington has identified risks from fish tissue consumption. This assessment was based on relatively small numbers of fish and was limited to Lake Washington. For instance, only 3 smallmouth bass and 10 of the larger size classes of cutthroat trout and northern pikeminnow were available. Additionally, all of the fish were analyzed as whole body samples, not as fillets which are typically consumed. The number of samples and species available for Lakes Union and Sammamish was even more limited. These limitations pose significant constraints on the understanding of human health risks from the consumption of fish in the study area. Further study of the levels of persistent chemicals in fish tissue and fate and transport of bioaccumulative substances into fish tissue is warranted.

In addition to insufficient information regarding the concentrations of COCs in tissues, there is little information regarding sources of these chemicals. Further information on the nature of bioaccumulative tissue contaminant sources and particularly whether those sources are historic or ongoing is prudent.

As discussed in the conclusions, PAHs, pentachlorophenol, and arsenic appear to be some of the greatest sources of human health risk which were analyzed across all scenarios. Chlorinated dioxins and furans, and PCBs are two potential sources of risk which were never analyzed or only sporadically analyzed respectively. From a human health perspective, these 5 chemical groups merit the most study since they appear to contribute the highest risk and/or the highest uncertainties.

10.2 Risk Management

The results of this HHRA are principally intended to identify data gaps and guide future assessment and monitoring efforts. The sensitivity and uncertainty sections have identified the dominant influences on human health risks. As discussed in the sensitivity section, 50% shifts in chemical concentrations only moderately influenced the overall cancer probabilities, but had a larger impact on the non-cancer endpoints. The study area also has a very large population and substantial variation in exposures exists. Combined, these facts suggest that additional data refining recreational 95th percentile human exposures and/or exposure point concentrations would not inform the public or decision makers substantively. Collecting additional data to allow for spatial and/or temporal averaging of concentrations across realistic areas of human use would allow for the most refined risk estimates. First priority for these data should be swimming beaches where data is generally absent.

Given the large geographic area of assessment, the data requirements are very high to provide sufficient data density watershed-wide. With proper definition of populations of interest, statistically robust random sampling can reduce data requirements. However, such a broad scale investigation requires concrete objectives to ensure the data answer definite questions and hypotheses.

Collecting additional information to inform and guide the public and management about the risks and status of study area water, sediment and fish tissue quality, including data to develop spatial and temporal averages, should be planned with the risk management objectives and goals in mind. USEPA guidance (1989) likewise stresses the planned, appropriate collection of data for risk assessment and management purposes.

Thus, to ensure that public health concerns are addressed with the best available science, the KC DNRP needs to define specific risk management objectives consistent with its mission and goals prior to conducting further risk investigations. Objectives should target activities under King County control and potential responsibility, and lead to the wise investment of tax and ratepayer resources in either exposure management tools (e.g. swimming beach closure program) or infrastructure improvements addressing prominent human health risks. Objectives should be developed in coordination with affected municipalities and other jurisdictions potential interest and responsibility for our shared waterbodies. With risk management goals in mind, KC DNRP scientists can develop the sampling and analysis plans to evaluate and address the greatest risks and economic expertise could be utilized to direct source control efforts where the greatest risk reductions can occur.

Adding parameters or sampling locations in an indiscriminate manner to existing ambient monitoring programs without specific risk management objectives (hypotheses) in mind would not be "best available science". A sporadic approach to sampling and/or analysis may inform management or the public about health risks, but has been recognized by EPA (1989) as inefficient for actual risk management. Thus, the recommended approach is to elucidate programmatic risk management objectives prior to making changes to King County's environmental monitoring efforts.

At this time, targeted efforts to identify the prominent sources and fate and transport pathways of the major risk drivers like PAHs, PCBs, pentachlorophenol, and arsenic are needed to direct resources towards manageable problems. Some of these chemicals may originate from stormwater runoff or combined sewer overflows, two sources potentially under King County jurisdiction. Others, such as PCBs in fish tissue, are likely to have accumulated up the food chain from sediment. A source identification study on a watershed-wide scale similar to the Puget Sound Partnership's could estimate loadings from direct permitted discharges from commercial/industrial properties, CSOs and stormwater outfalls to evaluate their relative contributions to ambient waters. The near-field modeling of the Duwamish CSOs may serve as an example (Parametrix, 1999). Another example of systematic prioritization of watershed pollution problems can be found in the Puget Sound Action team's efforts to understand low dissolved oxygen in Hood Canal (PSAT, 2006). This latter study has used estimates of relative nitrogen contributions (which leads to algal blooms and low DO) to prioritize pollution control actions.

Depending on management objectives, three different examples of programmatic objectives are provided below:

1. Develop a mass balance for PAHs in the greater Lake Washington major lakes and prioritize reduction efforts with other local jurisdictions,

2. Understand relative contributions of combined sewer overflow and stormwater discharges for bacteria control,

3. Increasing DNRP and partner jurisdictions and agency's knowledge of the fate and transport of PCBs from water, sediment, air, etc. into fish tissue to prioritize source control efforts.

These are merely three examples addressing the types of contaminant sources under the leadership and influence of King County and its jurisdiction. Other sources of human health risks may be significant, e.g. air quality. However, the KC DNRP has a limited ability to address every possible environmental human health threat. Many of the other environmental threats are best addressed by State initiatives and leadership, e.g. statewide mercury fish advisories. Governor Christine Gregoire's Puget Sound Initiative (Gregoire, 2005) is one example of a statewide toxics program.

Under broad programmatic objectives addressing sources under potential DRNP control, King County scientists can develop concrete, testable hypotheses. With defined management objectives and testable hypotheses, project specific investigations can utilize the appropriate analytical and statistical methods to address analytes of concern. Best available science requires all of these elements working in concert. This approach also allows for efficient use of public resources to address the more prominent likely management concerns: PAHs, pentachlorophenol, arsenic, and bacteria in water, and PCBs in sediment and fish tissue.

This report has identified a list of prospective analytes of highest concern. This assessment has also documented some locations with higher than average human health risks. Combined, this information should inform future studies of site and parameter specific human health risks. Developing specific management objectives is the next step, although they are beyond the scope of this document.

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Appendix A

Tier 1 Screening

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Appendix A-1: Tier 1 Screening for Chemicals Measured in Water

