PBT Trend Monitoring: Measuring Lead in Suspended Particulate Matter, 2013 Results

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2013 Highlighted Findings

- The highest lead concentrations (mg/kg) were found at the Spokane River sites, followed by the urban streams and Upper Columbia River sites.
- No significant temporal trends were detected at any of the monitoring sites from 2008-2013.
- The Spokane and Columbia River sites continue have high lead loads (kg/day)

Why Lead?

Ecology monitors lead in Washington rivers and streams because of concern over its toxic and persistent properties. While lead is a naturally occurring element, human activities have resulted in widespread environmental contamination.

Lead affects humans and wildlife by harming developing nervous systems, as well as other bodily systems. There are many sources of lead exposure from the indoor and outdoor environment, and even minor exposures may cause some harm.

Project Overview

In 2009, the state Department of Ecology (Ecology) and the state Department of Health developed a chemical action plan (CAP) for lead. The plan identified the toxic effects of lead, described lead's occurrence in the environment, and recommended ways to reduce human and wildlife exposure to lead.

In 2008, Ecology began a long-term monitoring program to assess temporal changes of lead in Washington rivers and streams. Ecology collects suspended particulate matter (SPM) samples from 15 sites for analysis of total lead. Samples are collected twice in the spring and twice in the fall at each site. Monitoring sites cover a range of watershed size, land use, and potential lead sources. Roberts et al. (2011) discussed potential lead sources in the Puget Sound region.

The primary goal of this program is to evaluate temporal trends in environmental lead concentrations as CAP reduction strategies are implemented.

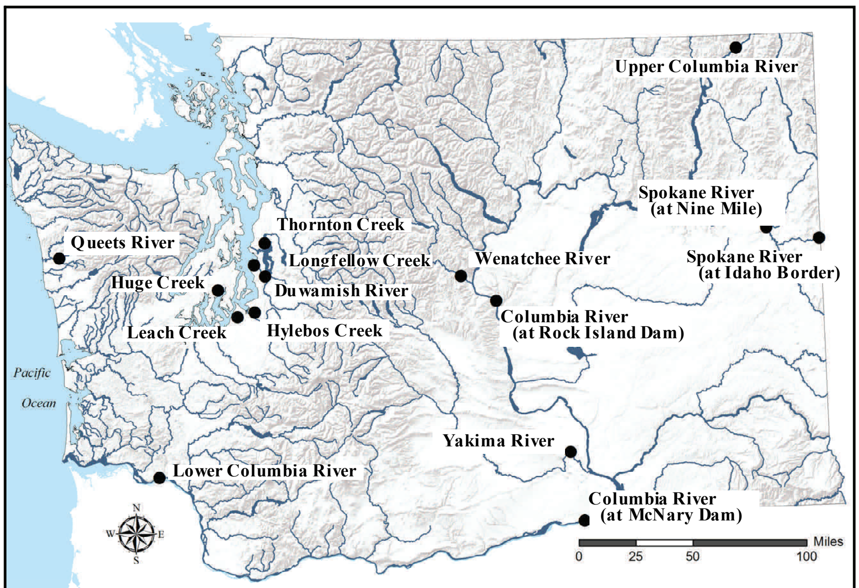

Figure 1. SPM Lead Monitoring Sites in Washington, 2013.

For More Information

PBT Monitoring Program website: http://www.ecy.wa.gov/programs/eap/toxics/pbt.html

Lead Chemical Action Plan website: http://www.ecy.wa.gov/programs/swfa/pbt/lead.html

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Methods and Data Quality

SPM samples were collected following Ecology's standard operating procedure (SOP) for collection of suspended particulates using in-line filtration (Meredith, 2008). Ambient water temperature, pH, and conductivity were measured following Ecology's SOP for collection and analysis of pH (Ward, 2007). Ecology's Manchester Environmental Laboratory analyzed total lead in the SPM samples following EPA Method 200.8.

All laboratory quality control (QC) tests met measurement quality objectives (MQOs) set for this project (Meredith and Furl, 2008). Field QC tests met MQOs with the following exceptions: (1) One field blank, collected at McNary Dam, contained a lead concentration higher than the reporting limit. The lead concentrations of the corresponding field samples were below the level in the contaminated blank and were rejected. (2) A field replicate collected at Rock Island Dam also exceeded MQOs. The native field sample for the field replicate was qualified as an estimate, "J".

