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Cover photo: Upper Columbia River near Northport, WA.

PBT Trend Monitoring

Lead in Suspended Particulate Matter 2008

by
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Waterbody Numbers

Duwamish River	WA-09-1010
Hylebos Creek	WA-10-1011
Lake Washington	WA-08-9340
Lower Columbia River	WA-CR-1010
McNary Dam	WA-CR-1026
Okanogan River	WA-49-1010
Queets River	WA-21-1030
Rock Island Dam	WA-CR-1040
Snohomish River	WA-07-1020
Spokane River at Idaho border	WA-57-1010
Spokane River at Nine Mile Dam	WA-54-1020
Upper Columbia River	WA-CR-1060
Walla Walla River	WA-32-1010
Wenatchee River	WA-45-1010
Yakima River	WA-37-1010

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Glossary, Acronyms, and Abbreviations

Anthropogenic: Human-caused.

Bioaccumulative pollutants: Pollutants that build up in the food chain.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Nonpoint source: Unconfined and diffuse sources of contamination. Pollution that enters water from dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System program.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Acronyms and Abbreviations

CAP	Chemical Action Plan
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EPA	U.S. Environmental Protection Agency
MEL	Manchester Environmental Laboratory
MQO	Method Quality Objective
Pb	Lead
PBDD/F	Polybrominated dibenzodioxins/furans
PBT	Persistent, Bioaccumulative Toxic chemical
QA	Quality Assurance
QC	Quality Control
RPD	Relative Percent Difference
SPM	Suspended Particulate Matter
TSS	Total Suspended Solids
UCR	Upper Columbia River at Canadian border
USGS	U.S. Geological Survey

Units of measurement

cfs	cubic feet per second
cm	centimeter
dw	dry weight
mg/kg	milligrams per kilogram
mm	millimeters
µg/L	micrograms per liter
µm	micrometer

Abstract

This report summarizes results from the first year of lead monitoring as part of the Washington State Department of Ecology (Ecology) persistent, bioaccumulative, and toxic chemical (PBT) trend monitoring program. Lead in suspended particulate matter (SPM) was added to the PBT trend monitoring program in 2008 to (1) establish a baseline of lead concentrations in Washington State rivers and lakes, and (2) evaluate spatial and temporal trends over time.

SPM was collected from 15 monitoring sites across Washington State and analyzed for total lead during the spring and fall of 2008. A total of 46 samples were collected.

Lead was detected in 93% of the samples. The highest lead concentration was 3,121 mg/kg, detected in the Spokane River at the Idaho border during the spring. Elevated lead concentrations were also found in the Spokane River at Nine Mile Dam and in the upper Columbia River near the Canadian border. Lead levels at the other 12 sites were relatively low, ranging from non-detect – 65 mg/kg.

Most lead concentrations in SPM were within the range of values measured in background freshwater sediment reference areas and in statewide lake sediment studies conducted by Ecology in 1989 and 1992. Exceptions to this were found in the two Spokane River sites and the upper Columbia River site, which had elevated lead concentrations.

The two Spokane River sites had higher SPM-associated lead levels in 2008 compared to historical Ecology sediment data (from early 1990s – 2001) near these sites. In contrast, lead concentrations in SPM at the upper Columbia River were lower than those measured by Ecology in the early 1990s.

Five SPM-associated lead samples were above Ecology's proposed Freshwater Sediment Quality Value guideline lowest apparent effects threshold of 335 mg/kg. All five exceedances occurred at the two Spokane River monitoring sites. No guidelines are currently available for lead concentrations in SPM.

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- Jerry Freilich (Olympic National Park) for Queets River research permission.
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Introduction

Background

Lead is considered a metal of concern because it is widespread and persistent in the environment, bioaccumulative, and highly toxic to humans and wildlife.

Anthropogenic releases of lead have increased environmental levels 1,000 fold (ATSDR, 2007). The use of alkyl-lead additives in gasoline since the 1920s resulted in widespread lead pollution in the environment. Lead emissions and concentrations in the air decreased sharply during the 1980s and 1990s due to U.S. restrictions (Davies, 2008).

Today, sources of lead to the environment in Washington State include industrial releases such as mining, the Hanford nuclear reservation, military bases, large energy users, and sewage treatment plants. Nonpoint sources of lead to the environment occur through product use, ammunition, aviation fuel, and road dust (Davies, 2008). Low concentrations of lead naturally enter surface waters through weathering of bedrock and soils.

Lead is a powerful neurotoxin, and children are especially at risk from exposure. It predominantly affects developing nervous systems, and also can harm the cardiovascular system, kidney, blood, gastrointestinal system, immune system, and reproductive system (Davies, 2008). Exposure to lead occurs primarily through ingestion or inhalation of lead-containing materials, such as contaminated water or dust (ATSDR, 2007). Lead also accumulates and is stored in the bones of humans and wildlife.

Concern with these health risks prompted the Washington State Departments of Ecology (Ecology) and Health (DOH) to prepare a Chemical Action Plan (CAP) for lead. The objective of the CAP is to reduce and phase out lead uses, releases, and exposure to humans and the environment in Washington State (Gallagher, 2007). The CAP for lead (1) describes the dangers of lead, (2) identifies where the substance is found in the environment, and (3) recommends ways to reduce or prevent its harm. A draft lead CAP was completed in 2008, and a final is expected in 2009 (Davies, 2008).

Lead sampling was added to Ecology's *Trend Monitoring Component for Organic PBTs in the Washington State Toxics Monitoring Program* (Johnson, 2007) in 2008. The PBT trend monitoring program was initiated in 2007 to assess levels of persistent, bioaccumulative, and toxic chemicals (PBTs) in rivers and lakes of Washington State. Ecology's target PBT list is located in Appendix A.

Sampling for lead in suspended particulate matter (SPM) was added to the PBT trend monitoring effort to (1) establish a baseline of lead levels in the environment, and (2) measure spatial and temporal trends over time as CAP reduction strategies are implemented.

Previous Studies on Lead in Suspended Particulate Matter and Sediments

Several Ecology studies have examined lead contamination in SPM and bottom sediments of Washington rivers and lakes. This report compares 2008 lead levels to concentrations found in the following Ecology studies.

SPM Studies

Serdar et al. (1994a) analyzed lead in SPM along the upper Columbia River in 1992 and 1993. Lead concentrations did not meet (exceeded) Province of Ontario sediment guidelines (Severe Effects Level 250 mg/kg dw) during both sampling events, at 554 and 498 mg/kg dw, respectively.

Statewide Sediment Surveys

Ecology conducted contaminant surveys of lake sediments throughout Washington in 1989 and 1992-1993 (Johnson and Norton, 1990; Serdar et al., 1994b). Ten lakes were analyzed for lead in 1989, and five lakes were surveyed in 1992-1993. Elevated lead concentrations were found in sediments collected from two lakes: American Lake near Tacoma, and Long Lake, an impoundment along the Spokane River. Ecology is currently preparing a statewide survey of reference waterbodies to establish baseline sediment conditions (Sloan, 2009 in preparation).

Upper Columbia and Spokane River Sediment Studies

Era and Serdar (2001) examined bottom sediments along the upper Columbia River for lead contamination. Lead levels were elevated from Northport to the Canadian border (182 – 344 mg/kg dw).

Several studies have been conducted along Spokane River to assess lead contamination in bottom sediments throughout the upper reach (Johnson et al., 1994; Batts and Johnson, 1995; Johnson, 1999; Johnson, 2000; Johnson and Norton, 2001). High lead levels were found consistently above Upriver Dam throughout the studies, averaging 195 – 659 mg/kg dw. Lead concentrations at Nine Mile Reservoir were considerably lower, at 22 and 54 mg/kg dw (Johnson et al., 1994 and Johnson, 1999, respectively).

Study Design

SPM was collected at 15 sites in 2008 to establish baseline levels in lead concentrations for the purpose of evaluating future trends. Sampling was conducted during spring run-off and fall low- flow conditions to assess seasonal differences. Intra-seasonal variability was addressed by collecting a second sample at eight stations three weeks apart during each sampling season. Sampling was conducted according to a project-specific Quality Assurance Project Plan (Meredith and Furl, 2008).