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
1,1,1-Trichloroethane	1,1,1-TRICHLOROETHANE	71556	1	3.17E+03	N	3.2E+02	No	No	-	No	
1,1,2,2-Tetrachloroethane	1,1,2,2-TETRACHLOROETHANE	79345	1	2.40E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
1,1,2-Trichloroethane	1,1,2-TRICHLOROETHANE	79005	1	8.54E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
1,1,2-Trichloroethylene	TRICHLOROETHENE	79016	1	1.20E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
1,1-Dichloroethane	1,1-DICHLOROETHANE	75343	1	7.98E+02	N	8.0E+01	No	No	-	No	
1,1-Dichloroethylene	1,1-DICHLOROETHENE	75354	1	3.53E+02	N	3.5E+01	No	No	-	No	
1,2,4-Trichlorobenzene	1,2,4-TRICHLOROBENZENE	120821	0.15	7.16E+00	N	7.2E-01	No	No	-	No	
1,2-Dichlorobenzene	1,2-DICHLOROBENZENE	95501	0.15	2.68E+02	N	2.7E+01	No	No	-	No	
1,2-Dichloroethane	**1,2-DICHLOROETHANE	107062	1	5.27E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
1,2-Dichloropropane	1,2-DICHLOROPROPANE	78875	1	4.35E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
1,2-Diphenylhydrazine	1,2-DIPHENYLHYDRAZINE	122667	0.49	3.70E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
1,3-Dichlorobenzene	1,3-DICHLOROBENZENE	541731	0.15	1.83E+01	N	1.8E+00	No	No	-	No	
1,4-Dichlorobenzene	1,4-DICHLOROBENZENE	106467	0.5	2.15E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
1,6,7-Trimethylnaphthalene		2245387	0.001			-	-	-	Yes, Detected w/No SC	No	
18a-Oleanane			0.0094			-	-	-	Yes, Detected w/No SC	No	
1-Methylnaphthalene		90120	0.5			-	-	-	Yes, Detected w/No SC	No	
1-Methylphenanthrene		832699	0.005			-	-	-	Yes, Detected w/No SC	No	
1-Napthol		90153	0.3			-	-	-	-	No	
2,3,4,5-Tetrachlorophenol		4901513	0.14			-	-	-	-	No	
2,3,4,6-Tetrachlorophenol	2,3,4,6-TETRACHLOROPHENOL	58902	0.14	1.10E+03	N	1.1E+02	No	No	-	No	
2,4,5-T	2,4,5-T	93765	0.68	3.65E+02	N	3.7E+01	No	No	-	No	
2,4,5-TB			0.24			-	-	-	-	No	
2,4,5-TP (Silvex)	2-(2,4,5-TRICHLOROPHENOXY)PROPIC	93721	0.21	2.92E+02	N	2.9E+01	No	No	-	No	
2,4,5-Trichlorophenol	2,4,5-TRICHLOROPHENOL	95954	0.98	3.65E+03	N	3.7E+02	No	No	-	No	
2,4,6-Trichlorophenol	2,4,6-TRICHLOROPHENOL	88062	0.98	2.69E+00	C	-	No	No	-	No	
2,4-D	2,4-D	94757	4.96	3.65E+02	N	3.7E+01	No	No	-	No	
2,4-DB	4-(2,4-DICHLOROPHENOXY)BUTYRIC A	94826	0.31	2.92E+02	N	2.9E+01	No	No	-	No	
2,4'-DDD		53190	0.39			-	-	-	-	No	
2,4'-DDE		3424826	0.39			-	-	-	-	No	
2,4'-DDT		789026	0.39			-	-	-	-	No	
2,4-Dichlorophenol	2,4-DICHLOROPHENOL	120832	0.49	1.10E+02	N	1.1E+01	No	No	-	No	
2,4-Dimethylphenol	2,4-DIMETHYLPHENOL	105679	1.7	7.30E+02	N	7.3E+01	No	No	-	No	
2,4-Dinitrophenol	2,4-DINITROPHENOL	51285	1.4	7.30E+01	N	7.3E+00	No	No	-	No	
2,4-Dinitrotoluene	2,4-DINITROTOLUENE	121142	0.98	7.30E+01	N	7.3E+00	No	No	-	No	
2,6-Diethylaniline		579668	0.006			-	-	-	-	No	
2,6-Dimethylnaphthalene		581420	0.5			-	-	-	Yes, Detected w/No SC	No	
2,6-Dinitrotoluene	2,6-DINITROTOLUENE	606202	0.98	3.65E+01	N	3.7E+00	No	No	-	No	
2-Butanone (MEK)	**METHYL ETHYL KETONE (2-BUTANO	78933	5	6.97E+03	N	7.0E+02	No	No	-	No	
2-Chloroethylvinyl ether		110758	1			-	-	-	-	No	
2-Chloronaphthalene	BETA-CHLORONAPHTHALENE	91587	0.31	4.87E+02	N	4.9E+01	No	No	-	No	
2-Chlorophenol	2-CHLOROPHENOL	95578	0.49	3.04E+01	N	3.0E+00	No	No	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
2-Hexanone		591786	5			-	-	-	-	No	
2-Methylnaphthalene	2-METHYLNAPHTHALENE	91576	1.25	2.43E+01	N	2.4E+00	No	No	-	**Yes**	4
2-Methylphenol	2-METHYLPHENOL	95487	2.06	1.83E+03	N	1.8E+02	No	No	-	No	
2-Nitroaniline	**2-NITROANILINE	88744	0.98	1.10E+02	N	1.1E+01	No	No	-	No	
2-Nitrophenol		88755	0.301			-	-	-	Yes, Detected w/No SC	No	
3,3'-Dichlorobenzidine	3,3'-DICHLOROBENZIDINE	91941	0.85	6.57E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
3,5-Dichlorobenzoic acid		51365	0.26			-	-	-	-	No	
3-beta-Coprostanol			2			-	-	-	-	No	
3-Hydroxycarbofuran		16655826	0.12			-	-	-	-	No	
3-Methylphenol	3-METHYLPHENOL	108394	0.552	1.83E+03	N	1.8E+02	No	No	-	No	
3-Nitroaniline	3-NITROANILINE	99092	0.98	1.48E+00	C	-	No	No	-	No	
3-Tert-butyl-4-hydroxy anisole (BHA)		121006	5			-	-	-	-	No	
4,4'-DDD	DDD	72548	0.39	1.23E-01	C	-	**Yes**	-	-	**Yes**	1
4,4'-DDE	DDE	72559	0.39	8.70E-02	C	-	**Yes**	-	-	**Yes**	1
4,4'-DDT	DDT	50293	0.39	8.70E-02	C	-	**Yes**	-	-	**Yes**	1
4,6-Dinitro-O-Cresol	4,6-DINITRO-2-METHYLPHENOL	534521	1.1	3.65E+00	N	3.7E-01	No	**Yes**	-	**Yes**	2
4-Bromophenyl Phenyl Ether		101553	0.17			-	-	-	-	No	
4-Chloro-3-Methylphenol		59507	0.49			-	-	-	-	No	
4-Chloroaniline	4-CHLOROANILINE	106478	0.49	1.46E+02	N	1.5E+01	No	No	-	No	
4-Chlorophenyl Phenyl Ether		7005723	0.25			-	-	-	-	No	
4-Cumylphenol		599644	1			-	-	-	-	No	
4-Methyl-2-Pentanone (MIBK)	**METHYL ISOBUTYL KETONE (4-METH	108101	5	6.28E+03	N	6.3E+02	No	No	-	No	
4-Methylphenol	4-METHYLPHENOL	106445	4.62	1.83E+02	N	1.8E+01	No	No	-	No	
4-Nitroaniline	4-NITROANILINE	100016	0.98	1.48E+00	C	-	No	No	-	No	
4-Nitrophenol		100027	5.06			-	-	-	Yes, Detected w/No SC	No	
4-Nonylphenol		104405	44.2			-	-	-	Yes, Detected w/No SC	No	
4-Octylphenol		1806264	1			-	-	-	-	No	
4-Tert-octylphenol		140669	1			-	-	-	-	No	
Abate (Temephos)		3383968	0.7			-	-	-	-	No	
Acenaphthene	ACENAPHTHENE	83329	0.824	3.65E+02	N	3.7E+01	No	No	-	**Yes**	4
Acenaphthylene		208968	0.29			-	-	-	Yes, Detected w/No SC	No	
Acephate		30560191	0.3			-	-	-	-	No	
Acetochlor	ACETOCHLOR	34256821	0.006	7.30E+02	N	7.3E+01	No	No	-	No	
Acetone	**ACETONE	67641	13	5.48E+03	N	5.5E+02	No	No	-	No	
Acetophenone	**ACETOPHENONE	98862	0.5	6.08E+02	N	6.1E+01	No	No	-	No	
Acetyl hexamethyl tetrahydro naphthalene			0.5			-	-	-	-	No	
Acifluorfen (Blazer)		50594666	1			-	-	-	-	No	
Acrolein	**ACROLEIN	107028	5	4.15E-02	N	4.2E-03	**Yes**	-	Yes, MDL>SC	No	
Acrylonitrile	ACRYLONITRILE	107131	5	1.66E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Alachlor	ALACHLOR	15972608	0.56	3.70E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
Aldicarb	ALDICARB	116063	0.12	3.65E+01	N	3.7E+00	No	No	-	No	
Aldicarb sulfone	ALDICARB SULFONE	1646884	0.12	3.65E+01	N	3.7E+00	No	No	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Aldicarb sulfoxide		1646873	0.12			-	-	-	-	No	
Aldrin	ALDRIN	309002	0.39	1.74E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Alpha-BHC	ALPHA-HCH	319846	0.39	4.69E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Aluminum, Total, ICP-MS	ALUMINUM	7429905	3360	3.65E+04	N	3.7E+03	No	No	-	No	
Ametryn		834128	0.16			-	-	-	-	No	
Aminomethylphosphonic acid		1066519	1.3			-	-	-	-	No	
Ammonia-nitrogen		7727379	4920			-	-	-	Yes, Detected w/No SC	No	
Aniline	ANILINE	62533	2	5.19E+00	C	-	No	No	-	No	
Anthracene	ANTHRACENE	120127	0.5	1.83E+03	N	1.8E+02	No	No	-	**Yes**	4
Anthraquinone (9,10-Anthraquinone)		84651	0.5			-	-	-	-	No	
Antimony, Total, ICP-MS	ANTIMONY	7440360	24.9	1.46E+01	N	1.5E+00	**Yes**	-	-	**Yes**	1
Aroclor 1016	AROCLOR-1016	12674112	0.057	4.22E-01	C	-	No	No	-	No	
Aroclor 1221	AROCLOR-1221	11104282	0.057	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Aroclor 1232	AROCLOR-1232	11141165	0.057	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Aroclor 1242	AROCLOR-1242	53469219	0.057	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Aroclor 1248	AROCLOR-1248	12672296	0.057	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
Aroclor 1254	AROCLOR-1254	11097691	0.057	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
Aroclor 1260	AROCLOR-1260	11096825	0.057	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
Arsenic, Total, ICP	ARSENIC	7440382	50	1.97E-02	C	-	**Yes**	-	-	**Yes**	1
Atraton		1610179	0.23			-	-	-	-	No	
Atrazine	ATRAZINE	1912249	0.98	1.34E-01	C	-	**Yes**	-	-	**Yes**	1
Azinphos-ethyl		2642719	0.25			-	-	-	-	No	
Azinphos-methyl (Guthion)		86500	0.25			-	-	-	-	No	
Barium, Total, ICP-MS	BARIUM	7440393	394	2.56E+03	N	2.6E+02	No	**Yes**	-	**Yes**	2
Baygon (Propoxur)	BAYGON	114261	0.12	1.46E+02	N	1.5E+01	No	No	-	No	
Benefin		1861401	0.23			-	-	-	-	No	
Bentazon	BENTAZON	25057890	0.39	1.10E+03	N	1.1E+02	No	No	-	No	
Benzamide, 2,6-dichloro-		2008584	0.21			-	-	-	Yes, Detected w/No SC	No	
Benzene	BENZENE	71432	1	1.52E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
Benzidine	BENZIDINE	92875	5.9	1.29E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Benzo(a)anthracene	BENZ[A]ANTHRACENE	56553	0.417	4.05E-02	C	-	**Yes**	-	-	**Yes**	1
Benzo(a)pyrene	BENZO[A]PYRENE	50328	0.5	4.05E-03	C	-	**Yes**	-	-	**Yes**	1
Benzo(b)fluoranthene	BENZO[B]FLUORANTHENE	205992	0.461	4.05E-02	C	-	**Yes**	-	-	**Yes**	1
Benzo(e)pyrene		192972	0.113			-	-	-	Yes, Detected w/No SC	No	
Benzo(g,h,i)perylene		191242	0.477			-	-	-	Yes, Detected w/No SC	No	
Benzo(k)fluoranthene	BENZO[K]FLUORANTHENE	207089	0.39	4.05E-01	C	-	No	No	-	**Yes**	3
Benzoic acid	BENZOIC ACID	65850	10.8	1.46E+05	N	1.5E+04	No	No	-	No	
Benzophenone		119619	0.5			-	-	-	-	No	
Benzothiophene, Total		11095435	0.0113			-	-	-	Yes, Detected w/No SC	No	
Benzyl alcohol	BENZYL ALCOHOL	100516	3.01	1.10E+04	N	1.1E+03	No	No	-	No	
Benzyl butyl phthalate	BUTYLBENZYLPHTHALATE	85687	2.06	7.30E+03	N	7.3E+02	No	No	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Beryllium, Total, ICP-MS	BERYLLIUM	7440417	1.6	7.30E+01	N	7.3E+00	No	No	-	No	
Beta-BHC	BETA-HCH	319857	0.39	1.64E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Beta-sitosterol		83465	2			-	-	-	-	No	
Biphenyl	BIPHENYL	92524	0.0103	3.04E+02	N	3.0E+01	No	No	-	No	
Bis(2-Chloroethoxy)Methane		111911	0.33			-	-	-	-	No	
Bis(2-Chloroethyl)Ether	BIS(2-CHLOROETHYL)ETHER	111444	0.29	4.36E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Bis(2-Chloroisopropyl)Ether	BIS(2-CHLOROISOPROPYL)ETHER	108601	0.49	1.18E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
Bis(2-ethylhexyl)adipate	DI(2-ETHYLHEXYL)ADIPATE	103231	2.12	2.46E+01	C	-	No	No	-	No	
Bis(2-Ethylhexyl)Phthalate	BIS(2-ETHYLHEXYL)PHTHALATE	117817	148	2.11E+00	C	-	**Yes**	-	-	**Yes**	1
Bisphenol A		80057	9.14			-	-	-	Yes, Detected w/No SC	No	
Bolstar (Sulprofos)		35400432	0.11			-	-	-	-	No	
Bromacil		314409	0.62			-	-	-	Yes, Detected w/No SC	No	
Bromodichloromethane	BROMODICHLOROMETHANE	75274	1	4.77E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
Bromoform	BROMOFORM	75252	1	3.74E+00	C	-	No	No	-	No	
Bromomethane	BROMOMETHANE	74839	1	8.52E+00	N	8.5E-01	No	**Yes**	-	No	
Bromoxynil		1689845	0.26			-	-	-	-	No	
Butachlor		23184669	0.93			-	-	-	-	No	
Butylate	BUTYLATE	2008415	0.31	1.83E+03	N	1.8E+02	No	No	-	No	
C29-Hopane			0.0604			-	-	-	-	No	
C30-Hopane			0.0837			-	-	-	-	No	
Cadmium, Total, ICP	CADMIUM-WATER	7440439	3	1.83E+01	N	1.8E+00	No	**Yes**	-	**Yes**	2
Caffeine		58082	7.71			-	-	-	Yes, Detected w/No SC	No	
Camphor		76222	0.5			-	-	-	-	No	
Captafol		2939802	1.9			-	-	-	-	No	
Captan		133062	1			-	-	-	-	No	
Carbaryl	CARBARYL	63252	1	3.65E+03	N	3.7E+02	No	No	-	No	
Carbazole	CARBAZOLE	86748	0.5	1.48E+00	C	-	No	No	-	No	
Carbofuran		1563662	0.4			-	-	-	Yes, Detected w/No SC	No	
Carbon Tetrachloride	CARBON TETRACHLORIDE	56235	1	7.33E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Carbophenothion		786196	0.8			-	-	-	-	No	
Carboxin		5234684	0.93			-	-	-	-	No	
Chlordane	CHLORDANE	57749	0.194	8.45E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Chlordecone (Kepone)	**KEPONE	143500	0.24	3.70E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Chlorobenzene	CHLOROBENZENE	108907	1	1.06E+02	N	1.1E+01	No	No	-	No	
Chlorodibromomethane	DIBROMOCHLOROMETHANE	124481	1	3.52E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
Chloroethane	CHLOROETHANE	75003	1	1.02E+01	C	-	No	No	-	No	
Chloroform	CHLOROFORM	67663	1	7.07E-02	N	7.1E-03	**Yes**	-	Yes, MDL>SC	No	
Chlorothalonil (Daconil)		1897456	0.37			-	-	-	-	No	
Chlorpropham		101213	0.62			-	-	-	-	No	
Chlorpyrifos	CHLORPYRIFOS	2921882	0.5	1.10E+02	N	1.1E+01	No	No	-	No	
Chlorpyrifos-methyl	CHLORPYRIFOS-METHYL	5598130	0.12	3.65E+02	N	3.7E+01	No	No	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Cholesterol		57885	2			-	-	-	Yes, Detected w/No SC	No	
Chromium, Total, ICP-MS	CHROMIUM III	16065831	43.7	5.48E+04	N	5.5E+03	No	No	-	No	
Chromium, Total, ICP-MS	CHROMIUM VI	18540299	43.7	1.10E+02	N	1.1E+01	No	**Yes**	-	**Yes**	2
Chrysene	CHRYSENE	218019	0.634	4.05E+00	C	-	No	No	-	**Yes**	3
cis-1,3-Dichloropropene		10061015	1			-	-	-	-	No	
cis-Chlordane		5103719	0.39			-	-	-	-	No	
cis-Chlordene			0.043			-	-	-	-	No	
cis-Nonachlor		5103731	0.39			-	-	-	-	No	
cis-Permethrin		54774457	0.006			-	-	-	-	No	
Cobalt, Total, ICP-MS	COBALT	7440484	37	7.30E+02	N	7.3E+01	No	No	-	No	
Copper, Total, ICP-MS	COPPER	7440508	179	1.46E+03	N	1.5E+02	No	**Yes**	-	**Yes**	2
Cotinine		486566	1			-	-	-	-	No	
Coumaphos		56724	0.09			-	-	-	-	No	
Cyanazine	CYANAZINE	21725462	0.23	3.52E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Cycloate		1134232	0.31			-	-	-	-	No	
Dacthal (DCPA)	DACTHAL	1861321	0.21	3.65E+02	N	3.7E+01	No	No	-	No	
Dalapon	DALAPON	75990	0.17	1.10E+03	N	1.1E+02	No	No	-	No	
DDMU		1022226	0.035			-	-	-	-	No	
Decalin, Total		91178	0.0058			-	-	-	Yes, Detected w/No SC	No	
Deethyl atrazine		6190654	0.006			-	-	-	-	No	
delta-BHC		319868	0.39			-	-	-	-	No	
Demeton-O		298033	0.11			-	-	-	-	No	
Demeton-S		126750	0.11			-	-	-	-	No	
Desulfinylfipronil			0.004			-	-	-	-	No	
Diallate (Avadex)		2303164	1.1			-	-	-	-	No	
Diazinon	DIAZINON	333415	0.82	3.29E+01	N	3.3E+00	No	No	-	No	
Dibenzo(a,h)anthracene	DIBENZ[A,H]ANTHRACENE	53703	0.39	4.05E-03	C	-	**Yes**	-	-	**Yes**	1
Dibenzofuran	DIBENZOFURAN	132649	0.515	1.22E+01	N	1.2E+00	No	No	-	No	
Dibenzothiophene, Total		132650	0.0265			-	-	-	Yes, Detected w/No SC	No	
Dicamba	DICAMBA	1918009	0.38	1.10E+03	N	1.1E+02	No	No	-	No	
Dichlobenil		1194656	0.31			-	-	-	Yes, Detected w/No SC	No	
Dichloroprop		120365	0.29			-	-	-	Yes, Detected w/No SC	No	
Dichlorvos (DDVP)	DICHLORVOS	62737	1	1.02E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
Diclofop-methyl		51338273	0.39			-	-	-	-	No	
Dicofol (Kelthane)		115322	1.6			-	-	-	-	No	
Dieldrin	DIELDRIN	60571	0.39	1.85E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Diethoxy-nonylphenol			5			-	-	-	-	No	
Diethoxyoctylphenol			1			-	-	-	-	No	
Diethyl Phthalate	DIETHYLPHTHALATE	84662	2.55	2.92E+04	N	2.9E+03	No	No	-	No	
Dimethoate		60515	0.12			-	-	-	-	No	
Dimethyl Phthalate	DIMETHYLPHTHALATE	131113	1.71	3.65E+05	N	3.7E+04	No	No	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Di-N-Butyl Phthalate	DIBUTYLPHTHALATE	84742	2.47	3.65E+03	N	3.7E+02	No	No	-	No	
Di-N-Octyl Phthalate	**DIOCTYLPHTHALATE	117840	3.23	1.46E+03	N	1.5E+02	No	No	-	No	
Dinoseb	DINOSEB	88857	0.39	3.65E+01	N	3.7E+00	No	No	-	No	
Dioxathion		78342	0.12			-	-	-	-	No	
Diphenamid		957517	0.47			-	-	-	-	No	
Disulfoton (Di-Syston)	DISULFOTON	298044	0.41	1.46E+00	N	1.5E-01	No	**Yes**	-	**Yes**	2
Diuron	DIURON	330541	0.93	7.30E+01	N	7.3E+00	No	No	-	No	
D-Limonene		5989275	0.5			-	-	-	-	No	
Endosulfan I		959988	0.39			-	-	-	Yes, Detected w/No SC	No	
Endosulfan II		33213659	0.39			-	-	-	-	No	
Endosulfan sulfate		1031078	0.39			-	-	-	-	No	
Endrin	ENDRIN	72208	0.49	1.10E+01	N	1.1E+00	No	No	-	No	
Endrin aldehyde		7421934	0.39			-	-	-	-	No	
Endrin ketone		53494705	0.39			-	-	-	-	No	
EPN		2104645	0.16			-	-	-	-	No	
Eptam		759944	0.31			-	-	-	-	No	
EPTC		759944	0.002			-	-	-	-	No	
Equilenin		517099	5			-	-	-	-	No	
Escherichia coli		bacteria	31,000	no detects	N	0.0E+00	**Yes**	-	-	**Yes**	1
Estradiol		50282	5			-	-	-	Yes, Detected w/No SC	No	
Estrone		53167	5			-	-	-	-	No	
Ethalfluralin (Sonalan)		55283686	0.23			-	-	-	-	No	
Ethanol, 2-butoxy-, phosphate (3:1)		78513	0.21			-	-	-	-	No	
Ethion	ETHION	563122	0.11	1.83E+01	N	1.8E+00	No	No	-	No	
Ethofumesate		26225796	2.4			-	-	-	-	No	
Ethoprop		13194484	0.12			-	-	-	-	No	
Ethylbenzene	ETHYLBENZENE	100414	1	1.34E+03	N	1.3E+02	No	No	-	No	
Ethynyl estradiol		57636	5			-	-	-	-	No	
Fecal coliforms		bacteria	40,000	no detects	N	0.0E+00	**Yes**	-	-	**Yes**	1
Fenamiphos	FENAMIPHOS	22224926	0.23	9.13E+00	N	9.1E-01	No	No	-	No	
Fenarimol		60168889	0.47			-	-	-	-	No	
Fenitrothion		122145	0.11			-	-	-	-	No	
Fensulfothion		115902	0.16			-	-	-	-	No	
Fenthion		55389	0.11			-	-	-	-	No	
Fipronil		1.2E+08	0.007			-	-	-	-	No	
Fipronil sulfide			0.005			-	-	-	-	No	
Fipronil sulfone			0.005			-	-	-	-	No	
Fluoranthene	FLUORANTHENE	206440	0.985	1.46E+03	N	1.5E+02	No	No	-	**Yes**	3
Fluorene	FLUORENE	86737	1.14	2.43E+02	N	2.4E+01	No	No	-	**Yes**	3
Fluoride		16984488	200			-	-	-	Yes, Detected w/No SC	No	
Fluridone		59756604	0.93			-	-	-	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Fonofos	FONOFOS	944229	0.093	7.30E+01	N	7.3E+00	No	No	-	No	
gamma-BHC (Lindane)	GAMMA-HCH (LINDANE)	58899	0.39	2.27E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
gamma-Chlordane		5103742	0.39			-	-	-	-	No	
gamma-Chlordene		56641384	0.035			-	-	-	-	No	
Glufosinate		51276472	0.1			-	-	-	-	No	
Glyphosate	GLYPHOSATE	1071836	2	3.65E+03	N	3.7E+02	No	No	-	No	
Heptachlor	HEPTACHLOR	76448	0.39	6.57E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Heptachlor epoxide	HEPTACHLOR EPOXIDE	1024573	0.39	3.25E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Hexachlorobenzene	HEXACHLOROBENZENE	118741	0.39	1.85E-02	C	-	**Yes**	-	-	**Yes**	1
Hexachlorobutadiene	HEXACHLOROBUTADIENE	87683	0.25	3.79E-01	C	-	No	No	-	No	
Hexachlorocyclopentadiene	HEXACHLOROCYCLOPENTADIENE	77474	2	2.19E+02	N	2.2E+01	No	No	-	No	
Hexachloroethane	HEXACHLOROETHANE	67721	0.29	2.11E+00	C	-	No	No	-	No	
Hexahydrohexamethyl cyclopentabenzopyran			0.5			-	-	-	-	No	
Hexazinone	HEXAZINONE	51235042	0.23	1.20E+03	N	1.2E+02	No	No	-	No	
Imidan		732116	0.17			-	-	-	-	No	
Indeno(1,2,3-cd)pyrene	INDENO[1,2,3-C,D]PYRENE	193395	0.448	4.05E-02	C	-	**Yes**	-	-	**Yes**	1
Indole		120729	0.5			-	-	-	-	No	
Ioxynil		1689834	0.26			-	-	-	-	No	
Iron, Total, ICP	IRON	7439896	73200	1.10E+04	N	1.1E+03	**Yes**	-	-	**Yes**	1
Isoborneol		124765	0.5			-	-	-	-	No	
Isophorone	ISOPHORONE	78591	1.3	3.11E+01	C	-	No	No	-	No	
Isopropylbenzene (cumene)	CUMENE	98828	0.5	6.58E+02	N	6.6E+01	No	No	-	No	
Isoquinoline		119653	0.5			-	-	-	-	No	
Lead, Total, ICP-MS		7439921	111	1.50E+01	N	1.5E+00	**Yes**	-	-	**Yes**	1(a)
Linuron		330552	0.035			-	-	-	-	No	
Magnesium, Dissolved		7439954	14300			-	-	-	-	No	
Malathion	MALATHION	121755	0.216	7.30E+02	N	7.3E+01	No	No	-	No	
Manganese, Total, ICP-MS	MANGANESE-NONFOOD	7439965	168	7.30E+02	N	7.3E+01	No	**Yes**	-	**Yes**	2
Manganese, Total, ICP-MS	MANGANESE-FOOD	7439965	168	5.11E+03	N	5.1E+02	No	No	-	No	
MCPA	2-METHYL-4-CHLOROPHENOXYACETI	94746	0.51	1.83E+01	N	1.8E+00	No	No	-	No	
MCPP (Mecoprop)		7085190	0.77			-	-	-	Yes, Detected w/No SC	No	
Menthol		89781	0.5			-	-	-	-	No	
Mercury, Total, CVAA	MERCURY (INORGANIC)	7439976	0.46	2.00E+00		-	No	No	-	**Yes**	4
Merphos		150505	0.19			-	-	-	-	No	
Metalaxyl		57837191	0.93			-	-	-	-	No	
Methamidophos		10265926	0.3			-	-	-	-	No	
Methiocarb		2032657	0.12			-	-	-	-	No	
Methomyl		16752775	0.12			-	-	-	-	No	
Methoxychlor	METHOXYCHLOR	72435	0.39	1.83E+02	N	1.8E+01	No	No	-	No	
Methyl salicylate		119368	0.5			-	-	-	-	No	
Methyl Chloride	CHLOROMETHANE	74873	1	1.90E+02	N	1.9E+01	No	No	-	No	
Methylene Chloride	METHYLENE CHLORIDE	75092	1	1.85E+00	C	-	No	No	-	No	
Methyltestosterone		58184	0.49			-	-	-	-	No	
Metolachlor	METOLACHLOR (DUAL)	51218452	0.62	5.48E+03	N	5.5E+02	No	No	-	No	
Metribuzin (Sencor)		21087649	0.16			-	-	-	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Mevinphos		7786347	0.075			-	-	-	-	No	
MGK-264		113484	1.2			-	-	-	-	No	
Microcystin-LR			0.6	1.00E+00		-	No	No	-	No	
Mirex	MIREX	2385855	0.39	7.30E+00	N	7.3E-01	No	No	-	No	
Molinate		2212671	0.31			-	-	-	-	No	
Molybdenum, Total, ICP	MOLYBDENUM	7439987	20	1.83E+02	N	1.8E+01	No	**Yes**	-	**Yes**	2
Monoethoxyoctylphenol			1			-	-	-	-	No	
N,N-Diethyl-meta-toluamide (DEET)		134623	0.5			-	-	-	-	No	
Naphthalene	NAPHTHALENE	91203	3.3545	6.51E+00	N	6.5E-01	No	**Yes**	-	**Yes**	2
Naphthobenzothiophene, Total			0.0764			-	-	-	Yes, Detected w/No SC	No	
Napropamide		15299997	0.47			-	-	-	-	No	
Nickel, Total, ICP-MS	NICKEL	7440020	51.6	7.30E+02	N	7.3E+01	No	No	-	No	
Nitrate nitrogen (as NO3)		14797558	6210	1.00E+01	N	1.0E+00	**Yes**	-	-	**Yes**	1(a)
Nitrite nitrogen (as NO2)		14797650	102	1.00E+00	N	1.0E-01	**Yes**	-	-	**Yes**	1(a)
Nitrobenzene	NITROBENZENE	98953	0.31	3.53E+00	N	3.5E-01	No	No	-	No	
N-Nitrosodimethylamine	**N-NITROSODIMETHYLAMINE	62759	0.98	5.80E-04	C	-	**Yes**	-	-	**Yes**	1
N-Nitrosodi-N-Propylamine	N-NITROSODIPROPYLAMINE	621647	0.25	4.22E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
N-Nitrosodiphenylamine	**N-NITROSODIPHENYLAMINE	86306	0.38	6.04E+00	C	-	No	No	-	No	
Norflurazon		27314132	0.31			-	-	-	-	No	
Ortho-Phosphate (as PO4)			236			-	-	-	Yes, Detected w/No SC	No	
Oxadiazon	OXADIAZON	19666309	0.066	1.83E+02	N	1.8E+01	No	No	-	No	
Oxamyl (Vydate)	OXAMYL	23135220	0.12	9.13E+02	N	9.1E+01	No	No	-	No	
Oxychlordane		26880488	0.39			-	-	-	-	No	
Oxyfluorofen	OXYFLUORFEN	42874033	0.62	1.10E+02	N	1.1E+01	No	No	-	No	
Paraoxon-methyl		950356	0.15			-	-	-	-	No	
Parathion	PARATHION	56382	0.12	2.19E+02	N	2.2E+01	No	No	-	No	
Parathion-methyl	METHYL PARATHION	298000	0.11	9.13E+00	N	9.1E-01	No	No	-	No	
Pebulate		1114712	0.31			-	-	-	-	No	
Pendimethalin		40487421	0.23			-	-	-	-	No	
Pentachloroanisole		1825214	0.39			-	-	-	-	No	
Pentachlorophenol	PENTACHLOROPHENOL	87865	2	2.46E-01	C	-	**Yes**	-	-	**Yes**	1
Perylene		198550	0.0473			-	-	-	Yes, Detected w/No SC	No	
Phenanthrene		85018	1.04			-	-	-	Yes, Detected w/No SC	No	
Phenol	PHENOL	108952	11.2	1.10E+04	N	1.1E+03	No	No	-	No	
Phorate		298022	0.11			-	-	-	-	No	
Phosphamidan			0.18			-	-	-	-	No	
Phosphorus, total	PHOSPHORUS (WHITE)	7723140	260	7.30E-01	N	7.3E-02	**Yes**	-	Yes, MDL>SC	No	
Picloram			0.26			-	-	-	-	No	
Profluralin		26399360	0.37			-	-	-	-	No	
Progesterone		57830	0.24			-	-	-	-	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Prometon (Pramitol 5p)	PROMETON	1610180	0.5	5.48E+02	N	5.5E+01	No	No	-	No	
Prometryn	PROMETRYN	7287196	0.16	1.46E+02	N	1.5E+01	No	No	-	No	
Pronamide (Kerb)		23950585	0.62			-	-	-	-	No	
Propachlor (Ramrod)	PROPACHLOR	1918167	0.37	4.75E+02	N	4.7E+01	No	No	-	No	
Propanil	PROPANIL	709988	0.011	1.83E+02	N	1.8E+01	No	No	-	No	
Propargite	PROPARGITE	2312358	0.31	7.30E+02	N	7.3E+01	No	No	-	No	
Propazine		139402	0.16			-	-	-	-	No	
Propetamphos		31218834	0.15			-	-	-	-	No	
Pyrene	PYRENE	129000	1.16	1.83E+02	N	1.8E+01	No	No	-	**Yes**	3
Pyridine	PYRIDINE	110861	2	3.65E+01	N	3.7E+00	No	No	-	No	
Ronnel	RONNEL	299843	0.11	1.83E+03	N	1.8E+02	No	No	-	No	
Selenium, Total, ICP	SELENIUM	7782492	50	1.83E+02	N	1.8E+01	No	**Yes**	-	**Yes**	2
Silver, Total, ICP	SILVER	7440224	4	1.83E+02	N	1.8E+01	No	No	-	No	
Simazine	SIMAZINE	122349	1.03	2.46E-01	C	-	**Yes**	-	-	**Yes**	1
Stigmastanol		19466478	2			-	-	-	-	No	
Styrene	STYRENE	100425	1	1.62E+03	N	1.6E+02	No	No	-	No	
Sulfate, Dissolved		14808798	18600			-	-	-	-	No	
Sulfotepp		3689245	0.093			-	-	-	-	No	
Tebuthiuron		34014181	0.23			-	-	-	Yes, Detected w/No SC	No	
Terbacil		5902512	0.47			-	-	-	-	No	
Terbufos		13071799	0.02			-	-	-	-	No	
Terbutryn (Igran)		886500	0.16			-	-	-	-	No	
Testosterone		58220	0.97			-	-	-	-	No	
Tetrachloroethylene	TETRACHLOROETHENE	127184	1	4.60E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Tetrachlorvinphos (Gardona)		22248799	0.15			-	-	-	-	No	
Thallium, Total, ICP	THALLIUM	7440280	200	2.56E+00	N	2.6E-01	**Yes**	-	-	**Yes**	1
Thiobencarb	THIOBENCARB	28249776	0.005	3.65E+02	N	3.7E+01	No	No	-	No	
Tin, Total, ICP-MS	TIN	7440315	0.3	2.19E+04	N	2.2E+03	No	No	-	No	
Toluene	TOLUENE	108883	1	7.47E+02	N	7.5E+01	No	No	-	No	
Total coliforms			40,000	5%(b)	N	2.5E-02	No	**Yes**	-	**Yes**	1(b)
Total PAHs			6.648			-	-	-	-	**Yes**	3
Total PCBs	POLYCHLORINATED BIPHENYLS	1336363	0.399	1.48E-02	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
Total Xylenes	XYLENES	1330207	1	2.13E+02	N	2.1E+01	No	No	-	No	
Toxaphene	TOXAPHENE	8001352	0.85	2.69E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
trans-1,2-Dichloroethylene	TRANS-1,2-DICHLOROETHENE	156605	1	1.22E+02	N	1.2E+01	No	No	-	No	
trans-1,3-Dichloropropene		10061026	1			-	-	-	-	No	
trans-Nonachlor		39765805	0.39			-	-	-	-	No	
Treflan (Trifluralin)		1582098	0.23			-	-	-	-	No	
Tri(2-chloroethyl) phosphate (Fyrol CEF)		115968	0.5			-	-	-	-	No	
Tri(dichloroisopropyl) phosphate (Fyrol PCF)		13674845	0.5			-	-	-	-	No	
Triadimefon		43121433	0.4			-	-	-	-	No	
Triallate		2303175	0.47			-	-	-	-	No	
Tribufos (DEF)		78488	0.11			-	-	-	-	No	
Tributylphosphate		126738	0.5			-	-	-	Yes, Detected w/No SC	No	