Results

Fifty-eight SPM samples were analyzed for lead in 2013. Lead concentrations ranged from below detection limits to 2,150 mg/kg, with a median of 51.2 mg/kg. Samples collected from the Spokane River at the Idaho border contained the highest lead levels, followed by the Spokane River at Nine Mile. Lead concentrations were also elevated at the three urban streams and the Upper Columbia River. A statistical summary of the 2013 lead results is shown in Table 1, and individual concentrations are displayed in Figure 2. The complete dataset is available for download at www.ecy.wa.gov/eim by searching Study ID: PbTrends13.

Table 1. Statistical Summary of Lead in Suspended Particulate Matter, 2013 (mg/kg).

Season	n	Det. Freq	Min	Max	Med	Mean	SD
Spring	30	97%	ND	2,150	39.3	221	470
Fall	28	82%	ND	701	71.4	129	157
2013	58	90%	ND	2,150	51.2	180	366

n = number of samples, Det. Freq = detection frequency,
ND = not detected above reporting limit of 0.5 ug/filter,
SD = standard deviation

Comparison to Guidelines

Currently, no regulatory criteria exists for lead in SPM. The Sediment Management Standard rule, which includes a freshwater Sediment Cleanup Objective (SCO) for lead, took effect September 1, 2013 (WAC 173-204). This SCO value is used as a sediment quality goal for bottom sediment only; however, it is a useful threshold to assess levels of lead in SPM.

Six of the 58 samples (10%) contained lead concentrations above Washington's freshwater SCO of 360 mg/kg (Figure 2). All samples collected from the Spokane River at the Idaho border, and both spring samples from the Spokane River at Nine Mile, were above this threshold. These five sites with the highest concentrations have been consistently at the top of the rankings since their inclusion in the study.

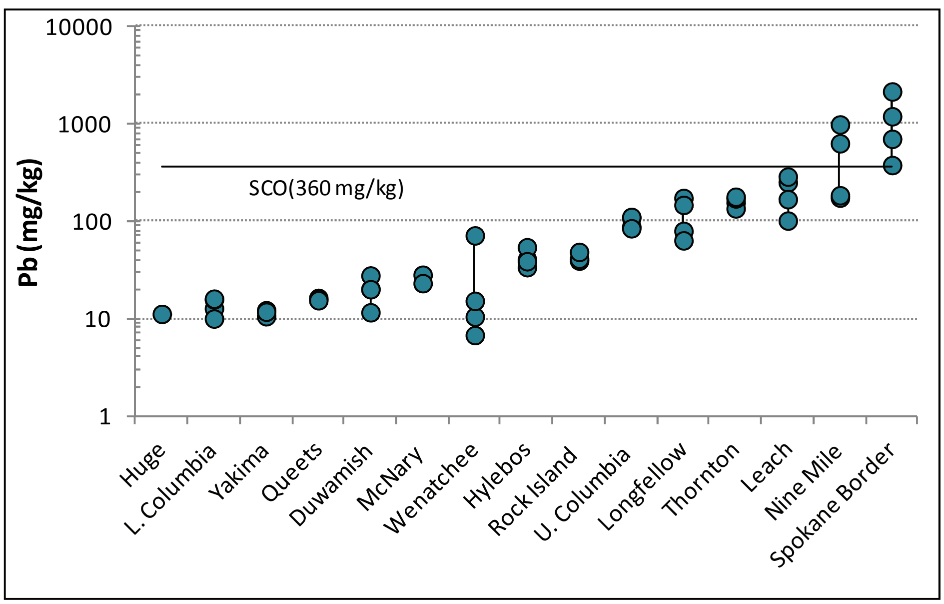


Figure 2. Monitoring Sites Ranked by Annual Average Lead Concentration, 2013 (mg/kg). *SCO = Sediment Cleanup Objective.*

Loading

Daily particulate lead loads were estimated for each sampling site, except Hylebos Creek, using daily mean flow (cfs) and lead concentrations per volume filtered (mg/L). Streamflow data were provided by the U.S. Geological Survey, U.S. Army Corps of Engineers, and the City of Seattle. Figures 3 and 4 display the seasonal mean lead loads for the river and small stream monitoring sites, respectively.

The Lower Columbia River site contained the highest lead loads, ranging from 30 to 147 kg/day. This site also had the greatest flows. The Upper Columbia site, near the Canada border, had the next highest lead loads (21-131 kg/day).