Monitoring sites for this project are shown in Figure 1. Twelve sites were chosen to correspond with the organic PBT trend monitoring sites (Johnson, 2007). Three additional sites with expected high lead concentrations were added to the study design: Hylebos Creek, Spokane River at the Idaho border, and the upper Columbia River (UCR) at the Canadian border. These sites have known metals contamination and are undergoing cleanup actions. Information on site locations is available in Appendix B.

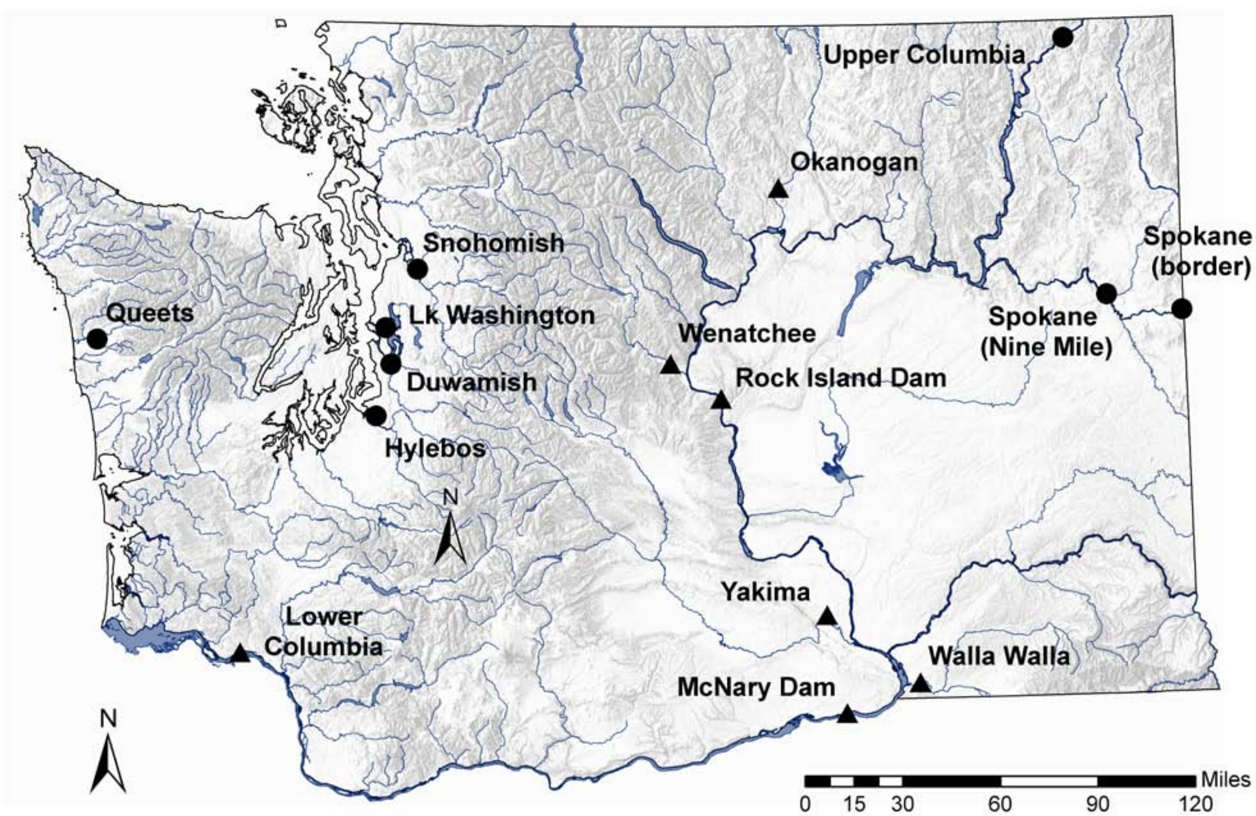

Figure 1. PBT Trend Monitoring sites for lead in SPM sampling, 2008. Sites sampled once per season are represented by triangles; sites sampled twice per season are identified by circles.

Methods

Field

SPM samples were collected following the Environmental Assessment (EA) Program's *Standard Operating Procedure for Collecting Freshwater Suspended Particulate Matter Samples using In-Line Filtration* (Meredith, 2008). River or lake water was pumped and filtered through 0.45-µm pore-size (47-mm membrane) nitrocellulose filters using in-line 47-mm membrane Teflon filter holders. The intake of the tubing was placed 1-3 feet below the water surface, suspended above the river or lake bottom, for the duration of sampling.

Once filters had accumulated enough SPM to restrict water flow, they were carefully removed from the filter holder and stored in pre-acid-washed aluminum sample containers. The containers were then bagged and stored upright with blue ice for transport to Ecology headquarters. One filter was collected per sample. Samples were stored at Ecology headquarters at 4° C until shipment to Manchester Environmental Laboratory (MEL). Holding times were not exceeded, and chain-of-custody was maintained.

The volume of water that passed through each filter was recorded after sampling. At each sampling site, pH, temperature, and conductivity were measured at the time of sampling.

Laboratory

SPM samples were analyzed for lead by MEL following EPA Method 200.8 (ICP-MS). Prior to analysis, filter samples were dried at 103-105° C and digested following EPA Method 3050B.

The amount of lead, in µg per filter, was determined by MEL. Filters were weighed to the nearest milligram before and after sampling to determine dry SPM weight. This weight was used to determine lead results in mg/kg. Lead results are also reported in µg/L, using the volume passed through each filter. See appendix C for lead results in mg/kg and µg/L, along with ancillary data.

Total suspended solids (TSS) values used throughout this report were calculated as the dried SPM weight divided by volume passed through the filter. This is not a true TSS analysis due to the filter size used (0.45 µm pore size).

Data Quality

MEL provided case narratives describing the quality of the data collected for this project. The narrative includes information on analytical methods, sample condition, holding times, instrument calibration, and quality assurance (QA) tests. Case narratives are available upon request.

MEL did not encounter any problems with the analyses of the samples, and results were reported without qualification. Instrument calibration and internal standards were within acceptance limits. QA tests consisted of laboratory control samples, matrix spikes, field replicates, and method blanks. Measurement quality objectives (MQOs) along with QA/QC results from each batch are located in Appendix D.

The data met all MQOs outlined in the QA Project Plan Addendum #1 (Meredith and Furl, 2008). The relative percent difference (RPD) for one field replicate and field sample was high, but within the MQO range for field replicates. This particular field sample and replicate were taken along the lower Columbia River at a time when tidal changes may have influenced SPM content.

Two field blank samples were collected during each sampling season. Three of the four field blanks were measured as non-detects (< 0.05 µg/filter). One field blank had quantifiable lead but was less than the QC limit of 1 mg/filter.

Results

Forty-six SPM samples from 15 sites statewide were analyzed for lead in the spring and fall of 2008. Lead was detected in 93% of the samples. The highest lead concentration, 3,121 mg/kg, was found in the Spokane River at the Idaho border during the spring. Elevated concentrations were also found in the Spokane River at Nine Mile Dam and in the upper Columbia River near the Canadian border. All other sites ranged from non-detect (< 1 mg/kg) to 65 mg/kg. Average seasonal lead concentrations for all sites are displayed in Figure 2. Lead concentrations are summarized in Table 1. Complete results of lead sampling are provided in Appendix C.