SWAMP Name	RBC Table Name	CAS	Max Conc (µg/L)	SC Tap Water (µg/L)	N or C	0.1 * SC (µg/L)	Max> SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Trichlorofluoromethane	TRICHLOROFLUOROMETHANE	75694	1	1.29E+03	N	1.3E+02	No	No	-	No	
Triclopyr		55335063	2.7			-	-	-	Yes, Detected w/No SC	No	
Triclosan		3380345	1			-	-	-	-	No	
Triethyl citrate (ethyl citrate)		77930	0.5			-	-	-	-	No	
Trifluralin		1582098	0.11			-	-	-	Yes, Detected w/No SC	No	
Triphenylphosphate		115866	0.5			-	-	-	-	No	
Tris(2-butoxyethyl) phosphate		78513	0.5			-	-	-	-	No	
Vanadium, Total, ICP-MS	**VANADIUM	7440622	83.4	3.65E+01	N	3.7E+00	**Yes**	-	-	**Yes**	1
Vernolate		1929777	0.31			-	-	-	-	No	
Vinclozolin	VINCLOZOLIN	50471448	0.24	9.13E+02	N	9.1E+01	No	No	-	No	
Vinyl acetate	VINYL ACETATE	108054	5	4.12E+02	N	4.1E+01	No	No	-	No	
Vinyl chloride	VINYL CHLORIDE inc earlylife(see cover	75014	1	1.90E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Zinc, Total, ICP-MS	ZINC	7440666	3150	1.10E+04	N	1.1E+03	No	**Yes**	-	**Yes**	2
									Number of included chemicals =		50
* Reason for inclusion:											
(1) Max concentration or MDL for detected compound exceeded SC											
(2) Max concentration or MDL for detected compound exceeded 1/10th SC for non-carcinogen											
(3) Re-included as special case											
(4) Re-included because of exceedance in other medium											
(a) Infant drinking water threshold used in lieu of RfD											
(b) Total coliform drinking water MCL is 5% of monthly samples coliform positive											
PC = USEPA Waste Minimization Priority Chemical											
PBT = USEPA Toxics Release Inventory Persistent Bioaccumulative Toxics											
! = Chemicals for which screening at an HI of 0.1, in accordance with Region III guidance, will result in noncancer RBCs being lower than the cancer RBCs.											
N = Non-carcinogen											
C = Carcinogen											

Appendix A-2: Tier 1 Screening for Chemicals Measured in Sediment

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Soil Residential (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
1,2,4-Trichlorobenzene	1,2,4-TRICHLOROBENZENE	120821	0.016	7.8E+02	N	7.8E+01	No	No	-	No	
1,2-Dichlorobenzene	1,2-DICHLOROBENZENE	95501	0.016	7.0E+03	N	7.0E+02	No	No	-	No	
1,2-Diphenylhydrazine	1,2-DIPHENYLHYDRAZINE	122667	0.06	5.0E-01	C	-	No	No	-	No	
1,3-Dichlorobenzene	1,3-DICHLOROBENZENE	541731	0.016	2.3E+02	N	2.3E+01	No	No	-	No	
1,4-Dichlorobenzene	1,4-DICHLOROBENZENE	106467	0.016	1.7E+01	C	-	No	No	-	No	
2,4,5-T	2,4,5-T	93765	0.0082	7.8E+02	N	7.8E+01	No	No	-	No	
2,4,5-TP (Silvex)	2-(2,4,5-TRICHLOROPHENOXY)PROPIONIC ACID	93721	0.0082	6.3E+02	N	6.3E+01	No	No	-	No	
2,4,5-Trichlorophenol	2,4,5-TRICHLOROPHENOL	95954	0.11	7.8E+03	N	7.8E+02	No	No	-	No	
2,4,6-Trichlorophenol	2,4,6-TRICHLOROPHENOL	88062	0.11	3.6E+01	C	-	No	No	-	No	
2,4-D	2,4-D	94757	0.0082	7.8E+02	N	7.8E+01	No	No	-	No	
2,4-DB	4-(2,4-DICHLOROPHENOXY)BUTYRIC ACID	94826	0.0082	6.3E+02	N	6.3E+01	No	No	-	No	
2,4-Dichlorophenol	2,4-DICHLOROPHENOL	120832	0.096	2.3E+02	N	2.3E+01	No	No	-	No	
2,4-Dimethylphenol	2,4-DIMETHYLPHENOL	105679	0.042	1.6E+03	N	1.6E+02	No	No	-	No	
2,4-Dinitrophenol	2,4-DINITROPHENOL	51285	0.053	1.6E+02	N	1.6E+01	No	No	-	No	
2,4-Dinitrotoluene	2,4-DINITROTOLUENE	121142	0.027	1.6E+02	N	1.6E+01	No	No	-	No	
2,6-Dinitrotoluene	2,6-DINITROTOLUENE	606202	0.06	7.8E+01	N	7.8E+00	No	No	-	No	
2-Chloronaphthalene	BETA-CHLORONAPHTHALENE	91587	0.096	6.3E+03	N	6.3E+02	No	No	-	No	
2-Chlorophenol	2-CHLOROPHENOL	95578	0.053	3.9E+02	N	3.9E+01	No	No	-	No	
2-Methylnaphthalene	2-METHYLNAPHTHALENE	91576	2.19	3.1E+02	N	3.1E+01	No	No	-	**Yes**	3
2-Methylphenol	2-METHYLPHENOL	95487	0.11	3.9E+03	N	3.9E+02	No	No	-	No	
2-Nitroaniline	**2-NITROANILINE	88744	0.11	2.3E+02	N	2.3E+01	No	No	-	No	
2-Nitrophenol		88755	0.09			-	-	-	-	No	
3,3'-Dichlorobenzidine	3,3'-DICHLOROBENZIDINE	91941	0.027	8.8E-01	C	-	No	No	-	No	
3-Nitroaniline	3-NITROANILINE	99092	0.11	2.0E+01	N	2.0E+00	No	No	-	No	
4,4'-DDD	DDD	72548	0.0322	1.7E+00	C	-	No	No	-	**Yes**	4
4,4'-DDE	DDE	72559	0.00688	1.2E+00	C	-	No	No	-	**Yes**	4
4,4'-DDT	DDT	50293	0.00747	1.2E+00	C	-	No	No	-	**Yes**	4
4,6-Dinitro-O-Cresol	4,6-DINITRO-2-METHYLPHENOL	534521	0.053	7.8E+00	N	7.8E-01	No	No	-	**Yes**	4
4-Bromophenyl Phenyl Ether		101553	0.054			-	-	-	-	No	
4-Chloro-3-Methylphenol		59507	0.053			-	-	-	-	No	
4-Chloroaniline	4-CHLOROANILINE	106478	0.053	3.1E+02	N	3.1E+01	No	No	-	No	
4-Chlorophenyl Phenyl Ether		7005723	0.078			-	-	-	-	No	
4-Methylphenol	4-METHYLPHENOL	106445	0.096	3.9E+02	N	3.9E+01	No	No	-	No	
4-Nitroaniline	4-NITROANILINE	100016	0.11	2.0E+01	C	-	No	No	-	No	
4-Nitrophenol		100027	0.053			-	-	-	-	No	
Acenaphthene	ACENAPHTHENE	83329	1.27	4.7E+03	N	4.7E+02	No	No	-	**Yes**	3
Acenaphthylene		208968	0.401			-	-	-	Yes, Detected w/No SC	**Yes**	3
Aldrin	ALDRIN	309002	0.003	2.3E-02	C	-	No	No	-	**Yes**	4

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Soil Residential (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Alpha-BHC	ALPHA-HCH	319846	0.0013	6.3E-02	C	-	No	No	-	No	
Aluminum, Total, ICP	ALUMINUM	7429905	3050	7.8E+04	N	7.8E+03	No	No	-	No	
Ammonia-nitrogen		7727379	47.5			-	-	-	Yes, Detected w/No SC	No	
Anthracene	ANTHRACENE	120127	2.46	2.3E+04	N	2.3E+03	No	No	-	**Yes**	3
Antimony, Total, ICP-MS	ANTIMONY	7440360	2.1	3.1E+01	N	3.1E+00	No	No	-	**Yes**	4
Aroclor 1016	AROCLOR-1016	12674112	0.405	5.5E+00	N	5.5E-01	No	No	-	No	
Aroclor 1221	AROCLOR-1221	11104282	0.025	2.0E-01	C	-	No	No	-	No	
Aroclor 1232	AROCLOR-1232	11141165	0.025	2.0E-01	C	-	No	No	-	No	
Aroclor 1242	AROCLOR-1242	53469219	0.013	2.0E-01	C	-	No	No	-	No	
Aroclor 1248	AROCLOR-1248	12672296	0.372	2.0E-01	C	-	**Yes**	-	-	**Yes**	1
Aroclor 1254	AROCLOR-1254	11097691	0.296	2.0E-01	C	-	**Yes**	-	-	**Yes**	1
Aroclor 1260	AROCLOR-1260	11096825	0.208	2.0E-01	C	-	**Yes**	-	-	**Yes**	1
Arsenic, Total, ICP-MS	ARSENIC	7440382	52.6	2.7E-01	C	-	**Yes**	-	-	**Yes**	1
Barium, Total, ICP	BARIUM	7440393	104	5.5E+03	N	5.5E+02	No	No	-	**Yes**	4
Benzo(a)anthracene	BENZ[A]ANTHRACENE	56553	7.47	5.5E-01	C	-	**Yes**	-	-	**Yes**	1
Benzo(a)pyrene	BENZO[A]PYRENE	50328	11.2	5.5E-02	C	-	**Yes**	-	-	**Yes**	1
Benzo(b)fluoranthene	BENZO[B]FLUORANTHENE	205992	1.45	5.5E-01	C	-	**Yes**	-	-	**Yes**	1
Benzo(g,h,i)perylene		191242	5.22			-	-	-	Yes, Detected w/No SC	No	
Benzo(k)fluoranthene	BENZO[K]FLUORANTHENE	207089	2.18	5.5E+00	C	-	No	No	-	**Yes**	1
Benzoic Acid	BENZOIC ACID	65850	0.415	3.1E+05	N	3.1E+04	No	No	-	No	
Benzyl alcohol	BENZYL ALCOHOL	100516	0.036	2.3E+04	N	2.3E+03	No	No	-	No	
Benzyl Butyl Phthalate	BUTYLBENZYLPHTHALATE	85687	0.268	1.6E+04	N	1.6E+03	No	No	-	No	
Beryllium, Total, ICP	BERYLLIUM	7440417	0.25	1.6E+02	N	1.6E+01	No	No	-	No	
beta-BHC	BETA-HCH	319857	0.0013	2.2E-01	C	-	No	No	-	No	
Bis(2-Chloroethoxy)Methane		111911	0.1			-	-	-	-	No	
Bis(2-Chloroethyl)Ether	BIS(2-CHLOROETHYL)ETHER	111444	0.09	3.6E-01	C	-	No	No	-	No	
Bis(2-Chloroisopropyl)Ether	BIS(2-CHLOROISOPROPYL)ETHER	108601	0.09	5.7E+00	C	-	No	No	-	No	
Bis(2-Ethylhexyl)Phthalate	BIS(2-ETHYLHEXYL)PHTHALATE	117817	4.51	2.8E+01	C	-	No	No	-	**Yes**	4
Cadmium, Total, ICP-MS	CADMIUM-FOOD	7440439	3	3.9E+01	N	3.9E+00	No	No	-	**Yes**	1
Cadmium, Total, ICP-MS	CADMIUM-WATER	7440439	3	7.8E+01	N	7.8E+00	No	No	-	**Yes**	1
Caffeine		58082	0.036			-	-	-	-	No	
Carbazole	CARBAZOLE	86748	0.493	2.0E+01	C	-	No	No	-	No	
Chlordane	CHLORDANE	57749	0.0725	1.1E+00	C	-	No	No	-	No	
Chlorpyrifos	CHLORPYRIFOS	2921882	0.053	2.3E+02	N	2.3E+01	No	No	-	No	
Chromium, Total, ICP-MS	CHROMIUM III	16065831	67	1.2E+05	N	1.2E+04	No	No	-	No	
Chromium, Total, ICP-MS	CHROMIUM VI	18540299	67	2.3E+02	N	2.3E+01	No	No	-	**Yes**	4

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Soil Residential (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Chrysene, Total	CHRYSENE	218019	8.71	5.5E+01	C	-	No	No	-	**Yes**	3
Copper, Total, ICP	COPPER	7440508	431	3.1E+03	N	3.1E+02	No	No	-	**Yes**	4
Dalapon	DALAPON	75990	0.023	2.3E+03	N	2.3E+02	No	No	-	No	
delta-BHC		319868	0.0013			-	-	-	-	No	
Diazinon	DIAZINON	333415	0.032	7.0E+01	N	7.0E+00	No	No	-	No	
Dibenzo(a,h)anthracene, Total	DIBENZ[A,H]ANTHRACENE	53703	0.777	5.5E-02	C	-	**Yes**	-	-	**Yes**	1
Dibenzofuran	DIBENZOFURAN	132649	0.615	1.6E+02	N	1.6E+01	No	No	-	No	
Dicamba	DICAMBA	1918009	0.0082	2.3E+03	N	2.3E+02	No	No	-	No	
Dichloroprop		120365	0.0082			-	-	-	-	No	
Dieldrin	DIELDRIN	60571	0.0025	2.5E-02	C	-	No	No	-	No	
Diethyl Phthalate	DIETHYLPHTHALATE	84662	0.036	6.3E+04	N	6.3E+03	No	No	-	No	
Dimethyl Phthalate	DIMETHYLPHTHALATE	131113	0.066	7.8E+05	N	7.8E+04	No	No	-	No	
Di-N-Butyl Phthalate	DIBUTYLPHTHALATE	84742	0.098	7.8E+03	N	7.8E+02	No	No	-	No	
Di-n-Butyltin (as dibutyltin ion)		1002535	0.229			-	-	-	Yes, Detected w/No SC	No	
Di-N-Octyl Phthalate	**DIOCTYLPHTHALATE	117840	0.048	3.1E+03	N	3.1E+02	No	No	-	No	
Dinoseb	DINOSEB	88857	0.0082	7.8E+01	N	7.8E+00	No	No	-	No	
Disulfoton (Di-Syston)	DISULFOTON	298044	0.032	3.1E+00	N	3.1E-01	No	No	-	**Yes**	4
Endosulfan	ENDOSULFAN	115297	0.0025	4.7E+02	N	4.7E+01	No	No	-	No	
Endosulfan II		33213659	0.0025			-	-	-	-	No	
Endosulfan sulfate		1031078	0.004			-	-	-	-	No	
Endrin	ENDRIN	72208	0.0025	2.3E+01	N	2.3E+00	No	No	-	No	
Endrin aldehyde		7421934	0.005			-	-	-	-	No	
Fluoranthene	FLUORANTHENE	206440	19.9	3.1E+03	N	3.1E+02	No	No	-	**Yes**	3
Fluorene, Total	FLUORENE	86737	1.58	3.1E+03	N	3.1E+02	No	No	-	**Yes**	3
gamma-BHC (Lindane)	GAMMA-HCH (LINDANE)	58899	0.0013	3.1E-01	C	-	No	No	-	No	
Heptachlor	HEPTACHLOR	76448	0.0013	8.8E-02	C	-	No	No	-	No	
Heptachlor epoxide	HEPTACHLOR EPOXIDE	1024573	0.003	4.4E-02	C	-	No	No	-	No	
Hexachlorobenzene	HEXACHLOROBENZENE	118741	0.016	2.5E-01	C	-	No	No	-	**Yes**	4
Hexachlorobutadiene	HEXACHLOROBUTADIENE	87683	0.027	5.1E+00	C	-	No	No	-	No	
Hexachlorocyclopentadiene	HEXACHLOROCYCLOPENTADIENE	77474	0.027	4.7E+02	N	4.7E+01	No	No	-	No	
Hexachloroethane	HEXACHLOROETHANE	67721	0.09	2.8E+01	C	-	No	No	-	No	
Indeno(1,2,3-cd)pyrene	INDENO[1,2,3-C,D]PYRENE	193395	4.1	5.5E-01	C	-	**Yes**	-	-	**Yes**	1
Iron, Total, ICP	IRON	7439896	4410	2.3E+04	N	2.3E+03	No	No	-	**Yes**	4
Isophorone	ISOPHORONE	78591	0.11	4.2E+02	C	-	No	No	-	No	
Lead, Total, ICP		7439921	790			-	-	-	Yes, Detected w/No SC	**Yes**	3
Malathion	MALATHION	121755	0.085	1.6E+03	N	1.6E+02	No	No	-	No	
Manganese, Total, ICP	MANGANESE-FOOD	7439965	825	1.1E+04	N	1.1E+03	No	No	-	No	
Manganese, Total, ICP	MANGANESE-NONFOOD	7439965	825	1.6E+03	N	1.6E+02	No	No	-	**Yes**	4

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Soil Residential (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
MCPA	2-METHYL-4-CHLOROPHENOXYACETIC ACID (MCPA)	94746	0.0082	3.9E+01	N	3.9E+00	No	No	-	No	
MCPP (Mecoprop)		7085190	0.0082			-	-	-	-	No	
Mercury, Total, CVAA	MERCURY (INORGANIC)	7439976	1.56	0.0E+00		-	-	-	Yes, Detected w/No SC	**Yes**	3
Methoxychlor	METHOXYCHLOR	72435	0.013	3.9E+02	N	3.9E+01	No	No	-	No	
Methyl Mercury	METHYLMERCURY	22967926	0.000454	7.8E+00	N	7.8E-01	No	No	-	**Yes**	4
Molybdenum, Total, ICP	MOLYBDENUM	7439987	1	3.9E+02	N	3.9E+01	No	No	-	**Yes**	4
Mono-n-Butyltin (as monobutyltin ion)			0.147			-	-	-	Yes, Detected w/No SC	No	
Naphthalene, Total	NAPHTHALENE	91203	2.31	1.6E+03	N	1.6E+02	No	No	-	**Yes**	3
Nickel, Total, ICP	NICKEL	7440020	31.8	1.6E+03	N	1.6E+02	No	No	-	No	
Nitrobenzene	NITROBENZENE	98953	0.096	3.9E+01	N	3.9E+00	No	No	-	No	
N-Nitrosodimethylamine	**N-NITROSODIMETHYLAMINE	62759	0.11	7.8E-03	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
N-Nitrosodi-N-Propylamine	N-NITROSODIPROPYLAMINE	621647	0.054	5.7E-02	C	-	No	No	-	No	
N-Nitrosodiphenylamine	**N-NITROSODIPHENYLAMINE	86306	0.12	8.1E+01	C	-	No	No	-	No	
Parathion	PARATHION	56382	0.085	4.7E+02	N	4.7E+01	No	No	-	No	
Parathion-methyl	METHYL PARATHION	298000	0.085	2.0E+01	N	2.0E+00	No	No	-	No	
Pentachlorophenol	PENTACHLOROPHENOL	87865	0.03	3.3E+00	C	-	No	No	-	**Yes**	1
Phenanthrene		85018	7.26			-	-	-	Yes, Detected w/No SC	No	
Phenol	PHENOL	108952	0.11	2.3E+04	N	2.3E+03	No	No	-	No	
Phorate		298022	0.053			-	-	-	-	No	
Pyrene	PYRENE	129000	21.8	2.3E+03	N	2.3E+02	No	No	-	**Yes**	3
Selenium, Total, ICP	SELENIUM	7782492	2.6	3.9E+02	N	3.9E+01	No	No	-	**Yes**	4
Silver, Total, ICP	SILVER	7440224	5	3.9E+02	N	3.9E+01	No	No	-	No	
Tetrabutyltin		1461252	0.01368			-	-	-	Yes, Detected w/No SC	No	
Thallium, Total, ICP	THALLIUM	7440280	10	5.5E+00	N	5.5E-01	**Yes**	-	-	**Yes**	1
Tin, Total, ICP	TIN	7440315	0.927	4.7E+04	N	4.7E+03	No	No	-	No	
Toluene	TOLUENE	108883	0.00747	1.6E+04	N	1.6E+03	No	No	-	No	
Total DDT			0.00747			-	-	-	Yes, Detected w/No SC	**Yes**	4
Total PAHs			92.678			-	-	-	Yes, Detected w/No SC	**Yes**	3
Total PCBs	POLYCHLORINATED BIPHENYLS	1336363	1.281	2.0E-01	C	-	**Yes**	-	-	No	1

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Soil Residential (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Toxaphene	TOXAPHENE	8001352	0.025	3.6E-01	C	-	No	No	-	No	
Tri-n-Butyltin (as tributyltin ion)		688733	0.728			-	-	-	Yes, Detected w/No SC	No	
Zinc, Total, ICP-MS	ZINC	7440666	516	2.3E+04	N	2.3E+03	No	No	-	**Yes**	4
								Number of included chemicals =			49
* Reason for inclusion:											
(1) Max concentration or MDL for detected compound exceeded RBC											
(2) Max concentration or MDL for detected compound exceeded 1/10th RBC for non-carcinogen											
(3) Re-included as special case											
(4) Re-included because of exceedance in other medium											
PC = USEPA Waste Minimization Priority Chemical											
PBT = USEPA Toxics Release Inventory Persistent Bioaccumulative Toxics											
! = Chemicals for which screening at an HI of 0.1, in accordance with Region III guidance, will result in noncancer RBCs being lower than the cancer RBCs.											
N = Non-carcinogen											
C = Carcinogen											