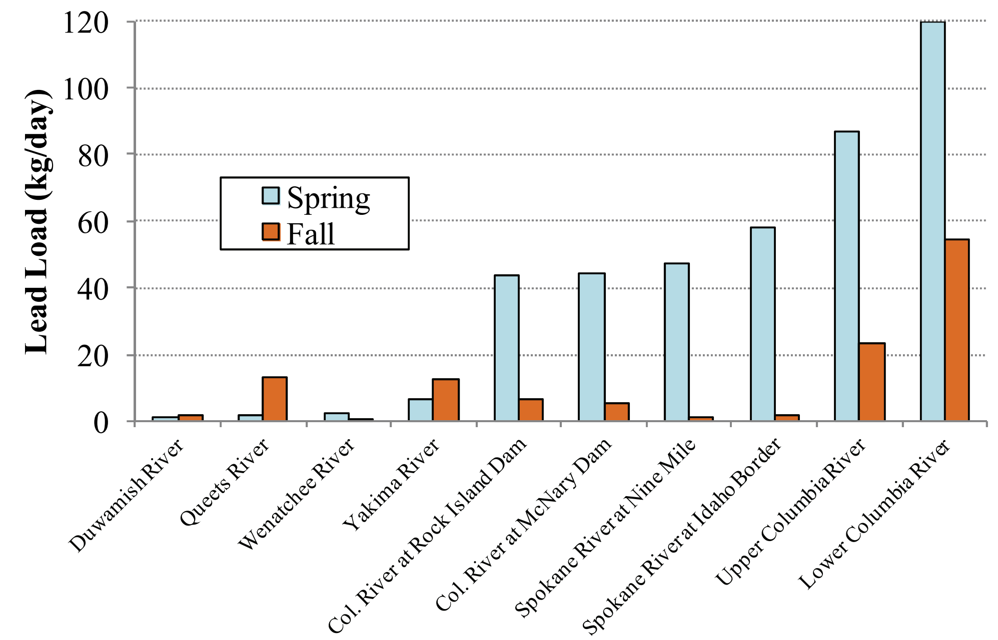


Figure 3. Estimated Mean Particle-bound Lead Loading at River Monitoring Sites, Spring and Fall 2013 (kg/day).
Values show the average of two samples per season when available.

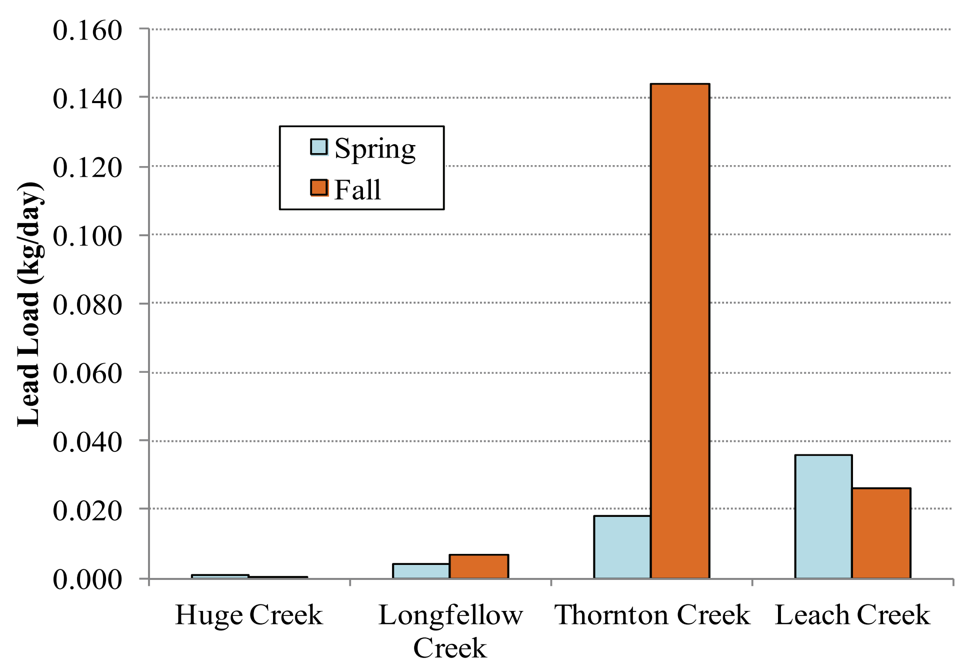


Figure 4. Estimated Mean Particle-bound Lead Loading at Small Stream Monitoring Sites, Spring and Fall 2013 (kg/day).
Values show the average of two samples per season when available.