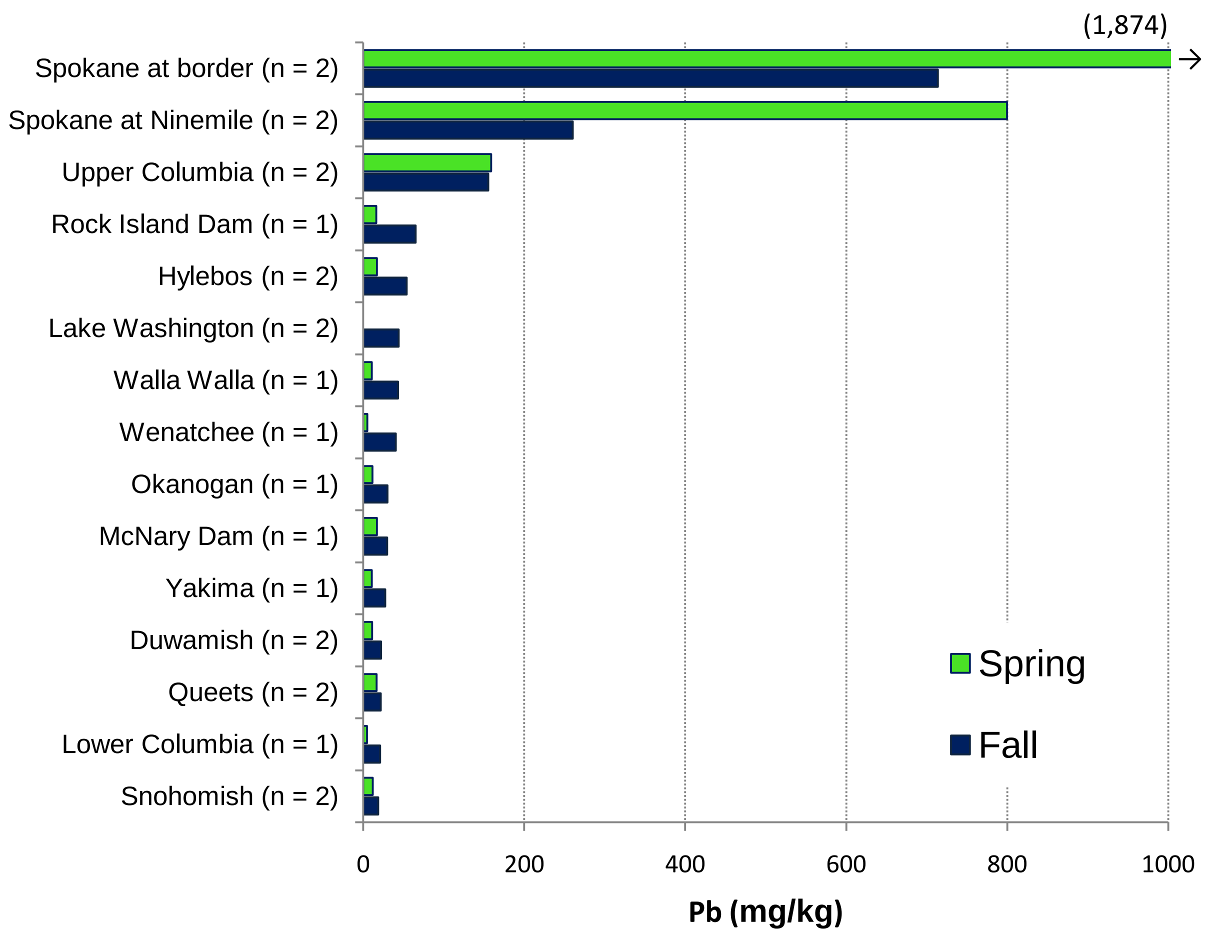

Figure 2. Average lead concentrations in SPM across monitoring sites during spring and fall, 2008.

Table 1. Statistical summary of lead concentrations in SPM (mg/kg) across monitoring sites during 2008.

No. of Samples	No. of Detections	Minimum	Maximum	Median	Mean
46	43	< 1	3121	26	189

Discussion

Seasonal Variability

Excluding the Spokane River sites and the UCR station, lead concentrations measured in the fall were significantly higher than spring results (mean difference = 23; $p < 0.001$). The UCR and Spokane River sites had higher concentrations in the spring compared to fall, though this finding was not significant (mean difference = 568; $p = 0.231$). Differences were assessed using paired samples t-tests. Figure 3 shows the seasonal difference in lead levels between sites with low lead contamination (12 sites) and high contamination (3 sites).

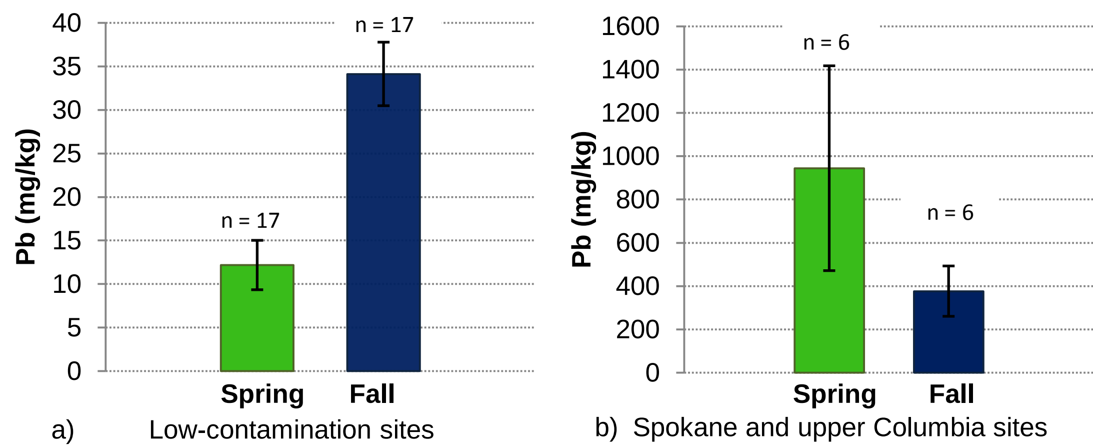

Figure 3. Mean seasonal lead concentrations for (a) 12 low-contamination sites and (b) high-contamination sites (Spokane River and UCR sites). Error bars represent one standard error.

Intra-seasonal Variability

Intra-seasonal variability was assessed by collecting a second sample at eight sites during the spring and fall: Duwamish River, Hylebos Creek, Lake Washington, Queets River, Snohomish River, Spokane River at the Idaho border and at Nine Mile Dam, and the upper Columbia River.

The greatest intra-seasonal difference in lead levels occurred at Hylebos Creek in the spring, where the first sample collected was a non-detection (< 1 mg/kg) and the second was 52 mg/kg. The two Spokane River sites also showed high variability during spring sampling. The RPDs in lead levels were 114% and 118% greater at the Idaho border and Nine Mile Dam, respectively, on the second spring visit. The second spring collection corresponded with peak high flow, whereas the first sample was collected on the rising limb of the hydrograph (see Appendix E). Similarly, a higher lead concentration was found at the UCR site on the second sample collection in spring, near peak flow (RPD = 47%). Other samples varied less considerably within the season, ranging in RPD from 0% – 31%.

Correlations with Flow and TSS

Positive relationships have been found with flow, TSS, and SPM-associated metal concentrations (Lawson et al., 2001; Alkhatib and Castor, 2000; Shafer et al., 1997). Bed sediment resuspension and contaminated riverbank erosion during high flows can result in increased lead SPM concentrations. However, high flow rates can also negatively influence lead concentrations by (1) washing relatively clean sediments into the river, or (2) diluting contamination from point sources (Sherrell and Ross, 1999; Carter et al., 2006).

Flow rates and TSS concentrations varied widely across the 15 monitoring sites. Most sampling dates captured high-flow run-off conditions in the spring and low-flow conditions in the fall (see Appendix E for flow data and sampling dates). Flow data were not available for Hylebos Creek, Lake Washington, lower Columbia River, or Rock Island Dam.

As noted earlier, lead concentrations in the three more contaminated sites were elevated at high flow in the spring, possibly due to resuspension of lead-containing bed sediments into the water column or contaminated river bank soils washing into the river. The other 12 sites showed decreased lead levels at high flow, which may be explained by erosion of clean bank sediments to the river or a dilution effect. These two patterns, however, were not supported by linear regression analysis with instantaneous flow and lead concentrations.

Simple linear regressions were used to determine the amount of variance in lead concentrations that flow, TSS, pH, and conductivity explained (Table 2). Lead values and variables were log-normalized to achieve a more uniform distribution. Sites were grouped into three categories for the linear regressions: all sites, low-contamination sites (12 sites with non-detect – 65 mg/kg lead range), and high-contamination sites (UCR and Spokane River sites).

Table 2. Linear regression r^2 values for lead concentrations (mg/kg) and variables.

Variable	All sites	Low contamination sites	High-contamination sites
Flow	0.007	0.302*	0.056
TSS	0.379*	0.688*	0.147
pH	0.058	0.018	0.646*
Conductivity	0.005	0.275*	0.579*

*Significant at the 0.05 confidence level.