Appendix A-3: Tier 1 Screening for Chemicals Measured in Fish Tissue

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Fish Tissue (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
1,2,4-Trichlorobenzene	1,2,4-TRICHLOROBENZENE	120821	0.016	1.4E+01	N	1.4E+00	No	No	-	No	
1,2-Dichlorobenzene	1,2-DICHLOROBENZENE	95501	0.016	1.2E+02	N	1.2E+01	No	No	-	No	
1,2-Diphenylhydrazine	1,2-DIPHENYLHYDRAZINE	122667	0.053	1.5E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
1,3-Dichlorobenzene	1,3-DICHLOROBENZENE	541731	0.016	4.1E+00	N	4.1E-01	No	No	-	No	
1,4-Dichlorobenzene	1,4-DICHLOROBENZENE	106467	0.016	5.0E-02	C	-	No	-	-	No	
2,4,5-Trichlorophenol	2,4,5-TRICHLOROPHENOL	95954	0.11	1.4E+02	N	1.4E+01	No	No	-	No	
2,4,6-Trichlorophenol	2,4,6-TRICHLOROPHENOL	88062	0.11	1.1E-01	C	-	**Yes**	-	Yes, MDL>SC	No	
2,4-Dichlorophenol	2,4-DICHLOROPHENOL	120832	0.027	4.1E+00	N	4.1E-01	No	No	-	No	
2,4-Dimethylphenol	2,4-DIMETHYLPHENOL	105679	0.027	2.7E+01	N	2.7E+00	No	No	-	No	
2,4-Dinitrophenol	2,4-DINITROPHENOL	51285	0.053	2.7E+00	N	2.7E-01	No	No	-	No	
2,4-Dinitrotoluene	2,4-DINITROTOLUENE	121142	0.011	2.7E+00	N	2.7E-01	No	No	-	No	
2,6-Dinitrotoluene	2,6-DINITROTOLUENE	606202	0.011	1.4E+00	N	1.4E-01	No	No	-	No	
2-Chloronaphthalene	BETA-CHLORONAPHTHALENE	91587	0.016	1.1E+02	N	1.1E+01	No	No	-	No	
2-Chlorophenol	2-CHLOROPHENOL	95578	0.053	6.8E+00	N	6.8E-01	No	No	-	No	
2-Methylnaphthalene	2-METHYLNAPHTHALENE	91576	0.043	5.4E+00	N	5.4E-01	No	No	-	**Yes**	3
2-Methylphenol	2-METHYLPHENOL	95487	0.027	6.8E+01	N	6.8E+00	No	No	-	No	
2-Nitroaniline	**2-NITROANILINE	88744	0.11	4.1E+00	N	4.1E-01	No	No	-	No	
2-Nitrophenol		88755	0.027			-	-	-	-	No	
3,3'-Dichlorobenzidine	3,3'-DICHLOROBENZIDINE	91941	0.027	2.7E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
3-Nitroaniline	3-NITROANILINE	99092	0.11	6.0E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
4,4'-DDD	DDD	72548	0.0763	5.0E-03	C	-	**Yes**	-	-	**Yes**	1
4,4'-DDE	DDE	72559	0.339	3.6E-03	C	-	**Yes**	-	-	**Yes**	1
4,4'-DDT	DDT	50293	0.025	3.6E-03	C	-	**Yes**	-	-	**Yes**	1
4,6-Dinitro-O-Cresol	4,6-DINITRO-2-METHYLPHENOL	534521	0.053	1.4E-01	N	1.4E-02	No	**Yes**	Yes, MDL>SC	**Yes**	4
4-Bromophenyl Phenyl Ether		101553	0.011			-	-	-	-	No	
4-Chloro-3-Methylphenol		59507	0.053			-	-	-	-	No	
4-Chloroaniline	4-CHLOROANILINE	106478	0.053	5.4E+00	N	5.4E-01	No	No	-	No	
4-Chlorophenyl Phenyl Ether		7005723	0.016			-	-	-	-	No	
4-Methylphenol	4-METHYLPHENOL	106445	0.027	6.8E+00	N	6.8E-01	No	No	-	No	
4-Nitroaniline	4-NITROANILINE	100016	0.11	6.0E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
4-Nitrophenol		100027	0.053			-	-	-	-	No	
Acenaphthene	ACENAPHTHENE	83329	0.011	8.1E+01	N	8.1E+00	No	No	-	**Yes**	4
Acenaphthylene		208968	0.016			-	-	-	-	No	

Appendix A-3: Tier 1 Screening for Chemicals Measured in Fish Tissue

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Fish Tissue (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Aldrin	ALDRIN	309002	0.0013	7.1E-05	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
alpha-BHC	ALPHA-HCH	319846	0.002	1.9E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Aluminum, Total	ALUMINUM	7429905	0.99	1.4E+03	N	1.4E+02	No	No	-	No	
Aniline	ANILINE	62533	0.053	2.1E-01	C	-	No	-	-	No	
Anthracene	ANTHRACENE	120127	0.016	4.1E+02	N	4.1E+01	No	No	-	**Yes**	4
Antimony, Total	ANTIMONY	7440360	0.02	5.4E-01	N	5.4E-02	No	No	-	**Yes**	4
Aroclor 1016	AROCLOR-1016	12674112	0.013	1.7E-02	C	-	No	-	-	No	
Aroclor 1221	AROCLOR-1221	11104282	0.013	6.0E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Aroclor 1232	AROCLOR-1232	11141165	0.013	6.0E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Aroclor 1242	AROCLOR-1242	53469219	0.013	6.0E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Aroclor 1248	AROCLOR-1248	12672296	0.013	6.0E-04	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Aroclor 1254	AROCLOR-1254	11097691	1.65	6.0E-04	C	-	**Yes**	-	-	**Yes**	1
Aroclor 1260	AROCLOR-1260	11096825	0.639	6.0E-04	C	-	**Yes**	-	-	**Yes**	1
Arsenic, Total	ARSENIC	7440382	0.195	8.0E-04	C	-	**Yes**	-	-	**Yes**	1
Benzidine	BENZIDINE	92875	0.64	5.2E-06	C	-	**Yes**	-	Yes, MDL>SC	No	
Benzo(a)anthracene	BENZ[A]ANTHRACENE	56553	0.016	1.7E-03	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Benzo(a)pyrene	BENZO[A]PYRENE	50328	0.027	1.7E-04	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Benzo(b)fluoranthene	BENZO[B]FLUORANTHENE	205992	0.043	1.7E-03	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Benzo(g,h,i)perylene		191242	0.027			-	-	-	-	No	
Benzo(k)fluoranthene	BENZO[K]FLUORANTHENE	207089	0.043	1.7E-02	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Benzoic Acid	BENZOIC ACID	65850	0.11	5.4E+03	N	5.4E+02	No	No	-	No	
Benzyl alcohol	BENZYL ALCOHOL	100516	0.027	4.1E+02	N	4.1E+01	No	No	-	No	
beta-BHC	BETA-HCH	319857	0.002	6.7E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Bis(2-Chloroethoxy)Methane		111911	0.027			-	-	-	-	No	
Bis(2-Chloroethyl)Ether	BIS(2-CHLOROETHYL)ETHER	111444	0.016	1.1E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Bis(2-Chloroisopropyl)Ether	BIS(2-CHLOROISOPROPYL)ETHER	108601	0.053	1.7E-02	C	-	**Yes**	-	Yes, MDL>SC	No	

Appendix A-3: Tier 1 Screening for Chemicals Measured in Fish Tissue

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Fish Tissue (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Bis(2-Ethylhexyl)Phthalate	BIS(2-ETHYLHEXYL)PHTHALATE	117817	0.016	8.6E-02	C	-	No	-	-	**Yes**	4
Butylbenzylphthalate	BUTYLBENZYLPHTHALATE	85687	0.016	2.7E+02	N	2.7E+01	No	No	-	No	
Cadmium, Total	CADMIUM-FOOD	7440439	0.008	6.8E-01	N	6.8E-02	No	No	-	**Yes**	4
Cadmium, Total	CADMIUM-WATER	7440439	0.008	1.4E+00	N	1.4E-01	No	No	-	**Yes**	4
Carbazole	CARBAZOLE	86748	0.027	6.0E-02	C	-	No	-	-	No	
Chlordane	CHLORDANE	57749	0.0067	3.4E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Chromium, Total	CHROMIUM III	16065831	0.489	2.0E+03	N	2.0E+02	No	No	-	No	
Chromium, Total	CHROMIUM VI	18540299	0.489	4.1E+00	N	4.1E-01	No	**Yes**	-	**Yes**	2
Chrysene	CHRYSENE	218019	0.016	1.7E-01	C	-	No	-	-	**Yes**	3
cis-Chlordane		5103719	0.0829			-	-	-	Yes, Detected w/No SC	No	
Copper, Total	COPPER	7440508	0.416	5.4E+01	N	5.4E+00	No	No	-	**Yes**	4
delta-BHC		319868	0.002			-	-	-	-	No	
Dibenzo(a,h)anthracene	DIBENZ[A,H]ANTHRACENE	53703	0.043	1.7E-04	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Dibenzofuran	DIBENZOFURAN	132649	0.027	2.7E+00	N	2.7E-01	No	No	-	No	
Dieldrin	DIELDRIN	60571	0.0013	7.5E-05	C	-	**Yes**	-	Yes, MDL>SC	No	
Diethyl Phthalate	DIETHYLPHTHALATE	84662	0.027	1.1E+03	N	1.1E+02	No	No	-	No	
Dimethyl Phthalate	DIMETHYLPHTHALATE	131113	0.011	1.4E+04	N	1.4E+03	No	No	-	No	
Di-N-Butyl Phthalate	DIBUTYLPHTHALATE	84742	0.027	1.4E+02	N	1.4E+01	No	No	-	No	
Di-n-Butyltin (as dibutyltin ion)		1002535	0.025			-	-	-	Yes, Detected w/No SC	No	
Di-N-Octyl Phthalate	**DIOCTYLPHTHALATE	117840	0.016	5.4E+01	N	5.4E+00	No	No	-	No	
Endosulfan I		959988	0.0013			-	-	-	-	No	
Endosulfan II		33213659	0.0013			-	-	-	-	No	
Endosulfan sulfate		1031078	0.0013			-	-	-	-	No	
Endrin	ENDRIN	72208	0.0013	4.1E-01	N	4.1E-02	No	No	-	No	
Endrin aldehyde		7421934	0.0013			-	-	-	-	No	
Fluoranthene	FLUORANTHENE	206440	0.016	5.4E+01	N	5.4E+00	No	No	-	**Yes**	3
Fluorene	FLUORENE	86737	0.016	5.4E+01	N	5.4E+00	No	No	-	**Yes**	3
gamma-BHC (Lindane)	GAMMA-HCH (LINDANE)	58899	0.002	9.3E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
gamma-Chlordane		5103742	0.0532			-	-	-	Yes, Detected w/No SC	No	

Appendix A-3: Tier 1 Screening for Chemicals Measured in Fish Tissue

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Fish Tissue (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Heptachlor	HEPTACHLOR	76448	0.0013	2.7E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Heptachlor epoxide	HEPTACHLOR EPOXIDE	1024573	0.0013	1.3E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
Hexachlorobenzene	HEXACHLOROBENZENE	118741	0.016	7.5E-04	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
Hexachlorobutadiene	HEXACHLOROBUTADIENE	87683	0.027	1.5E-02	C	-	**Yes**	-	Yes, MDL>SC	No	
Hexachlorocyclopentadiene	HEXACHLOROCYCLOPENTADIENE	77474	0.027	8.1E+00	N	8.1E-01	No	No	-	No	
Hexachloroethane	HEXACHLOROETHANE	67721	0.027	8.6E-02	C	-	No	-	-	No	
Indeno(1,2,3-cd)pyrene	INDENO[1,2,3-C,D]PYRENE	193395	0.027	1.7E-03	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	3
Iron, Total	IRON	7439896	4.58	4.1E+02	N	4.1E+01	No	No	-	**Yes**	4
Isophorone	ISOPHORONE	78591	0.027	1.3E+00	C	-	No	-	-	No	
Lead, Total		7439921	0.02			-	-	-	Yes, Detected w/No SC	**Yes**	3
Manganese, Total	MANGANESE-FOOD	7439965	0.257	1.9E+02	N	1.9E+01	No	No	-	**Yes**	4
Manganese, Total	MANGANESE-NONFOOD	7439965	0.257	2.7E+01	N	2.7E+00	No	No	-	**Yes**	4
Mercury, Total	MERCURY (INORGANIC)	7439976	0.758	0.0E+00		-	-	-	Yes, Detected w/No SC	**Yes**	3
Methoxychlor	METHOXYCHLOR	72435	0.0067	6.8E+00	N	6.8E-01	No	No	-	No	
Monomethyl Mercury	METHYLMERCURY	22967926	0.666	1.4E-01		-	**Yes**	-	-	**Yes**	1
Mono-n-Butyltin (as monobutyltin ion)			0.034			-	-	-	Yes, Detected w/No SC	No	
Naphthalene	NAPHTHALENE	91203	0.043	2.7E+01	N	2.7E+00	No	No	-	**Yes**	3
Nickel, Total	NICKEL	7440020	0.02	2.7E+01	N	2.7E+00	No	No	-	No	
Nitrobenzene	NITROBENZENE	98953	0.027	6.8E-01	N	6.8E-02	No	No	-	No	
N-Nitrosodimethylamine	**N-NITROSODIMETHYLAMINE	62759	0.11	2.4E-05	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
N-Nitrosodi-N-Propylamine	N-NITROSODIPROPYLAMINE	621647	0.027	1.7E-04	C	-	**Yes**	-	Yes, MDL>SC	No	
N-Nitrosodiphenylamine	**N-NITROSODIPHENYLAMINE	86306	0.027	2.5E-01	C	-	No	-	-	No	
Pentachlorophenol	PENTACHLOROPHENOL	87865	0.027	1.0E-02	C	-	**Yes**	-	Yes, MDL>SC	**Yes**	4
Phenanthrene		85018	0.016			-	-	-	-	No	
Phenol	PHENOL	108952	0.11	4.1E+02	N	4.1E+01	No	No	-	No	

Appendix A-3: Tier 1 Screening for Chemicals Measured in Fish Tissue

SWAMP Name	RBC Name	CAS	Max Conc (mg/kg)	SC Fish Tissue (mg/kg)	N or C	0.1 * SC (mg/kg)	Max>SC	Max>0.1 SC	MDL>SC or No SC?	Tier 2?	Reason*
Pyrene	PYRENE	129000	0.016	4.1E+01	N	4.1E+00	No	No	-	**Yes**	3
Selenium, Total	SELENIUM	7782492	0.2	6.8E+00	N	6.8E-01	No	No	-	**Yes**	4
Silver, Total	SILVER	7440224	0.008	6.8E+00	N	6.8E-01	No	No	-	No	
Tetra-n-Butyltin (as tetrabutyltin)		1461252	0.025			-	-	-	-	No	
Thallium, Total	THALLIUM	7440280	0.02	9.5E-02	N	9.5E-03	No	**Yes**	-	**Yes**	4
Total PCBs	POLYCHLORINATED BIPHENYLS	1336363	2.309	6.0E-04	C	-	**Yes**	-	-	No	1
Toxaphene	TOXAPHENE	8001352	0.013	1.1E-03	C	-	**Yes**	-	Yes, MDL>SC	No	
Tri-n-Butyltin (as tributyltin ion)		688733	0.0969			-	-	-	Yes, Detected w/No SC	No	
Zinc, Total	ZINC	7440666	6.2	4.1E+02	N	4.1E+01	No	No	-	**Yes**	4
									Number of included chemicals =		42

* Reason for inclusion:
(1) Max concentration or MDL for detected compound exceeded RBC
(2) Max concentration or MDL for detected compound exceeded 1/10th RBC for non-carcinogen
(3) Re-included as special case
(4) Re-included because of exceedance in other medium
PC = USEPA Waste Minimization Priority Chemical
PBT = USEPA Toxics Release Inventory Persistent Bioaccumulative Toxics
! = Chemicals for which screening at an HI of 0.1, in accordance with Region III guidance, will result in noncancer RBCs being lower than the cancer RBCs.
N = Non-carcinogen
C = Carcinogen

Table 2. Chemicals with method detection limits exceeding screening concentrations

		Media		
Chemical	**Volatile**	**Water**	**Sediment**	**Tissue**
1,1,2,2-Tetrachloroethane	VOC	MDL > SC		
1,1,2-Trichloroethane	VOC	MDL > SC		
1,1,2-Trichloroethylene	VOC	MDL > SC		
1,2-Dichloroethane	VOC	MDL > SC		
1,2-Dichloropropane	VOC	MDL > SC		
1,2-Diphenylhydrazine	SVOC	MDL > SC		MDL > SC
1,4-Dichlorobenzene	SVOC	MDL > SC		
2,4,6-Trichlorophenol	Phenolic	MDL > SC		MDL > SC
3-Nitroaniline	SVOC	MDL > SC		MDL > SC
3,3'-Dichlorobenzidine	SVOC	MDL > SC		MDL > SC
4,6-Dinitro-O-Cresol	Phenolic	MDL > SC		MDL > SC
4-Nitroaniline	SVOC	MDL > SC		MDL > SC
Acrolein	Pesticide	MDL > SC		
Acrylonitrile	VOC	MDL > SC		
Alachlor	Pesticide	MDL > SC		
Aldrin	Pesticide	MDL > SC		MDL > SC
Alpha-BHC	Pesticide	MDL > SC		MDL > SC
Aroclor 1221	PCB	MDL > SC		MDL > SC
Aroclor 1232	PCB	MDL > SC		MDL > SC
Aroclor 1242	PCB	MDL > SC		MDL > SC
Aroclor 1248	PCB	MDL > SC		MDL > SC
Aroclor 1254	PCB	MDL > SC		

		Media		
Chemical	**Volatile**	**Water**	**Sediment**	**Tissue**
Aroclor 1260	PCB	MDL > SC		
Benzene	VOC	MDL > SC		
Benzidine	SVOC	MDL > SC		MDL > SC
Benzo(a)anthracene	SVOC	MDL > SC		MDL > SC
Benzo(a)pyrene	SVOC	MDL > SC		MDL > SC
Benzo(b)fluoranthene	SVOC	MDL > SC		MDL > SC
Benzo(k)fluoranthene	SVOC	MDL > SC		MDL > SC
Beta-BHC	Pesticide	MDL > SC		MDL > SC
Bis(2-Chloroethyl)Ether	SVOC	MDL > SC		MDL > SC
Bis(2-Chloroisopropyl)Ether	SVOC	MDL > SC		MDL > SC
Bromodichloromethane	VOC	MDL > SC		
Carbon Tetrachloride	VOC	MDL > SC		
Chlordane	Pesticide	MDL > SC		MDL > SC
Chlordecone (Kepone)	Pesticide	MDL > SC		
Chlorodibromomethane	VOC	MDL > SC		
Chloroform	VOC	MDL > SC		
Cyanazine	Pesticide	MDL > SC		
Dibenzo(a,h)anthracene	SVOC	MDL > SC		MDL > SC
Dichlorvos (DDVP)	Pesticide	MDL > SC		
Dieldrin	Pesticide	MDL > SC		MDL > SC
gamma-BHC (Lindane)	Pesticide	MDL > SC		MDL > SC
Heptachlor	Pesticide	MDL > SC		MDL > SC
Heptachlor epoxide	Pesticide	MDL > SC		MDL > SC
Hexachlorobenzene	SVOC	MDL > SC		MDL > SC

		Media		
Chemical	**Volatile**	**Water**	**Sediment**	**Tissue**
Hexachlorobutadiene	SVOC	MDL > SC		MDL > SC
Indeno(1,2,3-cd)pyrene	SVOC	MDL > SC		MDL > SC
N-Nitrosodimethylamine	SVOC	MDL > SC	MDL > SC	MDL > SC
N-Nitrosodi-N-Propylamine	SVOC	MDL > SC		MDL > SC
Phosphorus, total	Conventional	MDL > SC		
Tetrachloroethylene	VOC	MDL > SC		
Total PCBs	SVOCs	MDL > SC		
Toxaphene	Pesticide	MDL > SC		MDL > SC
Vinyl chloride	VOC	MDL > SC		

Table 3. Chemicals analyzed at least once in water, but which were never detected.