The lowest lead loads were found in the small streams (0.0003-0.3 kg/day), with the rural reference stream (Huge Creek) ranking lowest. These low lead loads correspond to lower flows in the small streams.

In contrast to other monitoring years, several sites had higher lead loading in the fall, compared to spring. Fall lead loads were higher at Longfellow Creek, Thornton Creek, Queets River, Duwamish River, and Yakima River. These sites were affected by high rainfall in the days before sampling.

On average, spring lead loads were 2, 5, and 43 times higher than fall loads in the mid-sized, Columbia, and Spokane Rivers, respectively. Sampling events generally captured high-flow spring conditions and low-flow fall conditions at all river sites.

Temporal Trends

Sampling conducted in 2013 was the sixth year of monitoring at 11 of the study sites. Data were collected at the monitoring sites from 2008 to 2013 for the 11 long-term sites, and from 2010 to 2013 for those sites added to the program later (Thornton, Longfellow, Leach, and Huge Creeks).

We used the Mann-Kendall test to evaluate the data for temporal trends. Mann-Kendall is a non-parametric rank test for identifying trends in time series data. Negative tau values indicate a decreasing trend, and positive values indicate an increasing trend.

Data below reporting limits, but above method detection limits, were included in the analysis, when available. Values that failed MQOs were excluded. Huge Creek was not included in the analysis, as > 80% of the values were below reporting limits.

The Mann-Kendall test results showed no significant trends ($p<0.05$) at any of the monitoring sites. Spring and fall data were combined for this analysis.

The following sections describe general trends in lead concentrations observed at the monitoring sites, with spring and fall data separated. Simple linear regressions are displayed on the following graphs to show the overall direction of change. However, data were not normally distributed in all cases, and trendlines should be considered solely as a visual tool to display the general pattern in the data.

Table 2. Temporal Trend Statistics for All SPM Lead Data, 2008-2013 (mg/kg).

Waterbody	n	Mann-Kendall	
		tau	p-value
Spokane River			
Spokane River at Idaho Border	24	0.043	0.785
Spokane River at Nine Mile	24	0.058	0.710
Columbia River			
Columbia River, Upper	24	-0.145	0.333
Columbia River at Rock Island Dam	22	0.195	0.215
Columbia River at McNary Dam	21	0.138	0.398
Columbia River, Lower	22	-0.195	0.215
Mid-sized Rivers			
Duwamish River	24	0.116	0.442
Queets River	24	-0.188	0.206
Yakima River	20	-0.232	0.163
Wenatchee River	21	0.133	0.415
Small Streams			
Thornton Creek	12	-0.030	0.945
Longfellow Creek	12	-0.273	0.244
Leach Creek	12	0.182	0.451
Hylebos Creek	22	-0.004	1.000

Spokane River

Figure 5 shows lead concentrations and streamflow at the Spokane River sites from 2008 to 2013. No consistently increasing or decreasing patterns emerged at either of the Spokane River sites. Maximum lead concentrations for both sites occurred in the spring of 2008 and 2012 during the highest flows, and minimum spring concentrations occurred during low-flow years (2009, 2010). Fall samples had less variability than spring samples. Hallock (2010) found that metals, including lead, decreased in Spokane River water samples between 1994 and 2009.