A significant negative relationship with TSS for the low-contamination sites grouped separately explained the greatest amount of variation in lead concentrations for those sites ($r^2 = 0.688$). pH and conductivity had strong negative relationships for high-contamination sites ($r^2 = 0.646$ and $r^2 = 0.579$, respectively). Weaker relationships were found for flow negatively affecting lead levels ($r^2 = 0.302$) and for conductivity positively influencing lead levels ($r^2 = 0.275$) at low-contamination sites.

Comparison to Other Lead Data in Washington State

SPM Studies

Table 3 shows the mean SPM-associated lead concentrations and ranges at the UCR found in the early 1990s compared to those measured for this project. No other Ecology studies have measured lead concentrations in freshwater SPM near the 2008 monitoring sites. Based on a comparison of mean lead levels measured in the upper Columbia River, 2008 concentrations are approximately one-third of those measured by Ecology in SPM and bottom sediments during the early 1990s (Serdar et al., 1994a; Era and Serdar, 2001).

Table 3. Upper Columbia River lead concentrations in SPM measured in 1992-1993 and 2008.

	1992-1993 (Serdar et al., 1994a)	2008 (current study)
n =	2	4
Mean	526	157
Minimum	498	109
Maximum	554	209

Statewide Sediment Surveys

Ecology has analyzed lead more frequently in bottom sediments than in SPM throughout Washington State. In this study, SPM concentrations were compared to bottom sediment concentrations to gain an understanding of relative contamination. Regardless of matrix differences, comparison of lead SPM values to bottom sediments is still helpful for a qualitative assessment of concentration differences.

Comparison of SPM-associated lead concentrations to statewide sediment surveys is limited to three Ecology studies (Johnson and Norton, 1990; Serdar et al., 1994b; Sloan, 2009 in prep.). The Spokane River and UCR sites were not included in this comparison in order to omit outliers. Lead concentrations of the 12 low-contamination monitoring sites were within the ranges of the three statewide surveys. Lead concentrations from the bottom sediment surveys and the current SPM study are summarized in Table 4.

Table 4. Lead concentrations in Ecology sediment surveys and the 2008 SPM survey.

	Lakes and Reservoir Water Quality Assessment Program[1] (1989)	Survey of Chemical Contaminants in Ten WA Lakes[2] (1992)	Freshwater Sediment Reference Sites[3] (2008)	Current Study Low-contamination Sites (2008)
matrix	bottom sediments	bottom sediments	bottom sediments	SPM
n =	18	10	27	34
Mean	42	66 J	13.6	23
Minimum	6.7	7.2 J	3.2	0.05 U
Maximum	199	165 J	55	65

[1]Johnson and Norton, 1990.
[2]Serdar et al., 1994b.
[3]Data collected by Sloan (in preparation).

Mean lead concentrations in SPM were lower than in bottom sediments analyzed during the 1989 and 1992-1993 statewide lake contaminant surveys (Johnson and Norton, 1990; Serdar et al., 1994b). The statewide study lakes were selected partly for contaminant potential, which may account for higher lead values than the present study.

Average SPM-associated lead levels were slightly higher than average reference bottom sediments measured by Ecology in a sediment reference study (Sloan, 2009 in preparation). This is likely due to the inclusion of both urban and undeveloped sites in the present study, whereas the sediment reference study included only undeveloped or remote sites. Sediment samples were taken from the top 2 cm for the statewide lakes surveys and the top 10 cm for the sediment reference study.

Spokane River Sediments

Lead levels in bottom sediments of the Spokane River have been well-documented by previous Ecology studies (Johnson et al., 1994; Batts and Johnson, 1995; Johnson, 1999; Johnson, 2000; and Johnson and Norton, 2001). Comparison of SPM samples from the Spokane River at the Idaho border to historical sediment levels was limited to sediments collected from several places above Upriver Dam, about 15 river miles downstream of the border. Sediment samples were taken from a range of depths: 0-2, 0-5, and 0-10 cm.

Average lead concentrations in SPM were higher at the Idaho border in this 2008 study than in previous sediment studies from above Upriver Dam. Lead levels at Nine Mile Reservoir were also higher than in previous sediment studies there. Figure 4 displays the mean lead concentrations of historical data and the current study's SPM data for the Spokane River sites.

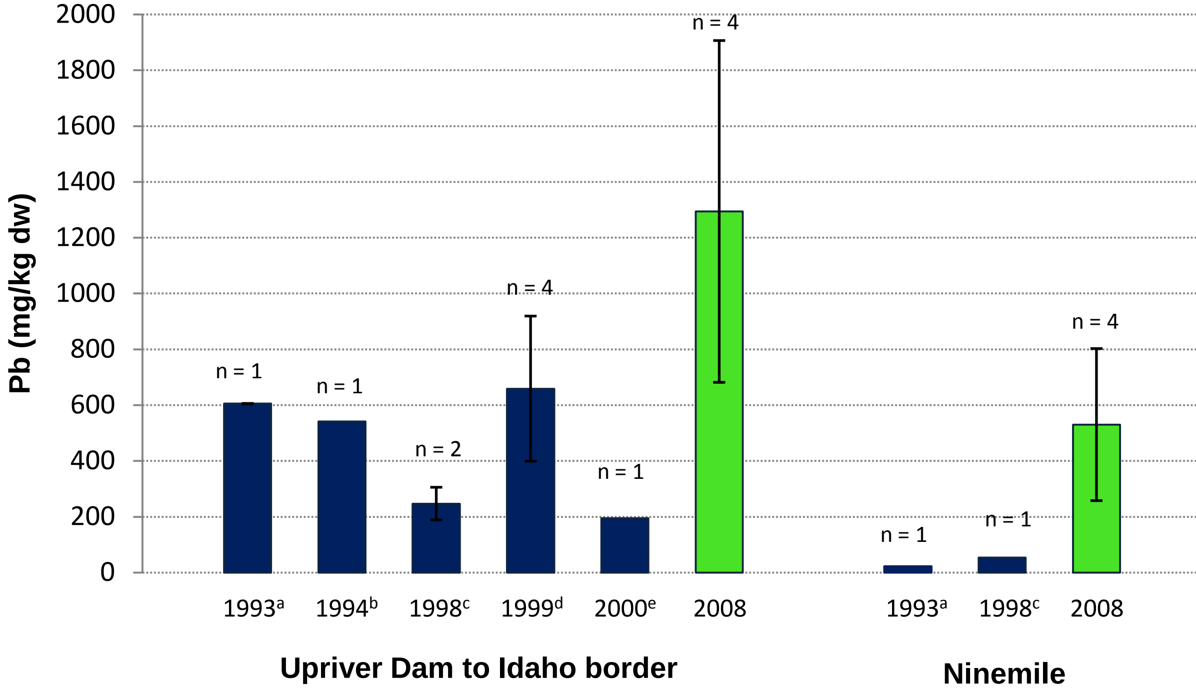

Figure 4. Average lead concentrations in bottom sediments (dark blue bars) and SPM (green bars) in the Spokane River from Upriver Dam to Idaho border and from Nine Mile Reservoir. Most values are from previous Ecology studies: [a]Johnson et al., 1994; [b]Batts and Johnson, 1995; [c]Johnson, 1999; [d]Johnson, 2000; [e]Johnson and Norton, 2001. 2008 values are from the present study. Error bars represent one standard error.

Guidelines for Freshwater Sediment Quality

Ecology proposed Freshwater Sediment Quality Value guidelines in 1997 in order to identify contaminant levels at which possible biological effects occur in sediments (Cubbage et al., 1997). Those values were updated in 2003 (Betts, 2003), and the lowest apparent effects threshold (LAET) for lead was identified as 335 mg/kg dry weight.

All four lead samples collected from the Spokane River at the Idaho border were above Ecology's LAET. One sample from Spokane River at Nine Mile collected in the spring also exceeded the LAET.

No guidelines or criteria have been developed for freshwater SPM.

Conclusions

As part of the PBT trend monitoring program, suspended particulate matter (SPM) samples were collected from 15 sites statewide and analyzed for lead in 2008. A total of 46 SPM samples were collected in the spring and fall for this first year of lead sampling.

Lead was detected in 93% of the samples. The highest lead concentration, 3,121 mg/kg, was found along the Spokane River at the Idaho border during spring collection. Lead concentrations were also elevated in the Spokane River at Nine Mile Dam and in the upper Columbia River near the Canadian border. Results from the other 12 sites were generally low, ranging from non-detect (<1 mg/kg) to 65 mg/kg.