Chemical	Number of water analyses
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1,2-Trichloroethylene	1
1,1-Dichloroethane	1
1,1-Dichloroethylene	1
1,2,4-Trichlorobenzene	800
1,2-Dichlorobenzene	875
1,2-Dichloroethane	1
1,2-Dichloropropane	1
1,3-Dichlorobenzene	875
1,4-Dichlorobenzene	887
1-Napthol	1
2,4,5-TB	65
2,4-DB	857
2,4'-DDD	74
2,4'-DDE	74
2,4'-DDT	74
2,4-Dinitrotoluene	800
2,6-Diethylaniline	67
2,6-Dinitrotoluene	800
2-Butanone (MEK)	1

Chemical	Number of water analyses
2-Chloroethylvinyl ether	1
2-Hexanone	1
2-Nitroaniline	800
3,3'-Dichlorobenzidine	800
3,5-Dichlorobenzoic acid	77
3-beta-Coprostanol	11
3-Hydroxycarbofuran	4
3-Nitroaniline	800
3-tert-Butyl-4-hydroxy anisole (BHA)	12
4,6-Dinitro-O-Cresol	800
4-Chloroaniline	800
4-Methyl-2-Pentanone (MIBK)	1
4-Methylphenol	12
4-Nitroaniline	800
Abate (Temephos)	1
Acephate	1
Acetochlor	67
Acetone	1
Acetophenone	12
Acetyl hexamethyl tetrahydro naphthalene	12
Acifluorfen (Blazer)	77
Acrolein	1
Acrylonitrile	1

Chemical	Number of water analyses
Alachlor	144
Aldicarb	4
Aldicarb sulfone	4
Aldicarb sulfoxide	4
Aldrin	953
alpha-BHC	1020
Ametryn	77
Aniline	59
Anthraquinone (9,10-Anthraquinone)	12
Aroclor 1016	874
Aroclor 1221	874
Aroclor 1232	874
Aroclor 1242	874
Aroclor 1248	874
Aroclor 1254	874
Aroclor 1260	874
Atraton	77
Azinphos-ethyl	77
Azinphos-methyl (Guthion)	144
Baygon (Propoxur)	4
Benefin	144
Bentazon	77
Benzene	1

Chemical	Number of water analyses
Benzidine	47
Benzophenone	12
Beryllium, Dissolved	1645
beta-BHC	953
beta-Sitosterol	11
Bis(2-Chloroethoxy)Methane	800
Bis(2-Chloroethyl)Ether	800
Bis(2-Chloroisopropyl)Ether	800
Bolstar (Sulprofos)	77
Bromodichloromethane	1
Bromoform	13
Bromomethane	1
Bromoxynil	77
Butachlor	77
Butylate	144
Camphor	12
Captafol	74
Captan	74
Carbon Tetrachloride	1
Carbophenothion	77
Carboxin	77
Chlordecone (Kepone)	31
Chlorobenzene	1

Chemical	Number of water analyses
Chlorodibromomethane	1
Chloroethane	1
Chloroform	1
Chlorothalonil (Daconil)	77
Chlorpropham	77
Chlorpyrifos-methyl	77
cis-1,3-Dichloropropene	1
cis-Chlordane	179
cis-Chlordene	62
cis-Nonachlor	73
cis-Permethrin	67
Cotinine	12
Coumaphos	65
Cyanazine	144
Cycloate	77
Dacthal (DCPA)	144
Dalapon	780
DDMU	62
delta-BHC	952
Demeton-O	77
Demeton-S	77
Desulfinylfipronil	4
Diallate (Avadex)	77

Chemical	Number of water analyses
Dibenzo(a,h)anthracene	863
Dichlorvos (DDVP)	77
Diclofop-methyl	77
Dicofol (Kelthane)	74
Dieldrin	1020
Diethoxy-nonylphenol	12
Diethoxyoctylphenol	12
Dimethoate	77
Dinoseb	857
Dioxathion	65
Diphenamid	77
Disulfoton (Di-Syston)	924
D-Limonene	12
Endosulfan II	953
Endosulfan sulfate	953
Endrin	953
Endrin aldehyde	953
Endrin ketone	74
EPN	77
Eptam	77
EPTC	67
Equilenin	12
Estrone	216

Chemical	Number of water analyses
Ethalfluralin (Sonalan)	144
Ethion	77
Ethoprop	144
Ethylbenzene	1
Ethynyl estradiol	216
Fenamiphos	77
Fenarimol	77
Fenitrothion	77
Fensulfothion	77
Fenthion	77
Fipronil	4
Fipronil sulfide	4
Fipronil sulfone	4
Fluridone	66
Fonofos	144
gamma-BHC (Lindane)	1020
gamma-Chlordane	183
gamma-Chlordene	62
Glufosinate	12
Heptachlor	953
Heptachlor epoxide	953
Hexachlorobutadiene	800
Hexachlorocyclopentadiene	59

Chemical	Number of water analyses
Hexachloroethane	788
Hexahydrohexamethyl cyclopentabenzopyran	12
Hexazinone	77
Imidan	77
Indole	12
Ioxynil	77
Isoborneol	12
Isopropylbenzene (cumene)	12
Isoquinoline	12
Linuron	67
Menthol	12
Merphos	77
Methamidophos	1
Methiocarb	4
Methomyl	4
Methoxychlor	953
Methyl Chloride	1
Methyl salicylate	12
Methylene Chloride	1
Methyltestosterone	204
Metribuzin (Sencor)	144
Mevinphos	65
MGK-264	77

Chemical	Number of water analyses
Mirex	71
Molinate	144
Monoethoxyoctylphenol	12
N,N-Diethyl-meta-toluamide (DEET)	12
Nitrobenzene	800
N-Nitrosodi-N-Propylamine	800
N-Nitrosodiphenylamine	800
Norflurazon	77
Oxamyl (Vydate)	4
Oxychlordane	74
Oxyfluorofen	77
Paraoxon-methyl	65
Parathion	924
Parathion-methyl	924
Pebulate	144
Pendimethalin	144
Pentachloroanisole	24
Phorate	924
Phosphamidon (mixed isomers)	65
Picloram	77
Profluralin	77
Progesterone	204
Prometryn	77

Chemical	Number of water analyses
Pronamide (Kerb)	144
Propachlor (Ramrod)	144
Propanil	67
Propargite	79
Propazine	77
Propetamphos	65
Pyridine	43
Ronnel	77
Stigmastanol	11
Styrene	1
Sulfotepp	77
Terbacil	144
Terbufos	67
Terbutryn (Igran)	77
Testosterone	204
Tetrachloroethylene	13
Tetrachlorvinphos (Gardona)	65
Thiobencarb	67
Tin	14
Tin, Dissolved	14
Toluene	1
Total Xylenes	1
Toxaphene	915

Chemical	Number of water analyses
trans-1,2-Dichloroethylene	1
trans-1,3-Dichloropropene	1
trans-Nonachlor	73
Treflan (Trifluralin)	76
Tri(2-chloroethyl) phosphate (Fyrol CEF)	12
Tri(dichloroisopropyl) phosphate (Fyrol PCF)	11
Triadimefon	77
Triallate	144
Tribufos (DEF)	65
Trichlorofluoromethane	1
Triclosan	8
Triethyl citrate (ethyl citrate)	12
Triphenylphosphate	8
Tris(2-butoxyethyl) phosphate	12
Vernolate	77
Vinclozolin	204
Vinyl acetate	1
Vinyl chloride	1

Table 4. Chemicals analyzed at least once in sediment, but which were never detected.

Chemical	Number of sediment analyses
1,2,4-Trichlorobenzene	112

Chemical	Number of sediment analyses
1,2-Diphenylhydrazine	112
1,3-Dichlorobenzene	112
2,4,5-T	107
2,4,5-TP (Silvex)	107
2,4,5-Trichlorophenol	112
2,4,6-Trichlorophenol	112
2,4-D	107
2,4-DB	107
2,4-Dichlorophenol	112
2,4-Dimethylphenol	112
2,4-Dinitrophenol	69
2,4-Dinitrotoluene	112
2,6-Dinitrotoluene	112
2-Chloronaphthalene	112
2-Chlorophenol	112
2-Methylphenol	112
2-Nitroaniline	69
2-Nitrophenol	112
3,3'-Dichlorobenzidine	37
3-Nitroaniline	53
4,6-Dinitro-O-Cresol	69
4-Bromophenyl Phenyl Ether	112
4-Chloro-3-Methylphenol	69

Chemical	Number of sediment analyses
4-Chloroaniline	16
4-Chlorophenyl Phenyl Ether	112
4-Nitroaniline	61
4-Nitrophenol	69
Aldrin	112
alpha-BHC	112
Aroclor 1221	112
Aroclor 1232	112
Aroclor 1242	112
beta-BHC	112
Bis(2-Chloroethoxy)Methane	112
Bis(2-Chloroethyl)Ether	112
Bis(2-Chloroisopropyl)Ether	112
Caffeine	112
Chlorpyrifos	104
Dalapon	107
delta-BHC	112
Diazinon	104
Dicamba	107
Dichloroprop	107
Dieldrin	112
Diethyl Phthalate	112
Dinoseb	107

Chemical	Number of sediment analyses
Disulfoton (Di-Syston)	104
Endosulfan	112
Endosulfan II	112
Endosulfan sulfate	112
Endrin	112
Endrin aldehyde	112
gamma-BHC (Lindane)	112
Heptachlor	112
Heptachlor epoxide	112
Hexachlorobutadiene	112
Hexachlorocyclopentadiene	53
Hexachloroethane	112
Isophorone	112
Malathion	104
MCPA	107
MCPP (Mecoprop)	107
Methoxychlor	112
Molybdenum	21
Nitrobenzene	112
N-Nitrosodimethylamine	72
N-Nitrosodi-N-Propylamine	112
N-Nitrosodiphenylamine	112
Parathion	104

Chemical	Number of sediment analyses
Parathion-methyl	104
Pentachlorophenol	112
Phorate	104
Toxaphene	112

Appendix B

Tier 2 Data Values

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Table 5. Water and Sediment data used in Domestic Water with Backyard Wading Use and Wading scenarios.

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0430	Arsenic	29	100.00%	1	0.00%		2.41E-03	
0430	Benzo(a)anthracene	10	10.00%	not analyzed			1.87E-05	
0430	Benzo(a)pyrene	10	20.00%	not analyzed			1.75E-05	
0430	Benzo(b)fluoranthene	10	20.00%	not analyzed			3.98E-05	
0430	Benzo(k)fluoranthene	10	20.00%	not analyzed			3.75E-05	
0430	Chrysene	10	20.00%	not analyzed			4.17E-05	
0430	Iron	29	100.00%	not analyzed			2.76E+00	
0430	Vanadium	28	100.00%	not analyzed			5.66E-03	
0434	Antimony	24	91.67%	not analyzed			6.75E-04	
0434	Arsenic	25	100.00%	1	0.00%		2.81E-03	
0434	Benzo(a)anthracene	9	11.11%	not analyzed		4.60E-05		
0434	Benzo(a)pyrene	9	22.22%	not analyzed		5.76E-05		
0434	Benzo(b)fluoranthene	9	22.22%	not analyzed		1.49E-04		
0434	Benzo(k)fluoranthene	9	22.22%	not analyzed		7.65E-05		
0434	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		5.50E-03		
0434	Chrysene	9	11.11%	not analyzed		1.22E-04		
0434	Iron	25	100.00%	not analyzed			2.41E+00	
0434	Pentachlorophenol	9	11.11%	not analyzed		4.75E-04		
0434	Pyrene	9	77.78%	not analyzed		1.87E-04		
0434	Vanadium	24	100.00%	not analyzed			4.71E-03	
0437	Antimony	2	50.00%	not analyzed		5.00E-04		
0437	Arsenic	2	100.00%	not analyzed		2.84E-03		
0437	Manganese	1	100.00%	not analyzed		1.68E-01		
0437	Vanadium	2	100.00%	not analyzed		3.01E-03		
0440	Arsenic	34	100.00%	1	0.00%		2.48E-03	
0440	Benzo(a)pyrene	10	10.00%	not analyzed			1.20E-05	
0440	Benzo(b)fluoranthene	10	10.00%	not analyzed			1.73E-05	

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0440	Benzo(k)fluoranthene	10	10.00%	not analyzed			1.32E-05	
0440	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.27E-03		
0440	Chrysene	10	10.00%	not analyzed			2.30E-05	
0440	Iron	31	100.00%	not analyzed			4.44E+00	
0440	Pentachlorophenol	14	21.43%	not analyzed			2.04E-04	
0440	Vanadium	32	100.00%	not analyzed			1.02E-02	
0441	Antimony	2	50.00%	not analyzed		5.90E-04		
0441	Arsenic	2	100.00%	not analyzed		8.53E-03		
0441	Barium	2	100.00%	not analyzed		1.50E-01		
0441	Cadmium	2	50.00%	not analyzed		4.30E-04		
0441	Pentachlorophenol	4	100.00%	not analyzed		9.10E-05		
0441	Vanadium	2	100.00%	not analyzed		4.00E-02		
0442	Arsenic	24	100.00%	1	0.00%		7.55E-03	
0442	Barium	23	100.00%	1	100.00%		7.55E-02	66.4
0442	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		1.46E-02		
0442	Iron	25	100.00%	not analyzed			1.18E+01	
0442	Vanadium	24	100.00%	not analyzed			1.32E-02	
0444	Arsenic	28	100.00%	2	50.00%		2.43E-03	3
0444	Benzo(a)anthracene	8	12.50%	not analyzed		2.60E-05		
0444	Benzo(a)pyrene	8	25.00%	not analyzed		3.02E-05		
0444	Benzo(b)fluoranthene	8	25.00%	not analyzed		5.26E-05		
0444	Benzo(k)fluoranthene	8	25.00%	not analyzed		6.75E-05		
0444	Chrysene	8	12.50%	not analyzed		5.69E-05		
0444	Pentachlorophenol	10	20.00%	not analyzed			6.71E-05	
0444	Vanadium	28	100.00%	not analyzed			3.12E-03	
0446	Antimony	22	54.55%	not analyzed			3.91E-04	
0446	Arsenic	23	100.00%	1	0.00%		2.11E-03	
0446	Benzo(a)pyrene	9	11.11%	not analyzed		1.90E-05		
0446	Benzo(b)fluoranthene	9	11.11%	not analyzed		4.10E-05		

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0446	Benzo(k)fluoranthene	9	11.11%	not analyzed		2.30E-05		
0446	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		6.39E-03		
0446	Chrysene	9	11.11%	not analyzed		2.50E-05		
0446	Iron	23	100.00%	not analyzed			3.37E+00	
0446	Vanadium	22	100.00%	not analyzed			6.06E-03	
0450	Arsenic	13	100.00%	4	0.00%		1.92E-03	
0450	Benzo(b)fluoranthene	11	9.09%	4	100.00%		1.42E-05	0.0436
0450	Benzo(k)fluoranthene	11	9.09%	2	100.00%		1.32E-05	0.0136
0450	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		1.00E-02		
0450A	Arsenic	3	100.00%	2	100.00%	2.10E-03		3.6
0450A	Benzo(a)anthracene	4	25.00%	2	100.00%	1.89E-05		0.0352
0450A	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		8.91E-04		
0450A	Chrysene	4	25.00%	2	50.00%	3.55E-05		0.0512
0450A	Naphthalene	6	50.00%	2	0.00%	2.00E-03		
0450B	Benzo(a)anthracene	1	100.00%	not analyzed		1.15E-05		
0450B	Chrysene	1	100.00%	not analyzed		1.30E-05		
0450BB	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.06E-03		
0450BB	Pentachlorophenol	1	100.00%	not analyzed		2.90E-04		
0450C	Arsenic	3	100.00%	2	50.00%	1.52E-03		14.9
0450C	Benzo(a)anthracene	4	25.00%	2	100.00%	1.90E-05		0.0269
0450C	Benzo(a)pyrene	4	0.00%	1	100.00%			0.0177
0450C	Chrysene	4	25.00%	2	100.00%	3.80E-05		0.0353
0450C	Naphthalene	5	20.00%	2	0.00%	2.00E-03		
0450D	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		4.60E-03		
0456	Arsenic	32	100.00%	1	0.00%		1.81E-03	
0456	Benzo(b)fluoranthene	9	11.11%	not analyzed		1.30E-05		
0456	Benzo(k)fluoranthene	9	11.11%	not analyzed		1.40E-05		
0456	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		7.46E-03		
0456	Vanadium	30	100.00%	not analyzed			2.53E-03	
0470	Arsenic	31	100.00%	1	0.00%		1.82E-03	
0470	Benzo(b)fluoranthene	9	11.11%	not analyzed		1.30E-05		

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0470	Pentachlorophenol	13	23.08%	not analyzed			1.56E-04	
0470	Vanadium	30	100.00%	not analyzed			2.44E-03	
0474	Arsenic	26	96.15%	1	0.00%		4.95E-03	
0474	Cadmium	26	19.23%	5	0.00%		2.25E-04	
0474	Iron	25	100.00%	not analyzed			1.80E+00	
0474	Manganese	1	100.00%	not analyzed		1.57E-01		
0474	Pentachlorophenol	10	10.00%	not analyzed			1.95E-04	
0474	Thallium	25	12.00%	1	0.00%		1.23E-02	
0474	Vanadium	24	100.00%	not analyzed			3.83E-03	
0478	Arsenic	33	100.00%	1	0.00%		3.22E-03	
0478	Cadmium	33	78.79%	5	20.00%		2.34E-04	0.15
0478	Iron	25	100.00%	not analyzed			3.09E+00	
0478	Pentachlorophenol	15	40.00%	not analyzed			6.67E-05	
0478	Vanadium	32	100.00%	not analyzed			6.52E-03	
0484	Arsenic	25	100.00%	1	0.00%		2.06E-03	
0484	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		2.39E-03		
0484	Vanadium	25	100.00%	not analyzed			3.68E-03	
0486	Arsenic	13	100.00%	2	50.00%		1.00E-03	3.5
0498	Arsenic	24	100.00%	1	0.00%		7.84E-03	
0498	Benzo(b)fluoranthene	9	11.11%	not analyzed		1.30E-05		
0498	Benzo(k)fluoranthene	9	11.11%	not analyzed		1.10E-05		
0498	Vanadium	23	100.00%	not analyzed			3.28E-03	
0512	Arsenic	28	100.00%	not analyzed			1.23E-03	
0512	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.01E-03		
0512	Pentachlorophenol	34	2.94%	not analyzed			1.15E-04	
0518	Arsenic	26	100.00%	not analyzed			1.04E-03	
0527	Arsenic	4	100.00%	not analyzed		7.20E-04		
0527	Bis(2-Ethylhexyl)Phthalate	4	100.00%	not analyzed		3.77E-04		
0535	Arsenic	2	100.00%	1	100.00%	6.60E-04		1.84
0535	Benzo(a)anthracene	2	0.00%	1	100.00%			0.322

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0535	Benzo(a)pyrene	2	0.00%	1	100.00%			0.344
0535	Benzo(b)fluoranthene	2	0.00%	1	100.00%			0.549
0535	Bis(2-Ethylhexyl)Phthalate	2	100.00%	1	100.00%	1.77E-03		0.755
0535	Total PCB	Not analyzed		1	100.00%			0.064
0536	Arsenic	26	100.00%	not analyzed			8.34E-04	
0539	Arsenic	Not analyzed		1	100.00%			2.5
0539	Benzo(a)pyrene	Not analyzed		1	100.00%			0.0343
0539	Dibenzo(a,h)anthracene	Not analyzed		1	100.00%			0.012
0540	Arsenic	26	100.00%	not analyzed			7.90E-04	
0540	Bis(2-Ethylhexyl)Phthalate	3	100.00%	not analyzed		9.64E-03		
0540	Pentachlorophenol	28	3.57%	not analyzed			1.19E-04	
0544	Arsenic	2	100.00%	not analyzed		7.30E-04		
0544	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		8.56E-04		
0562	Arsenic	Not analyzed		1	100.00%			1.3
0562	Benzo(a)pyrene	Not analyzed		1	100.00%			0.0169
0603	Arsenic	22	100.00%	not analyzed			1.12E-03	
0604A	Arsenic	21	100.00%	not analyzed			1.31E-03	
0607A	Arsenic	23	100.00%	not analyzed			1.23E-03	
0610	Arsenic	Not analyzed		1	100.00%			4.22
0611	Arsenic	46	97.83%	not analyzed			1.25E-03	
0611	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.34E-03		
0611	Manganese	1	100.00%	not analyzed		9.46E-02		
0612	Arsenic	43	97.67%	not analyzed			1.59E-03	
0612	Manganese	1	100.00%	not analyzed		1.49E-01		
0612	N-Nitrosodimethylamine	24	4.17%	not analyzed			1.16E-05	
0614	Arsenic	23	100.00%	1	100.00%		9.34E-04	1.59
0614	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		6.80E-04		
0615	Arsenic	Not analyzed		1	100.00%			1.75
0615	Bis(2-	1	100.00%	not		3.07E-03		

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
	Ethylhexyl)Phthalate			analyzed				
0617	Arsenic	23	100.00%	1	100.00%		9.03E-04	1.9
0618	Arsenic	Not analyzed		3	100.00%			2.56
0618	Benzo(a)anthracene	27	0.00%	3	100.00%			0.752
0618	Benzo(a)pyrene	27	0.00%	3	100.00%			0.847
0618	Benzo(b)fluoranthene	27	0.00%	3	100.00%			1.19
0618	Bis(2-Ethylhexyl)Phthalate	1	100.00%	3	100.00%	8.32E-04		0.314
0618	Dibenzo(a,h)anthracene	27	0.00%	3	100.00%			0.129
0618	Indeno(1,2,3-cd)pyrene	27	0.00%	3	100.00%			0.591
0618	Total PCB	Not analyzed		1	100.00%			0.078
0622	Arsenic	21	100.00%	1	100.00%		8.76E-04	3.1
0623	Arsenic	Not analyzed		1	100.00%			2.37
0623	Benzo(a)pyrene	Not analyzed		1	100.00%			0.0737
0623	Benzo(b)fluoranthene	Not analyzed		1	100.00%			0.106
0624	Arsenic	Not analyzed		1	100.00%			4.24
0625	Arsenic	11	100.00%	1	100.00%		9.03E-04	4.63
0626	Arsenic	Not analyzed		1	100.00%			2.86
0626	Benzo(a)anthracene	Not analyzed		1	100.00%			0.199
0626	Benzo(a)pyrene	Not analyzed		1	100.00%			0.255
0626	Benzo(b)fluoranthene	Not analyzed		1	100.00%			0.309
0626	Indeno(1,2,3-cd)pyrene	Not analyzed		1	100.00%			0.159
0631	Arsenic	28	96.43%	1	0.00%		2.00E-03	
0631	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		8.45E-04		
0631	Iron	25	100.00%	not analyzed			4.68E+00	
0631	Pentachlorophenol	17	35.29%	not analyzed			1.28E-04	
0631	Vanadium	28	100.00%	not analyzed			7.90E-03	
0801A	Arsenic	Not analyzed		1	100.00%			2.45
0801A	Benzo(a)pyrene	Not analyzed		1	100.00%			0.053
0804	Arsenic	22	100.00%	not analyzed			8.74E-04	
0805A	Arsenic	21	100.00%	not analyzed			7.59E-04	

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0805A	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.07E-02		
0805B	Arsenic	22	100.00%	not analyzed			7.25E-04	
0807	Arsenic	20	100.00%	not analyzed			7.71E-04	
0807	Bis(2-Ethylhexyl)Phthalate	4	100.00%	not analyzed		6.60E-03		
0814	Arsenic	22	100.00%	not analyzed			7.53E-04	
0814A	Arsenic	23	100.00%	not analyzed			7.18E-04	
0817	Arsenic	23	100.00%	not analyzed			7.69E-04	
0817	Bis(2-Ethylhexyl)Phthalate	3	100.00%	not analyzed		1.03E-02		
0817A	Arsenic	Not analyzed		1	100.00%			6
0817A	Benzo(a)pyrene	Not analyzed		1	100.00%			0.12
0817A	Benzo(b)fluoranthene	Not analyzed		1	100.00%			0.163
0817A	Total PCB	Not analyzed		1	100.00%			0.1265
0826	Arsenic	44	100.00%	not analyzed			7.59E-04	
0826	Bis(2-Ethylhexyl)Phthalate	3	100.00%	not analyzed		4.07E-03		
0829	Arsenic	22	100.00%	not analyzed			6.82E-04	
0831	Arsenic	42	100.00%	not analyzed			7.14E-04	
0831	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		6.89E-03		
0832	Arsenic	10	100.00%	not analyzed			7.79E-04	
0834	Arsenic	20	100.00%	not analyzed			7.73E-04	
0834	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		6.08E-03		
0840	Arsenic	21	100.00%	not analyzed			7.86E-04	
0840	Bis(2-Ethylhexyl)Phthalate	3	100.00%	not analyzed		9.27E-03		
0845	Arsenic	25	100.00%	not analyzed			7.27E-04	
0846	Arsenic	24	100.00%	not analyzed			7.22E-04	
0847	Arsenic	22	100.00%	not analyzed			7.10E-04	
0848	Arsenic	24	100.00%	not analyzed			7.35E-04	
0852	Arsenic	45	100.00%	not analyzed			7.70E-04	
0852	Benzo(a)pyrene	26	7.69%	not analyzed			6.93E-06	