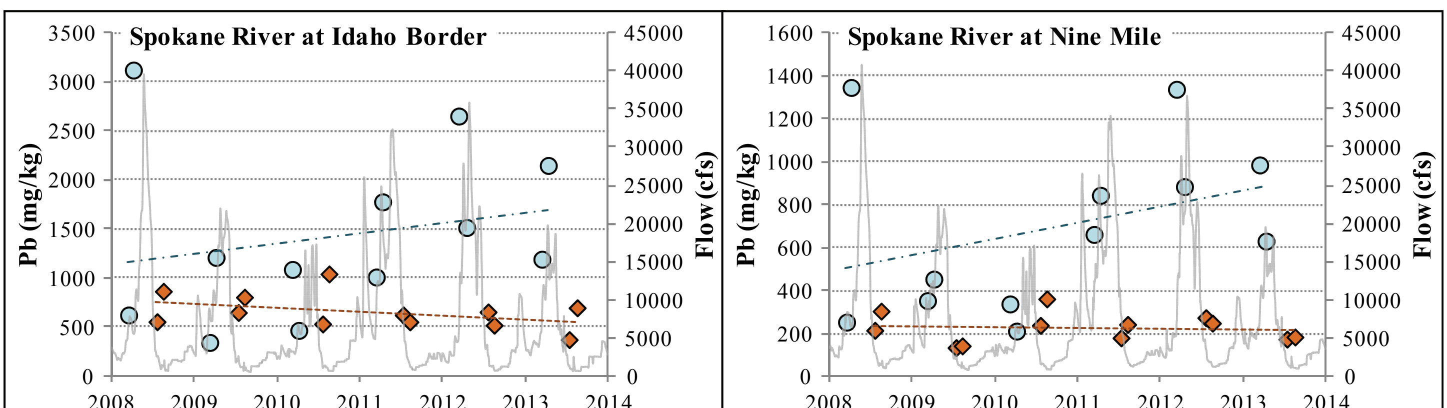


Figure 5. SPM-associated Lead Concentrations (mg/kg) at Spokane River Sites, 2008 to 2013. *Note the different y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Hollow Symbols=Values Above Detection Limit and Below Reporting Limit. Spokane River flow data provided by the U.S. Geological Survey.*

Columbia River

Figure 6 compares the Columbia River sites spatially. Lead levels tend to decrease from the site at the Canada border downstream to the site near the mouth of the river.

Figure 7 displays the Columbia River lead concentrations and streamflow from 2008 to 2013.

Linear regression on the spring lead values for the Columbia River at Rock Island Dam show an increasing trend from 2008 to 2013, denoted by a solid line in Figure 7. These data were normally distributed and appear to exhibit a true increasing trend at a 95% confidence level. The increase of approximately 5 mg/kg annually may be attributed to an increase in flow carrying greater suspended sediment loads. Streamflow at the time of sampling was highest in 2011 and 2012 and may have influenced the increasing trend in lead levels.

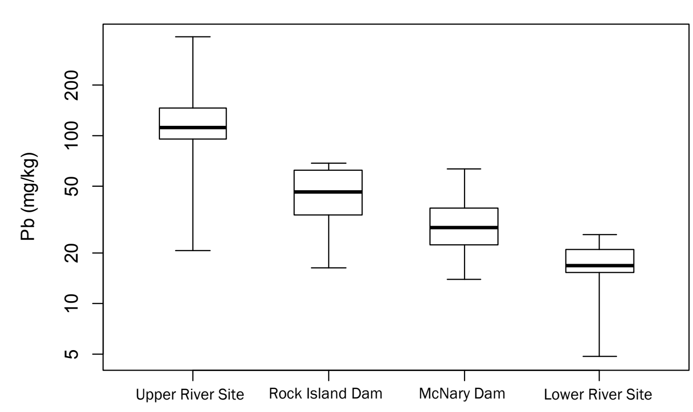


Figure 6. SPM-associated Lead Concentrations (mg/kg) at Columbia River Sites, Grouped by Site.

No other patterns were apparent for the other three Columbia River sites from 2008 to 2013. The Upper Columbia River site continued to have the highest values of the four sites. The highest lead concentrations at the Upper Columbia River site were measured in the spring of 2008 and 2012.