- Based on a comparison of mean lead levels measured in the upper Columbia River, concentrations in 2008 are approximately one-third of those measured by Ecology in SPM and bottom sediments during the early 1990s in this area of the Columbia River.

- In contrast to the upper Columbia River, 2008 lead concentrations in SPM were higher at the two Spokane River sites (the Idaho border and Nine Mile Dam), compared to historical levels in bottom sediments near those sites.

- With the exception of the upper Columbia River and Spokane River sites, lead concentrations in SPM at the remaining 12 sites were within the range measured at current background sediment reference conditions (2008) and statewide lake sediment surveys by Ecology in 1989 and 1992. Average 2008 lead values, with upper Columbia River and Spokane River omitted, were slightly higher than reference sediments and slightly lower than the statewide sediment survey averages.

- Excluding the three sites with elevated lead levels (upper Columbia River and Spokane River sites), lead concentrations measured during the 2008 spring run-off were significantly lower than those measured during the fall low-flow period. In contrast, the three high-contamination sites had highest concentrations in the spring.

- Large intra-seasonal variability was observed in lead concentrations during spring sampling at Hylebos Creek, the two Spokane River sites, and the upper Columbia River. Lead levels at these four sites increased during the second sampling event in the spring, near peak flow.

- With lowest apparent effects thresholds of 335 mg/kg, five SPM-associated lead samples were above Ecology's proposed Freshwater Sediment Quality Values guideline. Lead levels not meeting (above) these guidelines were found only at the two Spokane River monitoring sites (Idaho border and Nine Mile Dam).

Recommendations

Recommendations for future monitoring of lead in SPM include:

1. Continue SPM sampling at the 15 monitoring sites used in 2008, and increase the sampling frequency to twice per season for all sites. Attempt to sample at similar flow rates as captured in 2008.

2. Increase the number of field blanks analyzed to three per sampling season. Conduct two field blanks at low-contamination sites and one at a high-contamination site. Continue to rotate field blank stations each season.

3. In addition to regular sampling, deploy sediment traps at two monitoring sites to compare lead concentrations in a time-integrated sample to concentrations using current sampling methods.

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Appendices

Appendix A. PBT Chemical List

Table A-1. Chemicals, Chemical Groups, and Metals on the PBT List (Gallagher, 2007)

Metals	Flame Retardants	Banned Pesticides	Organic Chemicals
Methyl-mercury	PBDEs Tetrabromobisphenol A Hexabromocyclododecane Pentachlorobenzene	Aldrin/Dieldrin Chlordane DDT/DDD/DDE Heptachlor Epoxide Toxaphene Chlordecone Endrin Mirex	1,2,4,5-TCB Perfluorooctane sulfonates Hexachlorobenzene Hexachlorobutadiene Short-chain chlorinated paraffin Polychlorinated naphthalenes
Combustion By-Products	**Banned Flame Retardants**	**Banned Organic Chemicals**	**Metals of Concern**
PAHs PCDD PCDF PBDD/PBDF	Hexabromobiphenyl	PCBs	Cadmium Lead

Appendix B. Monitoring Sites

Table B-1. Lead monitoring site descriptions.

Monitoring Site Location	County	WBID[1]	WRIA[2] Number	Latitude[3]	Longitude[3]	Description
Columbia River, Lower	Wahkiakum	WA-CR-1010	25	46.18490	-123.18760	Columbia River near Clatskanie, OR, RM 54.
Columbia River, at McNary Dam	Benton	WA-CR-1026	31	45.93940	-119.29720	Columbia River at McNary Dam near Umatilla, OR, RM 292.0.
Columbia River, at Rock Island Dam	Chelan-Douglas	WA-CR-1040	44	47.34390	-120.09390	Columbia River at Rock Island Dam, RM 453.5, 10 miles south of Wenatchee.
Columbia River, Upper	Stevens	WA-CR-1060	61	48.92161	-117.77445	Upper Columbia River at Northport, RM 735.
Duwamish River	King	WA-09-1010	9	47.48525	-122.26140	Duwamish River at Foster Golf Links in Tukwila, RM 10.
Hylebos Creek	Pierce	WA-10-1011	10	47.25335	-122.35013	Hylebos Creek in Fife, at 4th St. bridge.
Lake Washington	King	WA-08-9340	8	47.64750	-122.30190	Lake Washington, in Seattle, at Montlake Cut, East of University of Washington Marina.
Okanogan River	Okanogan	WA-49-1010	49	48.28060	-119.70500	Okanogan River at Malott, RM 17, private property.
Queets River	Jefferson	WA-21-1030	21	47.55220	-124.19780	Queets River in Olympic National Forest, 2 miles up Queets River Rd, RM 11.5.
Snohomish River	Snohomish	WA-07-1020	7	47.91080	-122.09920	Snohomish River at Snohomish, behind visitor's center, RM 12.5.
Spokane River at Idaho border	Spokane	WA-57-1010	54	47.69483	-117.05133	Spokane River near the Idaho border, RM 96.
Spokane River at Nine Mile	Spokane	WA-54-1020	57	47.77470	-117.54440	Upstream side of Spokane River's Nine Mile Dam, RM 58.1.
Walla Walla River	Walla Walla	WA-32-1010	32	46.07090	-118.82680	Walla Walla River, about 5 miles east of Wallula Junction, RM 9, private property.
Wenatchee River	Chelan	WA-45-1010	45	47.50070	-120.42570	Wenatchee River, about 5 miles NW of Wenatchee, RM 7.1, near Old Monitor Rd. Bridge.
Yakima River	Benton	WA-37-1010	37	46.37830	-119.41810	Yakima River, 12 miles NW of Richland, RM 18.0. Diversion structure at Wanawish Dam.

[1]WBID – Waterbody Identification Number.
[2]WRIA – Water Resource Inventory Area.
[3] NAD83HARN.
RM – River Mile.

Appendix C. Lead in SPM Data

Table C-1. SPM-associated lead concentrations and ancillary data collected in the spring of 2008.

Waterbody	Collection Date	Lead (ug/L)	Lead (mg/kg)	TSS (mg/L)	pH	Conductivity (µs/cm)
Duwamish[1]	5/14/2008	0.157	11	14	6.8	48.0
Duwamish[2]	6/4/2008	0.186	11	17	7.0	54.0
Hylebos[1]	5/14/2008	0.092	ND	3	7.3	295.0
Hylebos[2]	6/4/2008	0.165	52	3	7.3	268.0
Lake Washington[1]	5/12/2008	----	ND	----	----	----
Lake Washington[2]	6/4/2008	0.102	ND	3	8.0	97
Lower Columbia	5/19/2008	0.316	5	65	8.1	148
McNary Dam (MCR)	5/22/2008	0.153	17	9	7.8	122
Okanogan	5/21/2008	1.700	12	147	7.7	75
Queets[1]	5/15/2008	1.200	16	74	7.4	54
Queets[2]	6/3/2008	0.380	17	23	6.6	74
Rock Island Dam	5/21/2008	0.237	16	14	7.9	112
Snohomish[1]	5/14/2008	0.355	10	35	6.0	29
Snohomish[2]	6/4/2008	0.340	14	25	7.0	20
Spokane at border[1]	5/8/2008	1.562	628	2	7.6	52
Spokane at border[2]	5/29/2008	11.173	3121	4	7.2	47
Spokane at Nine Mile[1]	5/9/2008	2.593	254	10	7.5	76
Spokane at Nine Mile[2]	5/29/2008	10.686	1346	8	7.3	54
Upper Columbia[1]	5/7/2008	0.104	109	1	8.2	131
Upper Columbia[2]	5/28/2008	0.929	209	4	8.0	123
Walla Walla	5/22/2008	0.765	11	72	7.6	65
Wenatchee	5/21/2008	0.302	5	57	7.6	28
Yakima	5/22/2008	0.433	11	41	7.5	102

[1]First sampling visit of season.
[2]Second sampling visit of season.
ND = Not Detected at 1 mg/kg.
---- = Data not available.

Table C-2. SPM-associated lead concentrations and ancillary data collected in the fall of 2008.