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
0852	Benzo(b)fluoranthene	26	7.69%	not analyzed			8.34E-06	
0852	Benzo(k)fluoranthene	26	7.69%	not analyzed			6.42E-06	
0852	Bis(2-Ethylhexyl)Phthalate	3	100.00%	not analyzed		2.31E-02		
0852	Chrysene	26	3.85%	not analyzed			1.30E-05	
0852	Indeno(1,2,3-cd)pyrene	26	3.85%	not analyzed			3.15E-05	
0864B	Arsenic	Not analyzed		1	100.00%			2.68
0864B	Benzo(a)pyrene	Not analyzed		1	100.00%			0.035
0890	Arsenic	44	100.00%	not analyzed			7.60E-04	
4903	Arsenic	11	100.00%	not analyzed			9.06E-04	
4903	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		2.33E-02		
4903A	Arsenic	Not analyzed		3	100.00%			3.55
4903A	Benzo(a)anthracene	Not analyzed		3	100.00%			1.44
4903A	Benzo(a)pyrene	Not analyzed		3	100.00%			1.86
4903A	Benzo(b)fluoranthene	Not analyzed		3	100.00%			1.45
4903A	Benzo(k)fluoranthene	Not analyzed		3	100.00%			2.18
4903A	Dibenzo(a,h)anthracene	Not analyzed		3	100.00%			0.158
4903A	Indeno(1,2,3-cd)pyrene	Not analyzed		3	100.00%			0.67
4903A	Total PCB	Not analyzed		1	100.00%			0.4953
4903B	Arsenic	Not analyzed		1	100.00%			2.78
4903B	Benzo(a)anthracene	Not analyzed		1	100.00%			0.528
4903B	Benzo(a)pyrene	Not analyzed		1	100.00%			0.765
4903B	Benzo(b)fluoranthene	Not analyzed		1	100.00%			0.493
4903B	Benzo(k)fluoranthene	Not analyzed		1	100.00%			0.81
4903B	Dibenzo(a,h)anthracene	Not analyzed		1	100.00%			0.073
4903B	Indeno(1,2,3-cd)pyrene	Not analyzed		1	100.00%			0.292
4903B	Total PCB	Not analyzed		1	100.00%			0.0931
4903C	Arsenic	2	100.00%	not analyzed		9.39E-04		
A432	Arsenic	32	100.00%	not analyzed			3.06E-03	

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
A432	Barium	30	100.00%	not analyzed			3.26E-02	
A432	Benzo(b)fluoranthene	14	7.14%	not analyzed			6.23E-06	
A432	Iron	32	100.00%	not analyzed			3.95E+00	
A432	Vanadium	31	100.00%	not analyzed			9.38E-03	
A438	Arsenic	21	61.90%	not analyzed			7.30E-04	
A438	Vanadium	20	100.00%	not analyzed			2.52E-03	
A499	Arsenic	25	100.00%	not analyzed			2.89E-03	
A499	Benzo(b)fluoranthene	9	11.11%	not analyzed		1.10E-05		
A499	Benzo(k)fluoranthene	9	11.11%	not analyzed		1.30E-05		
A499	Iron	25	100.00%	not analyzed			1.69E+00	
A499	Vanadium	24	100.00%	not analyzed			6.80E-03	
A522	Arsenic	56	100.00%	not analyzed			2.34E-03	
A522	Benzo(b)fluoranthene	27	3.70%	not analyzed			8.91E-06	
A522	Bis(2-Ethylhexyl)Phthalate	4	100.00%	not analyzed		1.48E-01		
A535	Arsenic	2	100.00%	not analyzed		9.20E-04		
A535	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		2.44E-03		
A617	Arsenic	28	100.00%	1	100.00%		3.99E-03	4.5
A617	Barium	27	100.00%	1	100.00%		6.08E-02	52.2
A617	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		4.64E-03		
A617	Iron	28	100.00%	not analyzed			9.19E+00	
A617	Vanadium	28	100.00%	not analyzed			1.15E-02	
A620	Arsenic	31	100.00%	1	0.00%		2.62E-03	
A620	Barium	30	100.00%	1	100.00%		3.25E-02	30.7
A620	Iron	32	100.00%	not analyzed			4.80E+00	
A620	Vanadium	31	100.00%	not analyzed			8.89E-03	
A631	Arsenic	9	100.00%	not analyzed		8.40E-04		
A631	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		2.50E-03		
A631	Vanadium	9	100.00%	not analyzed		2.46E-03		
A632	Arsenic	11	100.00%	not analyzed			1.14E-03	

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
A680	Arsenic	26	100.00%	1	100.00%		2.70E-03	4.2
A680	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		9.15E-04		
A680	Iron	27	100.00%	not analyzed			1.78E+00	
A680	Vanadium	26	100.00%	not analyzed			4.03E-03	
A685	Arsenic	24	100.00%	1	0.00%		1.69E-03	
A685	Iron	25	96.00%	not analyzed			1.80E+00	
A685	Vanadium	24	100.00%	not analyzed			4.81E-03	
A690	Arsenic	22	77.27%	1	0.00%		1.41E-03	
A690	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.00E-03		
A690	Iron	23	91.30%	not analyzed			2.70E+00	
A690	Vanadium	22	100.00%	not analyzed			6.48E-03	
B430	4,4'-DDD	9	11.11%	not analyzed		8.00E-06		
B430	4,4'-DDE	9	11.11%	not analyzed		8.00E-06		
B430	4,4'-DDT	9	22.22%	not analyzed		4.10E-05		
B430	Antimony	9	55.56%	not analyzed		7.60E-04		
B430	Arsenic	9	100.00%	not analyzed		6.75E-03		
B430	Barium	9	100.00%	not analyzed		5.72E-02		
B430	Cadmium	9	55.56%	not analyzed		3.20E-04		
B430	Pentachlorophenol	11	72.73%	not analyzed			1.04E-04	
B430	Vanadium	8	100.00%	not analyzed		1.72E-02		
B535	Arsenic	2	100.00%	not analyzed		6.30E-04		
B535	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		7.02E-03		
BB470	Arsenic	10	100.00%	not analyzed			1.45E-03	
BB470	Vanadium	10	100.00%	not analyzed			1.88E-03	
C446	4,4'-DDD	4	25.00%	not analyzed		5.50E-06		
C446	4,4'-DDE	4	25.00%	not analyzed		5.50E-06		
C446	4,4'-DDT	4	50.00%	not analyzed		8.40E-05		
C446	Antimony	4	50.00%	not analyzed		7.90E-04		
C446	Arsenic	4	100.00%	not		8.20E-03		

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
				analyzed				
C446	Barium	4	100.00%	not analyzed		1.11E-01		
C446	Cadmium	4	25.00%	not analyzed		4.70E-04		
C446	Pentachlorophenol	4	100.00%	not analyzed		1.10E-04		
C446	Vanadium	3	100.00%	not analyzed		3.13E-02		
C484	Arsenic	4	100.00%	not analyzed		2.00E-03		
C484	Pentachlorophenol	9	66.67%	not analyzed		4.75E-04		
C484	Vanadium	4	100.00%	not analyzed		1.92E-03		
C535	Arsenic	2	100.00%	not analyzed		6.60E-04		
C535	Bis(2-Ethylhexyl)Phthalate	2	100.00%	not analyzed		6.85E-04		
D444	Antimony	8	100.00%	not analyzed		5.48E-04		
D444	Arsenic	8	100.00%	not analyzed		2.85E-03		
D444	Benzo(a)anthracene	8	12.50%	not analyzed		4.90E-05		
D444	Benzo(a)pyrene	8	25.00%	not analyzed		5.67E-05		
D444	Benzo(b)fluoranthene	8	37.50%	not analyzed		1.29E-04		
D444	Benzo(k)fluoranthene	8	25.00%	not analyzed		1.36E-04		
D444	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		4.01E-03		
D444	Chrysene	8	25.00%	not analyzed		1.18E-04		
D444	Pyrene	8	50.00%	not analyzed		1.47E-04		
D444	Vanadium	8	100.00%	not analyzed		2.53E-03		
D474	Arsenic	11	100.00%	not analyzed			2.36E-03	
D474	Bis(2-Ethylhexyl)Phthalate	1	100.00%	not analyzed		1.66E-03		
D474	Vanadium	11	100.00%	not analyzed			3.21E-03	
DW474	Arsenic	3	100.00%	not analyzed		4.30E-03		
DW474	Pentachlorophenol	3	100.00%	not analyzed		1.10E-04		
DW474	Vanadium	3	100.00%	not analyzed		4.81E-03		
E444	Pentachlorophenol	2	50.00%	not analyzed		4.10E-05		
Juanita Creek (Mouth)	Hexachlorobenzene	1	100.00%	not analyzed		3.50E-05		

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
M438	Arsenic	4	75.00%	not analyzed		1.40E-03		
M438	Vanadium	3	100.00%	not analyzed		2.26E-03		
M621	Arsenic	21	100.00%	1	100.00%		9.11E-04	1.68
S478	Arsenic	2	100.00%	not analyzed		3.42E-03		
S478	Vanadium	2	100.00%	not analyzed		6.37E-03		
SAMM_BEAR_MOUTH	Arsenic	3	100.00%	2	50.00%	1.75E-03		2.8
SAMM_BRIDGE_116	Arsenic	3	100.00%	2	50.00%	1.46E-03		4.9
SAMM_BRIDGE_116	Naphthalene	4	25.00%	2	0.00%	2.00E-03		
SAMM_BRIDGE_145	Arsenic	3	100.00%	2	50.00%	1.50E-03		2.5
SAMM_BRIDGE_145	Naphthalene	4	25.00%	2	0.00%	2.00E-03		
SAMM_BRIDGE_90	Arsenic	4	100.00%	2	0.00%	1.37E-03		
SAMM_BRIDGE_90	Benzo(a)pyrene	4	0.00%	1	100.00%			0.0427
SAMM_BRIDGE_90	Naphthalene	5	20.00%	2	0.00%	2.00E-03		
SAMM_IRR_RETURN_124	Antimony	8	50.00%	not analyzed		7.10E-04		
SAMM_IRR_RETURN_124	Arsenic	8	100.00%	not analyzed		3.16E-03		
SAMM_IRR_RETURN_124	Barium	8	100.00%	not analyzed		4.25E-02		
SAMM_IRR_RETURN_124	Benzo(a)anthracene	3	33.33%	not analyzed		2.00E-05		
SAMM_IRR_RETURN_124	Benzo(a)pyrene	3	33.33%	not analyzed		2.85E-05		
SAMM_IRR_RETURN_124	Benzo(b)fluoranthene	3	33.33%	not analyzed		3.00E-05		
SAMM_IRR_RETURN_124	Benzo(k)fluoranthene	3	33.33%	not analyzed		2.85E-05		
SAMM_IRR_RETURN_124	Chrysene	3	33.33%	not analyzed		3.85E-05		
SAMM_IRR_RETURN_124	Naphthalene	4	25.00%	not analyzed		2.00E-03		
SAMM_IRR_RETURN_124	Pentachlorophenol	6	50.00%	not analyzed		2.30E-04		
SAMM_IRR_RETURN_124	Vanadium	8	100.00%	not analyzed		1.60E-02		
SAMM_IRR_RETURN_145	Arsenic	3	100.00%	not analyzed		1.73E-03		
SAMM_IRR_RETURN_145	Naphthalene	4	25.00%	not analyzed		2.00E-03		
SAMM_IRR_RETURN_145	Vanadium	3	100.00%	not analyzed		2.22E-03		
SAMM_LITTLEBEAR_MOUTH	Arsenic	3	100.00%	2	0.00%	2.07E-03		
SAMM_LITTLEBEAR_MOUTH	Naphthalene	5	60.00%	2	0.00%	2.00E-03		
SAMM_LITTLEBEAR_MOUTH	Vanadium	3	100.00%	not analyzed		1.94E-03		

Locator	Parameter	N water	FOD water	N sediment	FOD sediment	Water EPC, N>10 (mg/L)	Water EPC, N>10 (mg/L)	Sediment EPC (mg/Kg)
SAMM_WOODIN_MOUTH	Arsenic	3	100.00%	2	50.00%	1.79E-03		16.7
SAMM_WOODIN_MOUTH	Benzo(a)pyrene	3	0.00%	1	100.00%			0.0386
SAMM_WOODIN_MOUTH	Naphthalene	4	25.00%	2	0.00%	2.00E-03		
SAMMAMISH RIVER BELOW BEAR CREEK	Naphthalene	1	100.00%	not analyzed		2.00E-03		
X438	Arsenic	24	87.50%	not analyzed			1.13E-03	
X438	Iron	25	100.00%	not analyzed			2.12E+00	
X438	Vanadium	23	100.00%	not analyzed			4.85E-03	
X630	Arsenic	24	100.00%	not analyzed			2.04E-03	
X630	Iron	25	100.00%	not analyzed			3.92E+00	
X630	Vanadium	24	100.00%	not analyzed			5.87E-03	

EPC = Exposure point concentration

Table 6. Water data used in Swimming scenario.

Location	Waterbody	Parameter	N water	FOD water	Water EPC, N<10 (mg/L)	Water EPC, N>10 (mg/L)
0512	LAKE UNION	Arsenic	28	100.00%		1.23E-03
0512	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	1	100.00%	1.01E-03	
0512	LAKE UNION	Pentachlorophenol	34	2.94%		1.15E-04
0518	LAKE UNION	Arsenic	26	100.00%		1.04E-03
0527	LAKE UNION	Arsenic	4	100.00%	7.20E-04	
0527	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	4	100.00%	3.77E-04	
0535	LAKE UNION	Arsenic	2	100.00%	6.60E-04	
0535	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	2	100.00%	1.77E-03	
0536	LAKE UNION	Arsenic	26	100.00%		8.34E-04
0540	LAKE UNION	Arsenic	26	100.00%		7.90E-04
0540	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	3	100.00%	9.64E-03	
0540	LAKE UNION	Pentachlorophenol	28	3.57%		1.19E-04
0544	LAKE UNION	Arsenic	2	100.00%	7.30E-04	
0544	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	2	100.00%	8.56E-04	

Location	Waterbody	Parameter	N water	FOD water	Water EPC, N<10 (mg/L)	Water EPC, N>10 (mg/L)
0603	LAKE SAMMAMISH	Arsenic	22	100.00%		1.12E-03
0604A	LAKE SAMMAMISH	Arsenic	21	100.00%		1.31E-03
0607A	LAKE SAMMAMISH	Arsenic	23	100.00%		1.23E-03
0611	LAKE SAMMAMISH	Arsenic	46	97.83%		1.25E-03
0611	LAKE SAMMAMISH	Bis(2-Ethylhexyl)Phthalate	1	100.00%	1.34E-03	
0611	LAKE SAMMAMISH	Manganese	1	100.00%	9.46E-02	
0612	LAKE SAMMAMISH	Arsenic	43	97.67%		1.59E-03
0612	LAKE SAMMAMISH	Manganese	1	100.00%	1.49E-01	
0612	LAKE SAMMAMISH	N-Nitrosodimethylamine	24	4.17%		1.16E-05
0614	LAKE SAMMAMISH	Arsenic	23	100.00%		9.34E-04
0614	LAKE SAMMAMISH	Bis(2-Ethylhexyl)Phthalate	1	100.00%	6.80E-04	
0615	LAKE SAMMAMISH	Bis(2-Ethylhexyl)Phthalate	1	100.00%	3.07E-03	
0617	LAKE SAMMAMISH	Arsenic	23	100.00%		9.03E-04
0618	LAKE SAMMAMISH	Bis(2-Ethylhexyl)Phthalate	1	100.00%	8.32E-04	
0622	LAKE SAMMAMISH	Arsenic	21	100.00%		8.76E-04
0625	LAKE SAMMAMISH	Arsenic	11	100.00%		9.03E-04
0804	LAKE WASHINGTON	Arsenic	22	100.00%		8.74E-04
0805A	LAKE WASHINGTON	Arsenic	21	100.00%		7.59E-04
0805A	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	1	100.00%	1.07E-02	
0805B	LAKE WASHINGTON	Arsenic	22	100.00%		7.25E-04
0807	LAKE WASHINGTON	Arsenic	20	100.00%		7.71E-04
0807	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	4	100.00%	6.60E-03	
0814	LAKE WASHINGTON	Arsenic	22	100.00%		7.53E-04
0814A	LAKE WASHINGTON	Arsenic	23	100.00%		7.18E-04
0817	LAKE WASHINGTON	Arsenic	23	100.00%		7.69E-04
0817	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	3	100.00%	1.03E-02	
0826	LAKE WASHINGTON	Arsenic	44	100.00%		7.59E-04
0826	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	3	100.00%	4.07E-03	
0829	LAKE WASHINGTON	Arsenic	22	100.00%		6.82E-04
0831	LAKE WASHINGTON	Arsenic	42	100.00%		7.14E-04
0831	LAKE WASHINGTON	Bis(2-	1	100.00%	6.89E-03	

Location	Waterbody	Parameter	N water	FOD water	Water EPC, N<10 (mg/L)	Water EPC, N>10 (mg/L)
		Ethylhexyl)Phthalate				
0832	LAKE WASHINGTON	Arsenic	10	100.00%		7.79E-04
0834	LAKE WASHINGTON	Arsenic	20	100.00%		7.73E-04
0834	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	2	100.00%	6.08E-03	
0840	LAKE WASHINGTON	Arsenic	21	100.00%		7.86E-04
0840	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	3	100.00%	9.27E-03	
0845	LAKE WASHINGTON	Arsenic	25	100.00%		7.27E-04
0846	LAKE WASHINGTON	Arsenic	24	100.00%		7.22E-04
0847	LAKE WASHINGTON	Arsenic	22	100.00%		7.10E-04
0848	LAKE WASHINGTON	Arsenic	24	100.00%		7.35E-04
0852	LAKE WASHINGTON	Arsenic	45	100.00%		7.70E-04
0852	LAKE WASHINGTON	Benzo(a)pyrene	26	7.69%		6.93E-06
0852	LAKE WASHINGTON	Benzo(b)fluoranthene	26	7.69%		8.34E-06
0852	LAKE WASHINGTON	Benzo(k)fluoranthene	26	7.69%		6.42E-06
0852	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	3	100.00%	2.31E-02	
0852	LAKE WASHINGTON	Chrysene	26	3.85%		1.30E-05
0852	LAKE WASHINGTON	Indeno(1,2,3-cd)pyrene	26	3.85%		3.15E-05
0890	LAKE WASHINGTON	Arsenic	44	100.00%		7.60E-04
4903	LAKE WASHINGTON	Arsenic	11	100.00%		9.06E-04
4903	LAKE WASHINGTON	Bis(2-Ethylhexyl)Phthalate	1	100.00%	2.33E-02	
4903C	LAKE WASHINGTON	Arsenic	2	100.00%	9.39E-04	
A522	LAKE UNION	Arsenic	56	100.00%		2.34E-03
A522	LAKE UNION	Benzo(b)fluoranthene	27	3.70%		8.91E-06
A522	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	4	100.00%	1.48E-01	
A535	LAKE UNION	Arsenic	2	100.00%	9.20E-04	
A535	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	2	100.00%	2.44E-03	
B535	LAKE UNION	Arsenic	2	100.00%	6.30E-04	
B535	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	2	100.00%	7.02E-03	
C535	LAKE UNION	Arsenic	2	100.00%	6.60E-04	
C535	LAKE UNION	Bis(2-Ethylhexyl)Phthalate	2	100.00%	6.85E-04	
M621	LAKE SAMMAMISH	Arsenic	21	100.00%		9.11E-04

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Appendix C

Toxicity Values

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Table 7. Toxicity values and gastrointestinal absorption efficiencies

Parameter Name	CSF (unitless)	RfD (mg/Kg-day)	ABSgi (unitless)
2-Methylnaphthalene	None	0.004	1
4,4'-DDD	0.24	None	1
4,4'-DDE	0.34	None	1
4,4'-DDT	0.34	0.0005	1
4,6-Dinitro-O-Cresol	None	0.0001	1
Acenaphthene	None	0.06	1
Acenaphthylene	None	None	1
Aldrin	17	0.00003	1
Anthracene	None	0.3	1
Antimony	None	0.0004	0.15
Aroclor 1248	None	None	1
Aroclor 1254	None	0.00002	1
Aroclor 1260	None	None	1
Arsenic	1.5	0.0003	1
Barium	None	0.07	0.07
Benzo(a)anthracene	0.89425	None	1
Benzo(a)pyrene	7.3	None	1
Benzo(b)fluoranthene	0.97455	None	1
Bis(2-Ethylhexyl)Phthalate	0.014	0.02	1
Cadmium	None	0.0005	0.05
Chromium	None	1.5	0.025
Chrysene	0.01971	None	1

Parameter Name	CSF (unitless)	RfD (mg/Kg-day)	ABSgi (unitless)
Copper	None	0.04	1
Dibenzo(a,h)anthracene	7.7015	None	1
Disulfoton (Di-Syston)	None	0.00004	1
Fluoranthene	None	0.04	1
Fluorene	None	0.04	1
Hexachlorobenzene	1.6	0.0008	1
Indeno(1,2,3-cd)pyrene	0.56575	None	1
Iron	None	0.3	1
Lead	None	None	1
Manganese	None	0.14	0.04
Mercury	None	0.0001	1
Methyl Mercury	None	0.0001	1
Naphthalene	None	0.02	1
N-Nitrosodimethylamine	51	None	1
Pentachlorophenol	0.12	0.03	1
Phenanthrene	None	None	1
Pyrene	None	0.03	1
Simazine	None	0.005	1
Thallium	None	0.00007	1
Total PCB	2	None	1
Vanadium	None	0.009	0.026
Zinc	None	0.3	1

Appendix D

E. coli distribution data

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Table 8. E. coli distribution data used in Monte Carlo simulation.