Waterbody	Collection Date	Lead (ug/L)	Lead (mg/kg)	TSS (mg/L)	pH	Conductivity (µs/cm)
Duwamish[1]	9/11/2008	0.156	25.0	6.2	6.6	185
Duwamish[2]	10/9/2008	0.176	19.7	8.9	6.9	95
Hylebos[1]	9/12/2008	0.274	45.7	6.0	7.5	----
Hylebos[2]	10/10/2008	0.426	62.5	6.8	7.6	213
Lake Washington[1]	9/11/2008	0.047	38.5	1.2	6.1	105
Lake Washington[2]	10/9/2008	0.049	50.0	1.0	7.7	98
Lower Columbia	9/26/2008	0.170	21.2	8.0	7.7	135
McNary Dam (MCR)	9/29/2008	0.061	29.6	2.1	8.1	71
Okanogan	9/22/2008	0.075	30.2	2.5	8.3	297
Queets[1]	9/8/2008	0.115	23.9	4.8	6.3	81
Queets[2]	10/6/2008	0.536	20.0	26.8	7.2	55
Rock Island Dam	9/23/2008	0.060	65.0	0.9	7.6	130
Snohomish[1]	9/11/2008	0.092	20.9	4.4	6.2	50
Snohomish[2]	10/9/2008	0.101	16.3	6.2	7.1	33
Spokane at border[1]	9/10/2008	0.922	558.8	1.7	7.6	47
Spokane at border[2]	10/8/2008	0.736	869.2	0.8	7.9	43
Spokane at Nine Mile[1]	9/10/2008	0.158	215.6	0.7	8.3	289
Spokane at Nine Mile[2]	10/8/2008	0.450	304.9	1.5	7.9	171
Upper Columbia[1]	9/9/2008	0.160	137.9	1.2	7.9	145
Upper Columbia[2]	10/7/2008	0.174	172.7	1.0	8.2	131
Walla Walla	9/29/2008	0.091	43.3	2.1	8.7	126
Wenatchee	9/23/2008	0.039	40.6	1.0	8.2	71
Yakima	9/24/2008	0.084	27.5	3.1	8.1	296

[1]First sampling visit of season.

[2]Second sampling visit of season.

Appendix D. Quality Assurance Data

MEL analyzed the lead samples in July and October, 2008. MEL received the samples in good condition. Samples received in June were at 11° C, above the proper range (0-6° C), but analysis was not affected. Samples received in October were within the proper temperature range. MEL performed all analyses within established EPA holding times. Table D-1 states the measurement quality objectives for lead analyses.

Table D-1. Measurement Quality Objectives.

Analysis	Check Standards	Matrix Spikes (% recovery)	Field Replicates (RPD)	Lowest Concentration of Interest
Lead	± 15% LCS	70-130%	50%	1 mg/kg dw

LCS = laboratory control sample.

Tables D-2 through D-5 display results of quality control tests. Matrix spikes, laboratory blanks, laboratory control samples, and field replicates were analyzed as part of quality assurance.

Table D-2. Matrix Spikes.

Sample Number	Analysis Date	Recovery (%)
08244342	6/18/2008	99
08244352	6/30/2008	108
08374347	10/27/2008	103
08374358	10/27/2008	107

Table D-3. Laboratory Blanks.

Sample Number	Analysis Date	Result (ug)
MB08168I1	6/18/2008	0.05 U
MB08178I2	6/30/2008	0.05 U
MB08294I2	10/27/2008	0.05 U
MB08298I2	10/27/2008	0.05 U

U = not detected at displayed concentrations.

Table D-4. Laboratory Control Samples.

Sample Number	Analysis Date	Recovery (%)
ML08168I1	6/18/2008	100
ML08178I2	6/30/2008	104
ML08294I1	10/27/2008	102
ML08298I1	10/27/2008	106

Table D-5. Field Replicates.

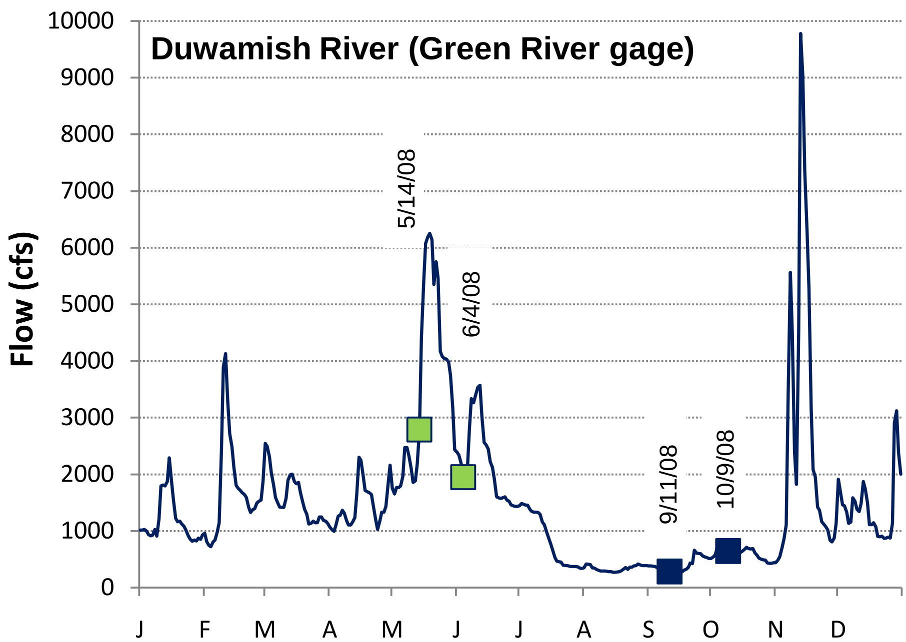
Sample Number	Collection Date	Result (mg/Kg)	RPD (%)
08244340 Rep 1	5/21/2008	5.3	1.8
08244341 Rep 2	5/21/2008	5.4	
08244349 Rep 1	5/29/2008	3120.7	9.7
08244350 Rep 2	5/29/2008	2831.0	
08374345 Rep 1	9/26/2008	21.2	15.3
08374346 Rep 2	9/26/2008	24.7	
08374356 Rep 1	10/10/2008	62.5	35.5
08374357 Rep 2	10/10/2008	89.5	

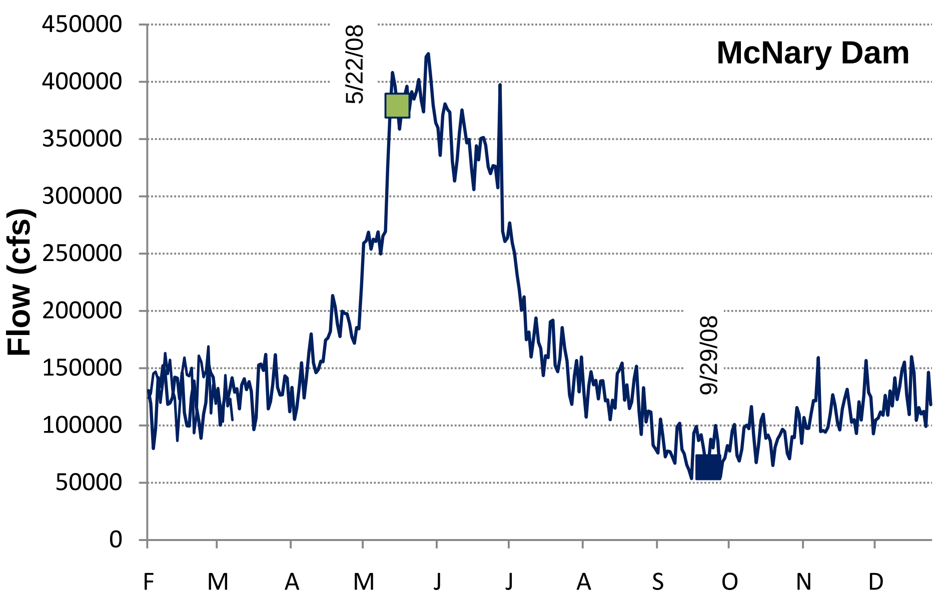
Rep – Replicate.

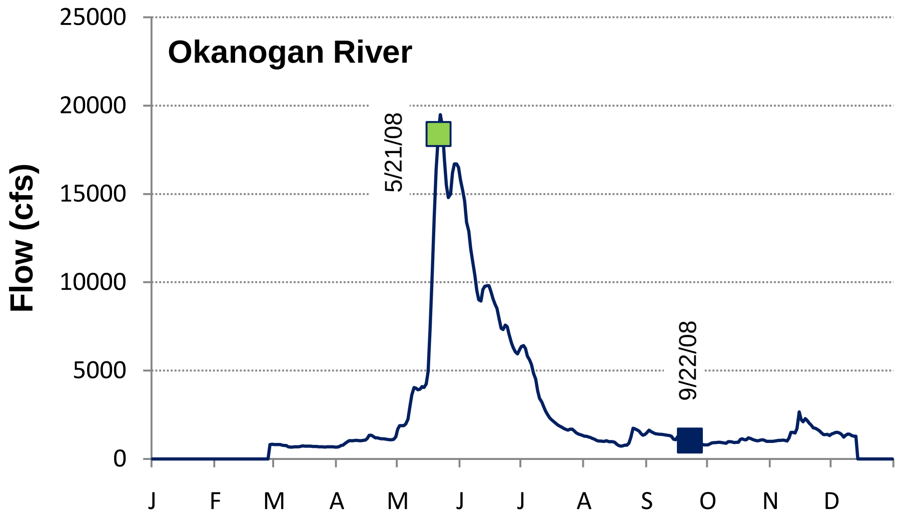
RPD - Relative Percent Difference = (max - min)/(mean)*100.

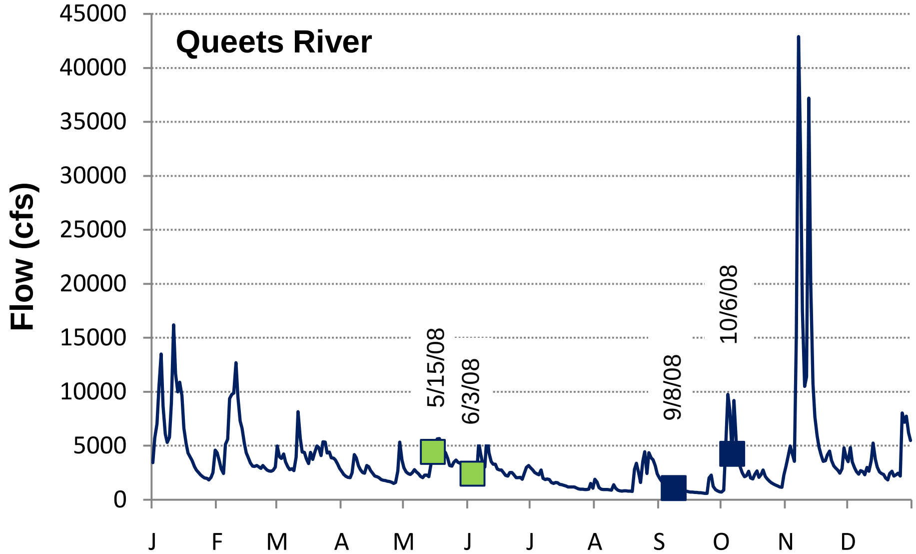
Appendix E. Flow Data and Sampling Dates

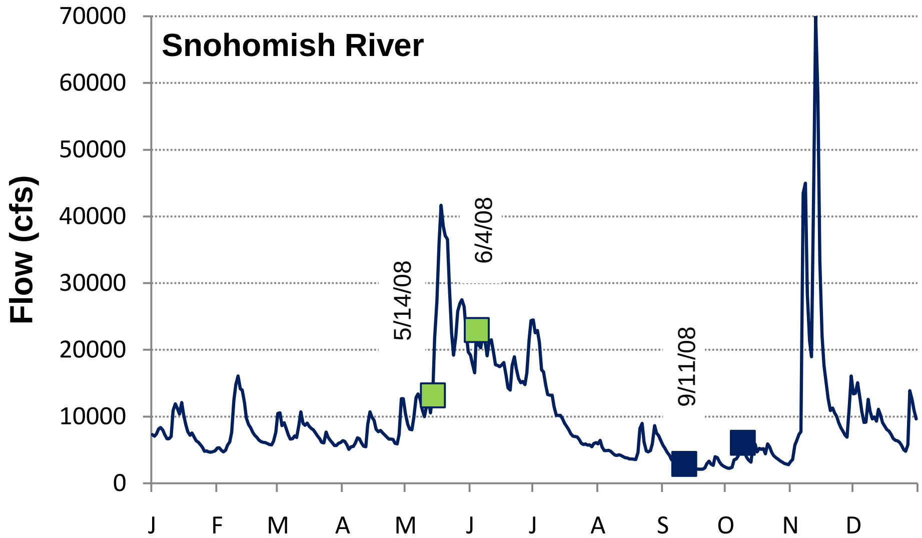
Figure E-1. Flow data and sampling dates for 2008 PBT Trend Monitoring lead sites. Flow data were compiled from the USGS National Water Information System (Retrieved from http://waterdata.usgs.gov/nwis on 01/27/09) and the University of Washington's Columbia River Data Access in Real Time (retrieved from www.cbr.washington.edu/dart on 01/27/09). Flow data were considered provisional and subject to change at the time of data retrieval. Light green squares represent spring sampling dates, and dark blue squares represent fall sampling dates. Flow data were not available for Hylebos Creek, Lake Washington, the lower Columbia River, or Rock Island Dam.

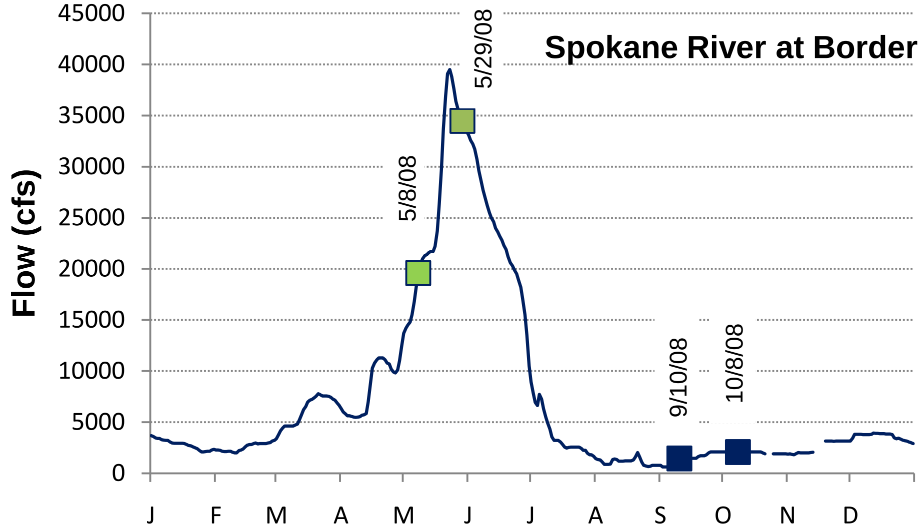





Okanogan River
Flow (cfs)
25000
20000
15000
10000
5000
0
5/21/08
9/22/08
J
F
M
A
M
J
J
A
S
O
N
D


Queets River
Flow (cfs)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
5/15/08
6/3/08
9/8/08
10/6/08
J
F
M
A
M
J
J
A
S
O
N
D


Snohomish River
Flow (cfs)
70000
60000
50000
40000
30000
20000
10000
0
5/14/08
6/4/08
9/11/08
J
F
M
A
M
J
J
A
S
O
N
D