Location	Distribution Type	Anderson-Darling Fit	Mean	Standard Deviation	Location	Scale	Shape
0430	lognormal	0.94	1,354.99	3,766.60			
0434	lognormal	0.71	1,351.29	2,247.23			
0440	lognormal	0.65	616.72	1,307.92			
0442	lognormal	0.51	942.94	4,707.07			
0444	lognormal	0.63	701.82	1,259.83			
0446	lognormal	2.78	899.12	1,478.69			
0450	lognormal	0.53	199.48	239.27			
0450A	lognormal	0.26	164.09	173.28			
0450C	gamma	0.19			0.44	99.14	1.139646
0456	lognormal	0.31	815.09	2,209.62			
0470	lognormal	0.89	398.45	611.94			
0474	lognormal	1.34	378.02	730.17			
0478	pareto	1.53			53.95		0.595011
0484	lognormal	0.74	548.90	1,189.86			
0486	gamma	0.2			0.71	55.86	1.034641
0498	lognormal	0.38	2,068.61	15,059.35			
0512	lognormal	0.52	85.76	172.05			
0518	lognormal	0.75	26.19	27.87			
0536	lognormal	0.98	28.06	42.05			
0602SB	lognormal	0.25	118.60	302.54			
0606SB	lognormal	0.31	87.03	235.33			
0615SB	lognormal	0.4	77.61	390.97			
0625	lognormal	0.58	8.50	19.96			

Location	Distribution Type	Anderson-Darling Fit	Mean	Standard Deviation	Location	Scale	Shape
0631	lognormal	0.54	390.31	832.72			
0805ASB	lognormal	1.11	24.02	77.66			
0805BSB	lognormal	0.25	30.31	88.90			
0806SB	lognormal	0.17	573.17	1,892.27			
0813SB	lognormal	0.68	45.17	141.40			
0818SB	lognormal	0.45	353.63	1,397.57			
0820SB	lognormal	0.64	53.60	124.94			
0825SB	lognormal	1.03	31.33	62.70			
0826OLA	lognormal	0.77	79.78	183.43			
0826SB	lognormal	0.54	73.63	230.88			
0828SB	lognormal	0.31	306.75	1,519.70			
0829	lognormal	0.89	20.80	77.62			
0834	lognormal	0.65	14.40	39.77			
0834SB	lognormal	0.89	584.04	2,190.17			
083930SB	lognormal	0.41	125.68	435.62			
0852SB	lognormal	1.37	161.29	637.07			
0860SB	lognormal	1.05	199.07	646.10			
4903	lognormal	0.34	54.07	119.61			
4903SB	lognormal	0.52	116.00	398.34			
A422SB	lognormal	0.29	91.91	191.09			
A432	lognormal	0.51	848.89	1,635.75			
A434	lognormal	0.89	908.69	1,063.99			
A438	lognormal	0.36	183.67	595.47			
A499	lognormal	0.28	332.53	1,565.38			
A522	lognormal	0.42	26.54	44.97			

Location	Distribution Type	Anderson-Darling Fit	Mean	Standard Deviation	Location	Scale	Shape
A617	lognormal	0.65	1,058.41	4,865.19			
A620	lognormal	1.05	1,075.21	2,585.18			
A631	lognormal	0.19	158.79	274.61			
A632	lognormal	0.22	201.37	283.62			
A680	weibull	0.18			0.77	259.62	0.819315
A685	lognormal	0.64	155.36	403.77			
A690	weibull	0.22			-0.04	97.13	0.729193
A734SB	lognormal	0.53	101.73	248.60			
B484	gamma	0.45			2.88	109.23	1.091909
BB470	gamma	0.31			27.37	135.67	1.094373
C446	lognormal	0.64	897.35	1,454.95			
C484	weibull	0.22			23.02	167.48	1.114343
D444	lognormal	0.66	558.15	1,007.51			
D474	gamma	0.35			52.56	140.95	1.232878
J484	lognormal	0.17	117.79	127.03			
KSHZ06	lognormal	1.93	1,331.23	4,264.15			
N484	lognormal	0.42	187.15	218.91			
S484	lognormal	0.24	62.98	97.42			
SD007SB	lognormal	0.26	62.82	177.07			
SD017SB	lognormal	1.2	58.98	238.36			
X438	lognormal	0.29	398.57	941.00			
X630	lognormal	0.31	597.44	1,706.63			

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Appendix E

Tier 2 Results

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Table 9. Study area locations with Drinking Water with Backyard Wading Use scenario total cancinogenic risks greater the 1E-6.

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	5.06E-01	99.83%	0.17%
0434	THORNTON CREEK	4.04E-01	99.81%	0.19%
D444	KELSEY CREEK	3.75E-01	99.80%	0.20%
0444	MERCER SLOUGH	1.91E-01	99.65%	0.35%
0446	JUANITA CREEK	1.19E-01	99.53%	0.47%
0430	LYON CREEK	1.16E-01	99.44%	0.56%
A522	LAKE UNION	8.81E-02	99.29%	0.71%
0440	MAY CREEK	7.70E-02	99.14%	0.86%
0852	LAKE WASHINGTON	6.24E-02	99.67%	0.33%
0450	SAMMAMISH RIVER	3.24E-02	98.42%	1.58%
0450A	SAMMAMISH RIVER	2.14E-02	97.32%	2.68%
C484	BEAR CREEK	2.05E-02	97.39%	2.61%
C446	JUANITA CREEK	1.68E-02	86.96%	13.04%
0470	SWAMP CREEK	1.51E-02	96.76%	3.24%
0456	FORBES CREEK	1.44E-02	96.64%	3.36%
0450C	SAMMAMISH RIVER	1.35E-02	96.63%	3.37%
4903	LAKE WASHINGTON	1.32E-02	98.15%	1.85%
0450BB	SAMMAMISH RIVER	1.28E-02	100.00%	0.00%
B430	LYON CREEK	1.17E-02	84.48%	15.52%
0498	FAIRWEATHER CREEK	1.15E-02	81.74%	18.26%
0540	LAKE UNION	1.05E-02	97.99%	2.01%
0442	COAL CREEK	1.01E-02	79.99%	20.01%
0474	NORTH CREEK	9.51E-03	86.05%	13.95%
A499	TRIBUTARY TO LAKE WASHINGTON	9.19E-03	91.57%	8.43%
Juanita Creek (Mouth)	JUANITA CREEK	7.51E-03	100.00%	0.00%
0631	ISSAQUAH CREEK	6.39E-03	91.63%	8.37%
0805A	LAKE WASHINGTON	6.13E-03	96.69%	3.31%
0441	TAYLOR CREEK	6.11E-03	62.60%	37.40%
0817	LAKE WASHINGTON	5.91E-03	96.52%	3.48%
DW474	NORTH CREEK	5.77E-03	80.05%	19.95%
0512	LAKE UNION	5.71E-03	94.24%	5.76%
0840	LAKE WASHINGTON	5.35E-03	96.06%	3.94%
A432	MCALEER CREEK	4.67E-03	82.46%	17.54%
B535	LAKE UNION	4.06E-03	95.84%	4.16%
0831	LAKE WASHINGTON	4.01E-03	95.23%	4.77%

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
0807	LAKE WASHINGTON	3.86E-03	94.65%	5.35%
0450B	SAMMAMISH RIVER	3.86E-03	100.00%	0.00%
0478	LITTLE BEAR CREEK	3.66E-03	76.46%	23.54%
A617	LEWIS CREEK	3.65E-03	70.38%	29.62%
0834	LAKE WASHINGTON	3.58E-03	94.21%	5.79%
0450D	SAMMAMISH RIVER	2.55E-03	100.00%	0.00%
0826	LAKE WASHINGTON	2.46E-03	91.73%	8.27%
0484	BEAR CREEK	1.88E-03	70.62%	29.38%
E444	Kelsey Creek	1.72E-03	100.00%	0.00%
0615	LAKE SAMMAMISH	1.71E-03	99.68%	0.32%
A631	ISSAQUAH CREEK	1.61E-03	86.03%	13.97%
A535	LAKE UNION	1.60E-03	84.58%	15.42%
D474	NORTH CREEK	1.55E-03	59.30%	40.70%
A680	PINE LAKE CREEK	1.24E-03	40.81%	59.19%
0535	LAKE UNION	1.19E-03	84.71%	15.29%
0611	LAKE SAMMAMISH	1.08E-03	68.90%	31.10%
A690	EDEN CREEK	9.32E-04	59.48%	40.52%
S478	LITTLE BEAR CREEK	9.16E-04	0.00%	100.00%
0437	TRIBUTARY TO LAKE WASHINGTON	7.61E-04	0.00%	100.00%
A620	IDYLWOOD CREEK	7.01E-04	0.00%	100.00%
0544	LAKE UNION	6.70E-04	70.81%	29.19%
0614	LAKE SAMMAMISH	6.32E-04	59.62%	40.38%
C535	LAKE UNION	5.56E-04	68.23%	31.77%
SAMM_LITTLEBEAR_MOUTH	SAMMAMISH RIVER	5.54E-04	0.00%	100.00%
0618	LAKE SAMMAMISH	5.54E-04	98.54%	1.46%
X630	TIBBETS CREEK	5.46E-04	0.00%	100.00%
SAMM_WOODIN_MOUTH	SAMMAMISH RIVER	5.37E-04	0.94%	99.06%
0612	LAKE SAMMAMISH	4.85E-04	12.19%	87.81%
SAMM_BEAR_MOUTH	BEAR CREEK	4.78E-04	0.00%	100.00%
SAMM_IRR_RETURN_145	SAMMAMISH_IRRIGATION RETURN_145	4.63E-04	0.00%	100.00%
A685	EBRIGHT CREEK	4.54E-04	0.00%	100.00%
SAMM_BRIDGE_145	SAMMAMISH RIVER	4.10E-04	0.00%	100.00%
SAMM_BRIDGE_116	SAMMAMISH RIVER	4.07E-04	0.00%	100.00%
0527	LAKE UNION	4.02E-04	52.00%	48.00%
BB470	SWAMP CREEK	3.89E-04	0.00%	100.00%
M438	ROCK CREEK	3.75E-04	0.00%	100.00%
SAMM_BRIDGE_90	SAMMAMISH RIVER	3.73E-04	1.49%	98.51%
0604A	LAKE SAMMAMISH	3.51E-04	0.00%	100.00%
0607A	LAKE SAMMAMISH	3.28E-04	0.00%	100.00%

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
A632	ISSAQUAH CREEK	3.04E-04	0.00%	100.00%
X438	CEDAR RIVER	3.01E-04	0.00%	100.00%
0603	LAKE SAMMAMISH	3.00E-04	0.00%	100.00%
0486	SAMMAMISH RIVER	2.80E-04	0.00%	100.00%
0518	LAKE UNION	2.78E-04	0.00%	100.00%
0625	LAKE SAMMAMISH	2.56E-04	0.00%	100.00%
4903C	LAKE WASHINGTON	2.52E-04	0.00%	100.00%
M621	LAKE SAMMAMISH	2.49E-04	0.00%	100.00%
0617	LAKE SAMMAMISH	2.48E-04	0.00%	100.00%
0622	LAKE SAMMAMISH	2.44E-04	0.00%	100.00%
0804	LAKE WASHINGTON	2.34E-04	0.00%	100.00%
0536	LAKE UNION	2.23E-04	0.00%	100.00%
0832	LAKE WASHINGTON	2.09E-04	0.00%	100.00%
0890	LAKE WASHINGTON	2.04E-04	0.00%	100.00%
0814	LAKE WASHINGTON	2.02E-04	0.00%	100.00%
0848	LAKE WASHINGTON	1.97E-04	0.00%	100.00%
A438	CEDAR RIVER	1.95E-04	0.00%	100.00%
0845	LAKE WASHINGTON	1.95E-04	0.00%	100.00%
0805B	LAKE WASHINGTON	1.94E-04	0.00%	100.00%
0846	LAKE WASHINGTON	1.93E-04	0.00%	100.00%
0814A	LAKE WASHINGTON	1.92E-04	0.00%	100.00%
0847	LAKE WASHINGTON	1.90E-04	0.00%	100.00%
0829	LAKE WASHINGTON	1.83E-04	0.00%	100.00%
4903A	LAKE WASHINGTON	1.82E-04	93.85%	6.15%
4903B	LAKE WASHINGTON	7.61E-05	88.47%	11.53%
0626	LAKE SAMMAMISH	3.07E-05	70.59%	29.41%
0817A	LAKE WASHINGTON	3.06E-05	38.09%	61.91%
0624	LAKE SAMMAMISH	1.34E-05	0.00%	100.00%
0610	LAKE SAMMAMISH	1.33E-05	0.00%	100.00%
0623	LAKE SAMMAMISH	1.32E-05	43.31%	56.69%
0801A	LAKE WASHINGTON	1.12E-05	30.84%	69.16%
0539	LAKE UNION	1.09E-05	27.91%	72.09%
0864B	LAKE WASHINGTON	1.07E-05	21.21%	78.79%
0562	LAKE UNION	5.20E-06	21.13%	78.87%

Table 10. Study area locations with Drinking Water with Backyard Wading Use scenario non-cancinogenic hazard quotients greater than 1.

Location	Waterbody	Target organ	Total HQ	uncertain portion	confident portion
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATI	Blood	5.48	0.00%	100.00%

Location	Waterbody	Target organ	Total HQ	uncertain portion	confident portion
	ON_RETURN_124				
C446	JUANITA CREEK	Blood	2.03	0.00%	100.00%
B430	LYON CREEK	Blood	1.95	0.00%	100.00%
0434	THORNTON CREEK	Blood	1.73	0.00%	100.00%
0441	TAYLOR CREEK	Blood	1.52	0.00%	100.00%
D444	KELSEY CREEK	Blood	1.41	0.00%	100.00%
0437	TRIBUTARY TO LAKE WASHINGTON	Blood	1.29	0.00%	100.00%
0446	JUANITA CREEK	Blood	1.01	0.00%	100.00%
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	Hair	30.92	0.00%	100.00%
0441	TAYLOR CREEK	Hair	25.77	0.00%	100.00%
C446	JUANITA CREEK	Hair	20.16	0.00%	100.00%
B430	LYON CREEK	Hair	11.08	0.00%	100.00%
0442	COAL CREEK	Hair	8.51	0.00%	100.00%
A617	LEWIS CREEK	Hair	7.44	0.00%	100.00%
0440	MAY CREEK	Hair	6.56	0.00%	100.00%
A432	MCALEER CREEK	Hair	6.04	0.00%	100.00%
A620	IDYLWOOD CREEK	Hair	5.73	0.00%	100.00%
0631	ISSAQUAH CREEK	Hair	5.09	0.00%	100.00%
A499	TRIBUTARY TO LAKE WASHINGTON	Hair	4.38	0.00%	100.00%
0478	LITTLE BEAR CREEK	Hair	4.20	0.00%	100.00%
A690	EDEN CREEK	Hair	4.17	0.00%	100.00%
S478	LITTLE BEAR CREEK	Hair	4.10	0.00%	100.00%
0446	JUANITA CREEK	Hair	3.90	0.00%	100.00%
X630	TIBBETS CREEK	Hair	3.78	0.00%	100.00%
SAMM_LITTLEBEAR_MOUTH	SAMMAMISH RIVER	Hair	3.75	0.00%	100.00%
0430	LYON CREEK	Hair	3.65	0.00%	100.00%
X438	CEDAR RIVER	Hair	3.12	0.00%	100.00%
A685	EBRIGHT CREEK	Hair	3.10	0.00%	100.00%
DW474	NORTH CREEK	Hair	3.10	0.00%	100.00%
0434	THORNTON CREEK	Hair	3.03	0.00%	100.00%
SAMM_IRR_RETURN_145	SAMMAMISH_IRRIGATION RETURN_145	Hair	2.86	0.00%	100.00%
A680	PINE LAKE CREEK	Hair	2.60	0.00%	100.00%
0474	NORTH CREEK	Hair	2.47	0.00%	100.00%
0484	BEAR CREEK	Hair	2.37	0.00%	100.00%
0498	FAIRWEATHER CREEK	Hair	2.11	0.00%	100.00%
D474	NORTH CREEK	Hair	2.07	0.00%	100.00%
0444	MERCER SLOUGH	Hair	2.01	0.00%	100.00%
0437	TRIBUTARY TO LAKE WASHINGTON	Hair	1.94	0.00%	100.00%

Location	Waterbody	Target organ	Total HQ	uncertain portion	confident portion
0456	FORBES CREEK	Hair	1.63	0.00%	100.00%
D444	KELSEY CREEK	Hair	1.63	0.00%	100.00%
A438	CEDAR RIVER	Hair	1.62	0.00%	100.00%
A631	ISSAQUAH CREEK	Hair	1.58	0.00%	100.00%
0470	SWAMP CREEK	Hair	1.57	0.00%	100.00%
M438	ROCK CREEK	Hair	1.46	0.00%	100.00%
C484	BEAR CREEK	Hair	1.24	0.00%	100.00%
BB470	SWAMP CREEK	Hair	1.21	0.00%	100.00%
0441	TAYLOR CREEK	Kidney	7.26	0.00%	100.00%
C446	JUANITA CREEK	Kidney	6.29	0.00%	100.00%
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	Kidney	3.96	0.00%	100.00%
B430	LYON CREEK	Kidney	3.71	0.00%	100.00%
0442	COAL CREEK	Kidney	2.34	0.00%	100.00%
A617	LEWIS CREEK	Kidney	1.89	0.00%	100.00%
0478	LITTLE BEAR CREEK	Kidney	1.42	0.00%	100.00%
0474	NORTH CREEK	Kidney	1.36	0.00%	100.00%
A432	MCALEER CREEK	Kidney	1.01	0.00%	100.00%
A620	IDYLWOOD CREEK	Kidney	1.01	0.00%	100.00%
0474	NORTH CREEK	Other	32.52	0.00%	100.00%
0442	COAL CREEK	Other	7.04	0.00%	100.00%
A617	LEWIS CREEK	Other	5.47	0.00%	100.00%
A620	IDYLWOOD CREEK	Other	2.86	0.00%	100.00%
0631	ISSAQUAH CREEK	Other	2.78	0.00%	100.00%
0440	MAY CREEK	Other	2.64	0.00%	100.00%
A432	MCALEER CREEK	Other	2.35	0.00%	100.00%
X630	TIBBETS CREEK	Other	2.34	0.00%	100.00%
0446	JUANITA CREEK	Other	2.01	0.00%	100.00%
0478	LITTLE BEAR CREEK	Other	1.84	0.00%	100.00%
0430	LYON CREEK	Other	1.64	0.00%	100.00%
A690	EDEN CREEK	Other	1.61	0.00%	100.00%
X438	CEDAR RIVER	Other	1.26	0.00%	100.00%
A685	EBRIGHT CREEK	Other	1.07	0.00%	100.00%
A680	PINE LAKE CREEK	Other	1.06	0.00%	100.00%
A499	TRIBUTARY TO LAKE WASHINGTON	Other	1.01	0.00%	100.00%
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	Skin	5.64	0.00%	100.00%
0441	TAYLOR CREEK	Skin	5.08	0.00%	100.00%
C446	JUANITA CREEK	Skin	4.88	0.00%	100.00%
0498	FAIRWEATHER CREEK	Skin	4.67	0.00%	100.00%
0442	COAL CREEK	Skin	4.50	0.00%	100.00%
B430	LYON CREEK	Skin	4.02	0.00%	100.00%

Location	Waterbody	Target organ	Total HQ	uncertain portion	confident portion
0450A	SAMMAMISH RIVER	Skin	3.83	0.00%	100.00%
SAMM_LITTLEBEAR_MOUTH	SAMMAMISH RIVER	Skin	3.70	0.00%	100.00%
0474	NORTH CREEK	Skin	2.95	0.00%	100.00%
DW474	NORTH CREEK	Skin	2.56	0.00%	100.00%
A617	LEWIS CREEK	Skin	2.40	0.00%	100.00%
SAMM_WOODIN_MOUTH	SAMMAMISH RIVER	Skin	2.37	0.00%	100.00%
0450	SAMMAMISH RIVER	Skin	2.28	0.00%	100.00%
SAMM_IRR_RETURN_145	SAMMAMISH_IRRIGATION RETURN_145	Skin	2.06	0.00%	100.00%
S478	LITTLE BEAR CREEK	Skin	2.04	0.00%	100.00%
0450C	SAMMAMISH RIVER	Skin	2.02	0.00%	100.00%
0478	LITTLE BEAR CREEK	Skin	1.92	0.00%	100.00%
SAMM_BRIDGE_145	SAMMAMISH RIVER	Skin	1.82	0.00%	100.00%
A432	MCALEER CREEK	Skin	1.82	0.00%	100.00%
SAMM_BRIDGE_116	SAMMAMISH RIVER	Skin	1.81	0.00%	100.00%
A499	TRIBUTARY TO LAKE WASHINGTON	Skin	1.72	0.00%	100.00%
D444	KELSEY CREEK	Skin	1.70	0.00%	100.00%
0437	TRIBUTARY TO LAKE WASHINGTON	Skin	1.69	0.00%	100.00%
0434	THORNTON CREEK	Skin	1.67	0.00%	100.00%
A680	PINE LAKE CREEK	Skin	1.63	0.00%	100.00%
SAMM_BRIDGE_90	SAMMAMISH RIVER	Skin	1.63	0.00%	100.00%
A620	IDYLWOOD CREEK	Skin	1.56	0.00%	100.00%
0440	MAY CREEK	Skin	1.48	0.00%	100.00%
0444	MERCER SLOUGH	Skin	1.46	0.00%	100.00%
0430	LYON CREEK	Skin	1.43	0.00%	100.00%
D474	NORTH CREEK	Skin	1.40	0.00%	100.00%
A522	LAKE UNION	Skin	1.39	0.00%	100.00%
0446	JUANITA CREEK	Skin	1.25	0.00%	100.00%
0486	SAMMAMISH RIVER	Skin	1.24	0.00%	100.00%
0484	BEAR CREEK	Skin	1.22	0.00%	100.00%
X630	TIBBETS CREEK	Skin	1.21	0.00%	100.00%
C484	BEAR CREEK	Skin	1.19	0.00%	100.00%
0631	ISSAQUAH CREEK	Skin	1.19	0.00%	100.00%
0470	SWAMP CREEK	Skin	1.08	0.00%	100.00%
0456	FORBES CREEK	Skin	1.08	0.00%	100.00%
SAMM_BEAR_MOUTH	BEAR CREEK	Skin	1.06	0.00%	100.00%
A685	EBRIGHT CREEK	Skin	1.01	0.00%	100.00%
0434	THORNTON CREEK	Other	2.73	47.42%	52.58%
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	Body weight	5.68	100.00%	0.00%