Spokane River at Border
Flow (cfs)
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40000
35000
30000
25000
20000
15000
10000
5000
0
J
F
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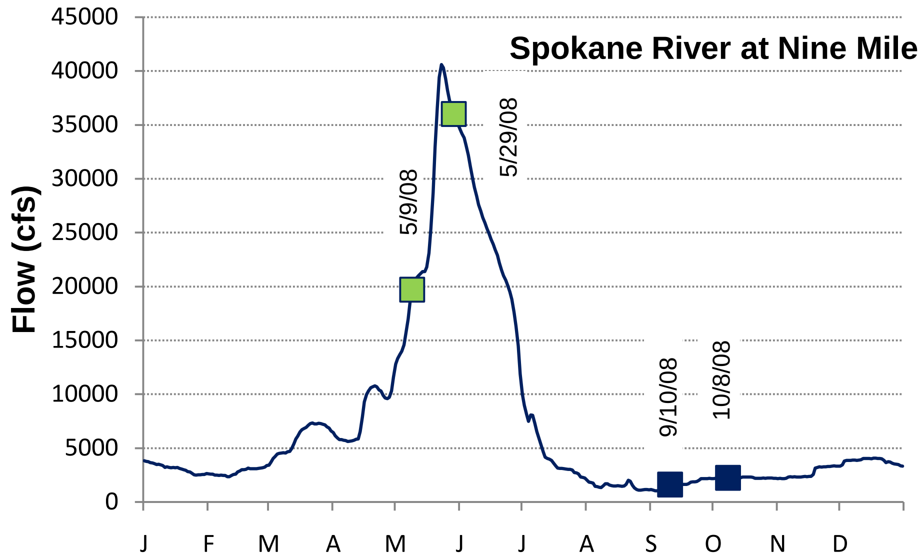
9/10/08
10/8/08


Spokane River at Nine Mile
Flow (cfs)
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35000
30000
25000
20000
15000
10000
5000
0
J
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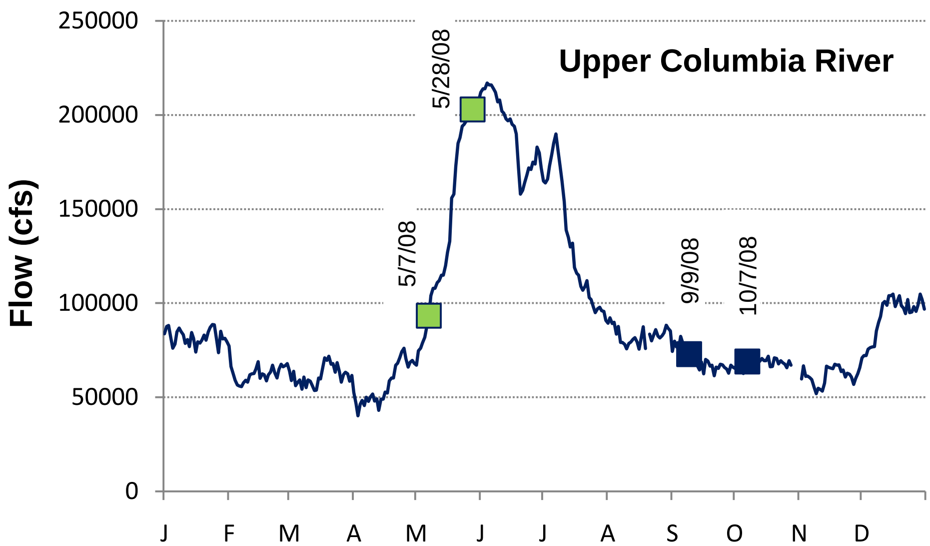
9/10/08
10/8/08


Upper Columbia River
Flow (cfs)
250000
200000
150000
100000
50000
0
J
F
M
A
M
J
J
A
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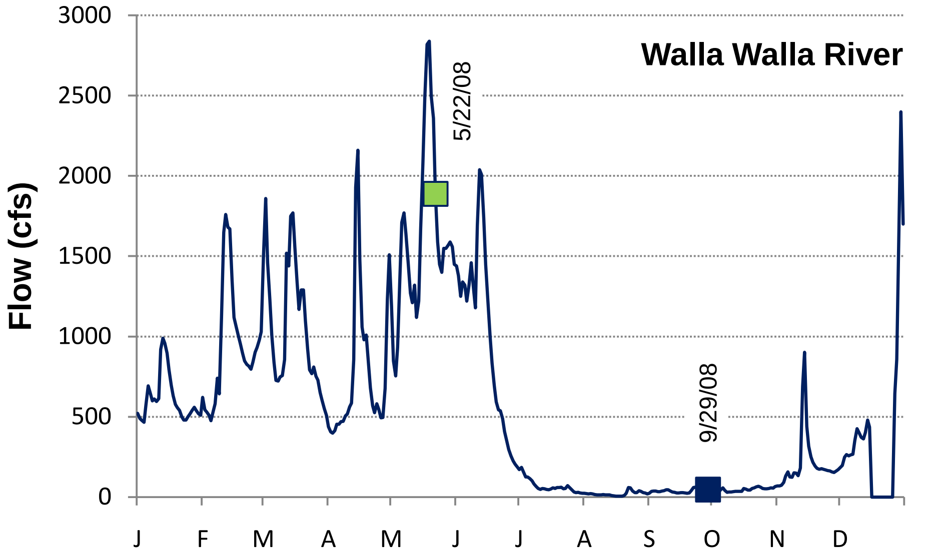
9/9/08
10/7/08


Walla Walla River
Flow (cfs)
3000
2500
2000
1500
1000
500
0
5/22/08
9/29/08
J
F
M
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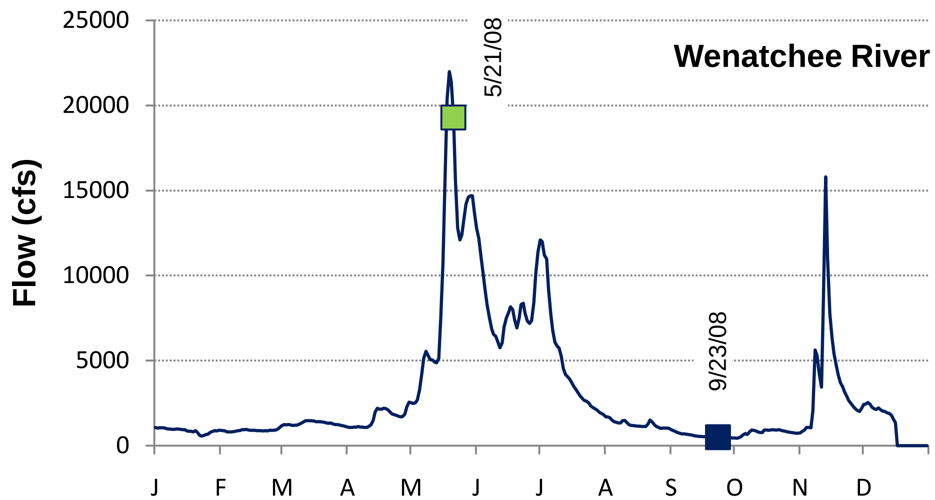
A
S
O
N
D


Wenatchee River
Flow (cfs)
25000
20000
15000
10000
5000
0
5/21/08
9/23/08
J
F
M
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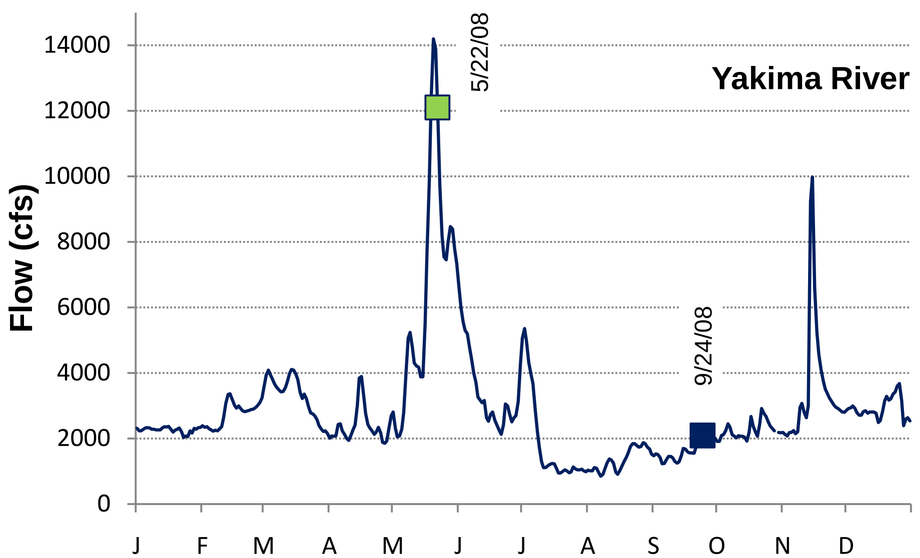
A
S
O
N
D


Yakima River
Flow (cfs)
14000
12000
10000
8000
6000
4000
2000
0
5/22/08
9/24/08
J
F
M
A
M
J
J
A
S
O
N
D