Location	Waterbody	Target organ	Total HQ	uncertain portion	confident portion
0450A	SAMMAMISH RIVER	Body weight	5.68	100.00%	0.00%
SAMM_LITTLEBEAR_MOUTH	SAMMAMISH RIVER	Body weight	5.68	100.00%	0.00%
SAMM_IRR_RETURN_145	SAMMAMISH_IRRIGATION RETURN_145	Body weight	3.79	100.00%	0.00%
SAMM_WOODIN_MOUTH	SAMMAMISH RIVER	Body weight	3.79	100.00%	0.00%
SAMM_BRIDGE_90	SAMMAMISH RIVER	Body weight	3.79	100.00%	0.00%
SAMM_BRIDGE_116	SAMMAMISH RIVER	Body weight	3.79	100.00%	0.00%
SAMM_BRIDGE_145	SAMMAMISH RIVER	Body weight	3.79	100.00%	0.00%
0450C	SAMMAMISH RIVER	Body weight	3.79	100.00%	0.00%
SAMMAMISH RIVER BELOW BEAR CREEK	SAMMAMISH RIVER	Body weight	1.89	100.00%	0.00%
0437	TRIBUTARY TO LAKE WASHINGTON	CNS	4.53	100.00%	0.00%
0474	NORTH CREEK	CNS	4.24	100.00%	0.00%
0612	LAKE SAMMAMISH	CNS	4.02	100.00%	0.00%
0611	LAKE SAMMAMISH	CNS	2.55	100.00%	0.00%
A522	LAKE UNION	Liver	292.90	100.00%	0.00%
C446	JUANITA CREEK	Liver	56.77	100.00%	0.00%
4903	LAKE WASHINGTON	Liver	46.11	100.00%	0.00%
0852	LAKE WASHINGTON	Liver	45.72	100.00%	0.00%
0450	SAMMAMISH RIVER	Liver	39.58	100.00%	0.00%
0442	COAL CREEK	Liver	28.89	100.00%	0.00%
B430	LYON CREEK	Liver	28.30	100.00%	0.00%
0805A	LAKE WASHINGTON	Liver	21.18	100.00%	0.00%
0540	LAKE UNION	Liver	20.46	100.00%	0.00%
0817	LAKE WASHINGTON	Liver	20.38	100.00%	0.00%
0840	LAKE WASHINGTON	Liver	18.35	100.00%	0.00%
0434	THORNTON CREEK	Liver	16.43	100.00%	0.00%
0456	FORBES CREEK	Liver	14.76	100.00%	0.00%
B535	LAKE UNION	Liver	13.89	100.00%	0.00%
0831	LAKE WASHINGTON	Liver	13.64	100.00%	0.00%
0807	LAKE WASHINGTON	Liver	13.06	100.00%	0.00%
0446	JUANITA CREEK	Liver	12.65	100.00%	0.00%
0834	LAKE WASHINGTON	Liver	12.03	100.00%	0.00%
A617	LEWIS CREEK	Liver	9.18	100.00%	0.00%
0450D	SAMMAMISH RIVER	Liver	9.10	100.00%	0.00%
0826	LAKE WASHINGTON	Liver	8.05	100.00%	0.00%

Location	Waterbody	Target organ	Total HQ	uncertain portion	confident portion
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	Liver	8.05	100.00%	0.00%
D444	KELSEY CREEK	Liver	7.94	100.00%	0.00%
0615	LAKE SAMMAMISH	Liver	6.08	100.00%	0.00%
Juanita Creek (Mouth)	JUANITA CREEK	Liver	5.86	100.00%	0.00%
C484	BEAR CREEK	Liver	5.54	100.00%	0.00%
0450BB	SAMMAMISH RIVER	Liver	5.48	100.00%	0.00%
0450A	SAMMAMISH RIVER	Liver	5.29	100.00%	0.00%
A631	ISSAQUAH CREEK	Liver	4.95	100.00%	0.00%
0440	MAY CREEK	Liver	4.90	100.00%	0.00%
A535	LAKE UNION	Liver	4.83	100.00%	0.00%
0484	BEAR CREEK	Liver	4.73	100.00%	0.00%
0535	LAKE UNION	Liver	3.50	100.00%	0.00%
0512	LAKE UNION	Liver	3.34	100.00%	0.00%
D474	NORTH CREEK	Liver	3.29	100.00%	0.00%
0631	ISSAQUAH CREEK	Liver	3.17	100.00%	0.00%
0611	LAKE SAMMAMISH	Liver	2.65	100.00%	0.00%
0474	NORTH CREEK	Liver	2.27	100.00%	0.00%
A690	EDEN CREEK	Liver	1.98	100.00%	0.00%
0470	SWAMP CREEK	Liver	1.82	100.00%	0.00%
A680	PINE LAKE CREEK	Liver	1.81	100.00%	0.00%
0544	LAKE UNION	Liver	1.69	100.00%	0.00%
0618	LAKE SAMMAMISH	Liver	1.65	100.00%	0.00%
C535	LAKE UNION	Liver	1.36	100.00%	0.00%
0614	LAKE SAMMAMISH	Liver	1.35	100.00%	0.00%
DW474	NORTH CREEK	Liver	1.28	100.00%	0.00%
0441	TAYLOR CREEK	Liver	1.06	100.00%	0.00%
D444	KELSEY CREEK	Other	1.02	100.00%	0.00%

Table 11. Study area locations with Wading scenario total cancinogenic risks greater the 1E-6.

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
SAMM_IRR_RETURN_124	SAMMAMISH_IRRIGATION_RETURN_124	7.33E-03	99.71%	0.29%
0434	THORNTON CREEK	5.86E-03	99.39%	0.61%
D444	KELSEY CREEK	5.43E-03	99.65%	0.35%
0444	MERCER SLOUGH	2.79E-03	98.56%	1.44%
0446	JUANITA CREEK	1.74E-03	98.46%	1.54%
0430	LYON CREEK	1.70E-03	98.19%	1.81%
A522	LAKE UNION	1.29E-03	97.70%	2.30%

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
0440	MAY CREEK	1.14E-03	97.22%	2.78%
0450	SAMMAMISH RIVER	4.86E-04	94.99%	5.01%
0450A	SAMMAMISH RIVER	3.27E-04	92.23%	7.77%
C484	BEAR CREEK	3.02E-04	95.56%	4.44%
C446	JUANITA CREEK	2.67E-04	79.38%	20.62%
0450C	SAMMAMISH RIVER	2.48E-04	76.92%	23.08%
0498	FAIRWEATHER CREEK	2.36E-04	57.67%	42.33%
0470	SWAMP CREEK	2.34E-04	90.10%	9.90%
0456	FORBES CREEK	2.24E-04	89.73%	10.27%
0442	COAL CREEK	2.13E-04	54.89%	45.11%
4903	LAKE WASHINGTON	1.98E-04	94.18%	5.82%
B430	LYON CREEK	1.87E-04	75.87%	24.13%
0450BB	SAMMAMISH RIVER	1.85E-04	100.00%	0.00%
4903A	LAKE WASHINGTON	1.82E-04	93.85%	6.15%
0474	NORTH CREEK	1.81E-04	65.23%	34.77%
0540	LAKE UNION	1.59E-04	93.70%	6.30%
A499	TRIBUTARY TO LAKE WASHINGTON	1.58E-04	76.77%	23.23%
0441	TAYLOR CREEK	1.12E-04	49.15%	50.85%
0631	ISSAQUAH CREEK	1.10E-04	76.92%	23.08%
Juanita Creek (Mouth)	JUANITA CREEK	1.08E-04	100.00%	0.00%
A617	LEWIS CREEK	1.02E-04	36.40%	63.60%
0618	LAKE SAMMAMISH	9.95E-05	91.88%	8.12%
DW474	NORTH CREEK	9.56E-05	69.86%	30.14%
A432	MCALEER CREEK	9.45E-05	58.85%	41.15%
0512	LAKE UNION	9.33E-05	83.28%	16.72%
0817	LAKE WASHINGTON	9.23E-05	89.40%	10.60%
0478	LITTLE BEAR CREEK	8.14E-05	49.70%	50.30%
4903B	LAKE WASHINGTON	7.53E-05	88.35%	11.65%
SAMM_WOODIN_MOUTH	SAMMAMISH RIVER	6.97E-05	7.20%	92.80%
0807	LAKE WASHINGTON	6.27E-05	84.34%	15.66%
0450B	SAMMAMISH RIVER	5.58E-05	100.00%	0.00%
0535	LAKE UNION	5.54E-05	81.52%	18.48%
A680	PINE LAKE CREEK	5.49E-05	13.35%	86.65%
0484	BEAR CREEK	4.53E-05	42.25%	57.75%
D474	NORTH CREEK	4.33E-05	30.71%	69.29%
0450D	SAMMAMISH RIVER	3.68E-05	100.00%	0.00%
A620	IDYLWOOD CREEK	3.33E-05	0.00%	100.00%
0817A	LAKE WASHINGTON	3.06E-05	38.09%	61.91%
0615	LAKE SAMMAMISH	3.01E-05	81.65%	18.35%
0626	LAKE SAMMAMISH	2.99E-05	69.80%	30.20%
0625	LAKE SAMMAMISH	2.61E-05	0.00%	100.00%

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
A690	EDEN CREEK	2.59E-05	30.87%	69.13%
X630	TIBBETS CREEK	2.59E-05	0.00%	100.00%
A631	ISSAQUAH CREEK	2.56E-05	78.05%	21.95%
SAMM_BRIDGE_116	SAMMAMISH RIVER	2.53E-05	0.00%	100.00%
E444	Kelsey Creek	2.49E-05	100.00%	0.00%
0486	SAMMAMISH RIVER	2.38E-05	0.00%	100.00%
S478	LITTLE BEAR CREEK	2.29E-05	0.00%	100.00%
0614	LAKE SAMMAMISH	2.23E-05	24.37%	75.63%
A685	EBRIGHT CREEK	2.15E-05	0.00%	100.00%
0622	LAKE SAMMAMISH	2.09E-05	0.00%	100.00%
SAMM_BEAR_MOUTH	BEAR CREEK	2.06E-05	0.00%	100.00%
0437	TRIBUTARY TO LAKE WASHINGTON	1.90E-05	0.00%	100.00%
BB470	SWAMP CREEK	1.85E-05	0.00%	100.00%
SAMM_BRIDGE_145	SAMMAMISH RIVER	1.79E-05	0.00%	100.00%
0617	LAKE SAMMAMISH	1.75E-05	0.00%	100.00%
M621	LAKE SAMMAMISH	1.69E-05	0.00%	100.00%
SAMM_BRIDGE_90	SAMMAMISH RIVER	1.47E-05	37.70%	62.30%
A632	ISSAQUAH CREEK	1.45E-05	0.00%	100.00%
X438	CEDAR RIVER	1.43E-05	0.00%	100.00%
SAMM_LITTLEBEAR_MOUTH	SAMMAMISH RIVER	1.39E-05	0.00%	100.00%
0624	LAKE SAMMAMISH	1.34E-05	0.00%	100.00%
0610	LAKE SAMMAMISH	1.33E-05	0.00%	100.00%
0518	LAKE UNION	1.32E-05	0.00%	100.00%
0623	LAKE SAMMAMISH	1.23E-05	39.06%	60.94%
SAMM_IRR_RETURN_145	SAMMAMISH_IRRIGATION RETURN_145	1.16E-05	0.00%	100.00%
0801A	LAKE WASHINGTON	1.12E-05	30.84%	69.16%
0864B	LAKE WASHINGTON	1.07E-05	21.21%	78.79%
0536	LAKE UNION	1.06E-05	0.00%	100.00%
0539	LAKE UNION	1.01E-05	22.05%	77.95%
M438	ROCK CREEK	9.38E-06	0.00%	100.00%
A438	CEDAR RIVER	9.28E-06	0.00%	100.00%
0829	LAKE WASHINGTON	8.68E-06	0.00%	100.00%
4903C	LAKE WASHINGTON	6.29E-06	0.00%	100.00%
0562	LAKE UNION	5.20E-06	21.13%	78.87%

Table 12. Study area locations with Wading scenario non-cancinogenic risks greater than 1.

Location	Waterbody	Target organ	HQ	Lower confidence portion	Higher confidence portion

Location	Waterbody	Target organ	HQ	Lower confidence portion	Higher confidence portion
A522	LAKE UNION	Liver	4.23	100.00%	0.00%
0474	NORTH CREEK	Other	1.49	100.00%	0.00%

Table 13. Study area locations with Swimming scenario total cancinogenic risks greater the 1E-6.

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
A522	LAKE UNION	3.70E-02	98.44%	1.56%
0852	LAKE WASHINGTON	2.61E-02	99.27%	0.73%
4903	LAKE WASHINGTON	5.59E-03	96.02%	3.98%
0540	LAKE UNION	4.49E-03	95.68%	4.32%
0805A	LAKE WASHINGTON	2.65E-03	92.97%	7.03%
0817	LAKE WASHINGTON	2.56E-03	92.62%	7.38%
0512	LAKE UNION	2.54E-03	88.12%	11.88%
0840	LAKE WASHINGTON	2.33E-03	91.71%	8.29%
B535	LAKE UNION	1.77E-03	91.26%	8.74%
0831	LAKE WASHINGTON	1.76E-03	90.05%	9.95%
0807	LAKE WASHINGTON	1.71E-03	88.91%	11.09%
0834	LAKE WASHINGTON	1.59E-03	88.06%	11.94%
0826	LAKE WASHINGTON	1.12E-03	83.41%	16.59%
A535	LAKE UNION	7.88E-04	71.31%	28.69%
0615	LAKE SAMMAMISH	7.07E-04	100.00%	0.00%
0611	LAKE SAMMAMISH	6.16E-04	50.10%	49.90%
0535	LAKE UNION	5.70E-04	71.54%	28.46%
0612	LAKE SAMMAMISH	4.19E-04	6.64%	93.36%
0614	LAKE SAMMAMISH	3.86E-04	40.56%	59.44%
0544	LAKE UNION	3.77E-04	52.36%	47.64%
0604A	LAKE SAMMAMISH	3.22E-04	0.00%	100.00%
C535	LAKE UNION	3.20E-04	49.31%	50.69%
0607A	LAKE SAMMAMISH	3.01E-04	0.00%	100.00%
0603	LAKE SAMMAMISH	2.76E-04	0.00%	100.00%
0527	LAKE UNION	2.64E-04	32.92%	67.08%
0518	LAKE UNION	2.55E-04	0.00%	100.00%
4903C	LAKE WASHINGTON	2.31E-04	0.00%	100.00%
M621	LAKE SAMMAMISH	2.24E-04	0.00%	100.00%
0617	LAKE SAMMAMISH	2.22E-04	0.00%	100.00%
0625	LAKE SAMMAMISH	2.22E-04	0.00%	100.00%
0622	LAKE SAMMAMISH	2.15E-04	0.00%	100.00%
0804	LAKE WASHINGTON	2.15E-04	0.00%	100.00%
0536	LAKE UNION	2.05E-04	0.00%	100.00%
0618	LAKE SAMMAMISH	1.92E-04	100.00%	0.00%

Location	Waterbody	Total risk	Lower confidence portion	Higher confidence portion
0832	LAKE WASHINGTON	1.91E-04	0.00%	100.00%
0890	LAKE WASHINGTON	1.87E-04	0.00%	100.00%
0814	LAKE WASHINGTON	1.85E-04	0.00%	100.00%
0848	LAKE WASHINGTON	1.81E-04	0.00%	100.00%
0845	LAKE WASHINGTON	1.79E-04	0.00%	100.00%
0805B	LAKE WASHINGTON	1.78E-04	0.00%	100.00%
0846	LAKE WASHINGTON	1.77E-04	0.00%	100.00%
0814A	LAKE WASHINGTON	1.76E-04	0.00%	100.00%
0847	LAKE WASHINGTON	1.75E-04	0.00%	100.00%
0829	LAKE WASHINGTON	1.68E-04	0.00%	100.00%

Table 14. Study area locations with Swimming scenario non-cancinogenic risks greater than 1.

Location	Waterbody	Target organ	HQ	Lower confidence portion	Higher confidence portion
A522	LAKE UNION	Liver	121.80	100.00%	0.00%
4903	LAKE WASHINGTON	Liver	19.17	100.00%	0.00%
0852	LAKE WASHINGTON	Liver	19.01	100.00%	0.00%
0805A	LAKE WASHINGTON	Liver	8.81	100.00%	0.00%
0540	LAKE UNION	Liver	8.51	100.00%	0.00%
0817	LAKE WASHINGTON	Liver	8.48	100.00%	0.00%
0840	LAKE WASHINGTON	Liver	7.63	100.00%	0.00%
B535	LAKE UNION	Liver	5.78	100.00%	0.00%
0831	LAKE WASHINGTON	Liver	5.67	100.00%	0.00%
0807	LAKE WASHINGTON	Liver	5.43	100.00%	0.00%
0834	LAKE WASHINGTON	Liver	5.00	100.00%	0.00%
0612	LAKE SAMMAMISH	CNS	4.35	100.00%	0.00%
0826	LAKE WASHINGTON	Liver	3.35	100.00%	0.00%
0611	LAKE SAMMAMISH	CNS	2.76	100.00%	0.00%
0615	LAKE SAMMAMISH	Liver	2.53	100.00%	0.00%
A535	LAKE UNION	Liver	2.01	100.00%	0.00%
0535	LAKE UNION	Liver	1.46	100.00%	0.00%
0512	LAKE UNION	Liver	1.39	100.00%	0.00%
A522	LAKE UNION	Skin	1.28	0.00%	100.00%

Location	Waterbody	Target organ	HQ	Lower confidence portion	Higher confidence portion
0611	LAKE SAMMAMISH	Liver	1.10	100.00%	0.00%

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Appendix F

PAHs vs. EIA comparison

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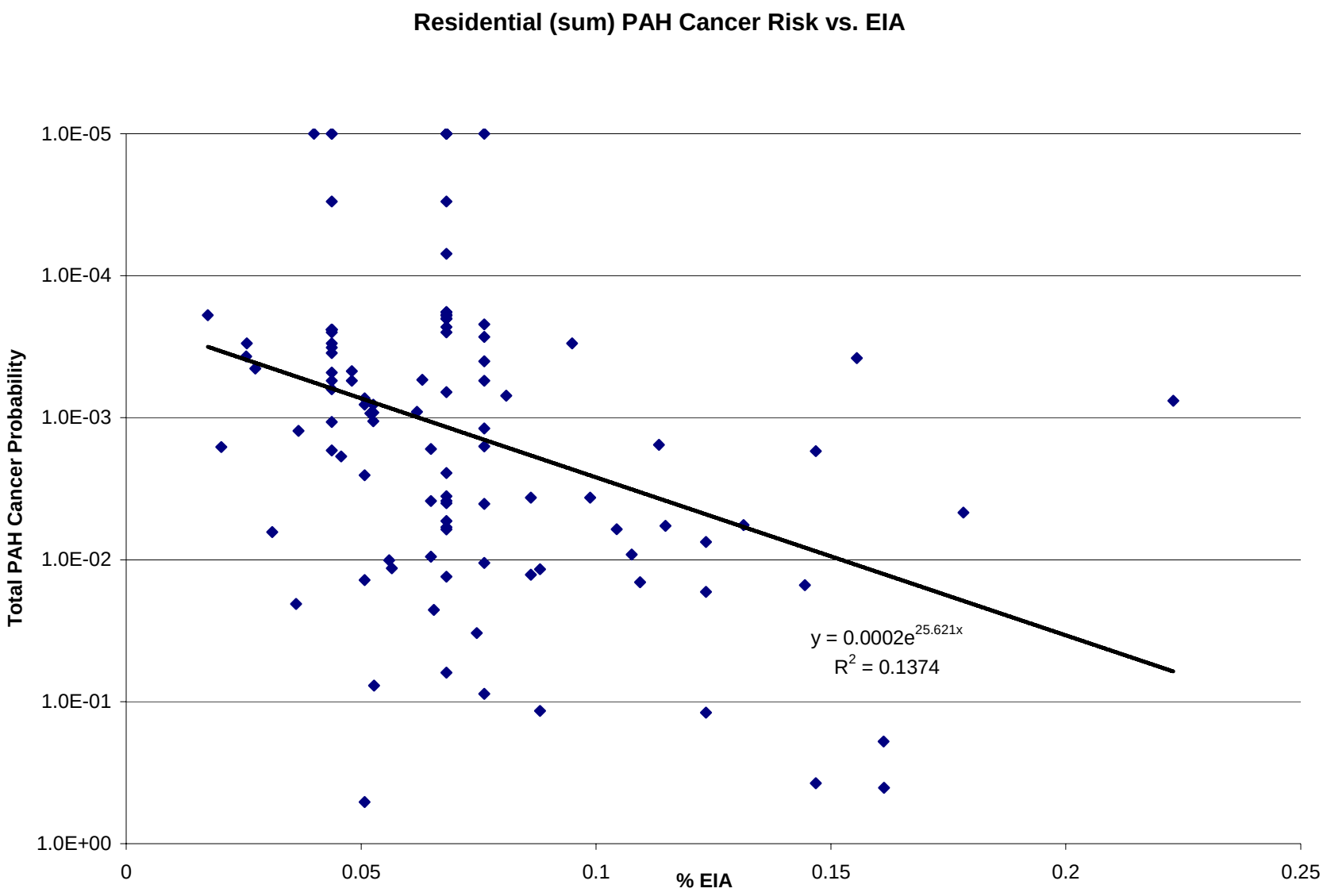
Residential (sum) PAH Cancer Risk vs. EIA
Total PAH Cancer Probability
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
0
0.05
0.1
0.15
0.2
0.25
% EIA
y = 0.0002e^25.621x
R^2 = 0.1374