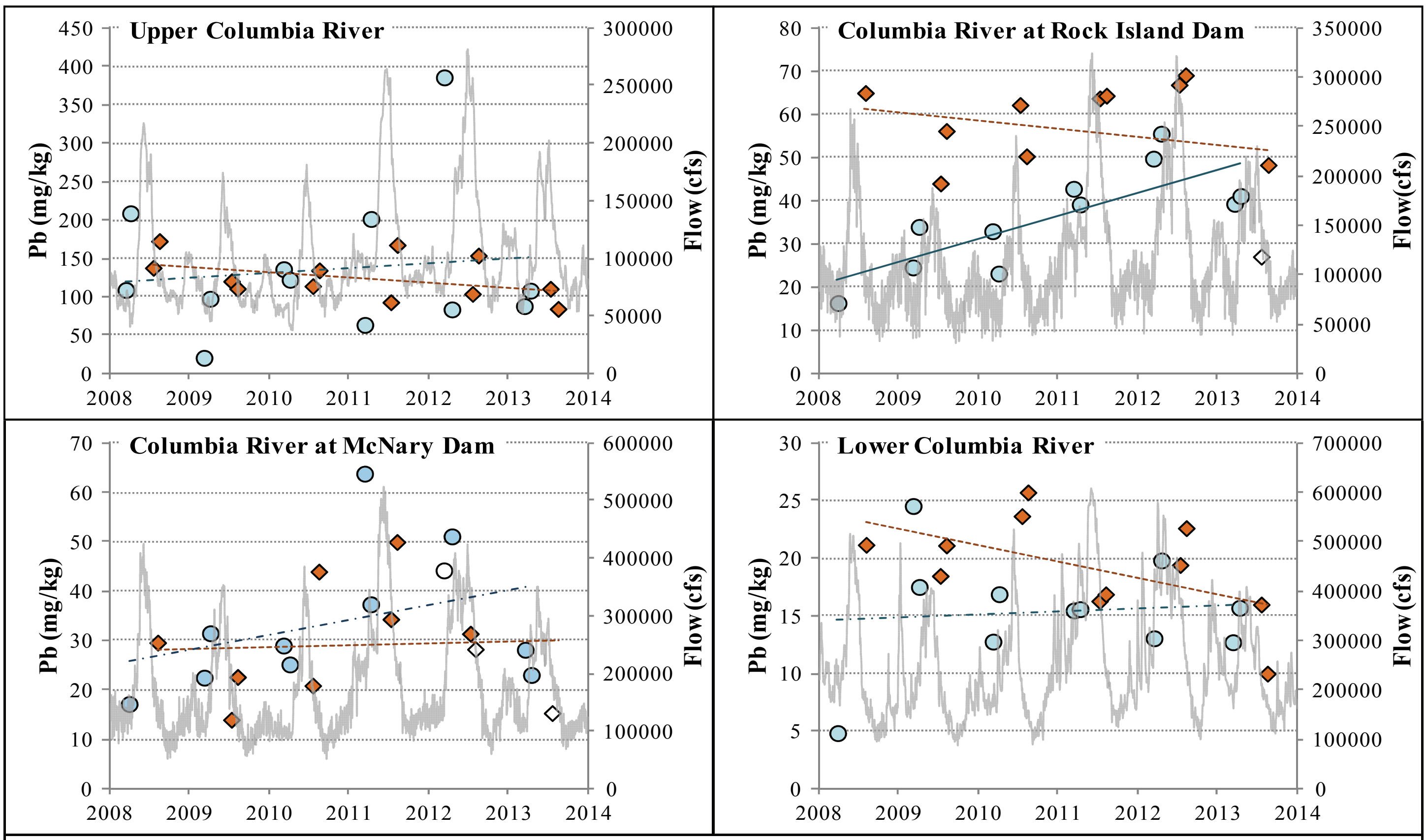


Figure 7. SPM-associated Lead Concentrations (mg/kg) at Columbia River Sites, 2008 to 2013.

Note the different y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Blue Solid Line = Spring Trendline significant at 95% confidence interval. Hollow Symbols=Values Above Detection Limit and Below Reporting Limit. Columbia River flow data provided by the U.S. Geological Survey and U.S. Army Corps of Engineers.

Mid-sized Rivers

The mid-sized rivers sampled for this study were the Duwamish, Queets, Wenatchee, and Yakima. Figure 8 displays the SPM lead concentration and streamflow data for the mid-sized rivers from 2008 to 2013.

No consistently increasing or decreasing trends emerged for the mid-sized rivers, except for a possible decline at Queets River. Queets River lead concentrations decreased in fall samples, although these data were not normally distributed, and the 2009 samples appear to have a large influence on the trend. Low concentrations were recorded in both seasons, with the 2013 samples among the lowest measured for that site. The Queets River serves as a mid-size river reference site for this study. The watershed lies primarily on national park land and has very few roads and little development.

Lead concentrations have generally been very low at all of the mid-size river sites between 2008 and 2013. With the exception of three samples (collected from the Duwamish and Wenatchee River sites), lead concentrations during the first six years of sampling remained within the range of 5-40 mg/kg. These values are comparable to, but slightly higher than, bottom sediments collected from freshwater river sediment reference sites in 2008 (range = 3.75-10.6 mg/kg; Sloan and Blakley, 2009). The median lead concentration of SPM collected from the four mid-sized rivers from 2008 to 2013 was 16.8 mg/kg, close to the median lead value of the river reference sediments from the Sloan and Blakley (2009) study: 8.86 mg/kg.

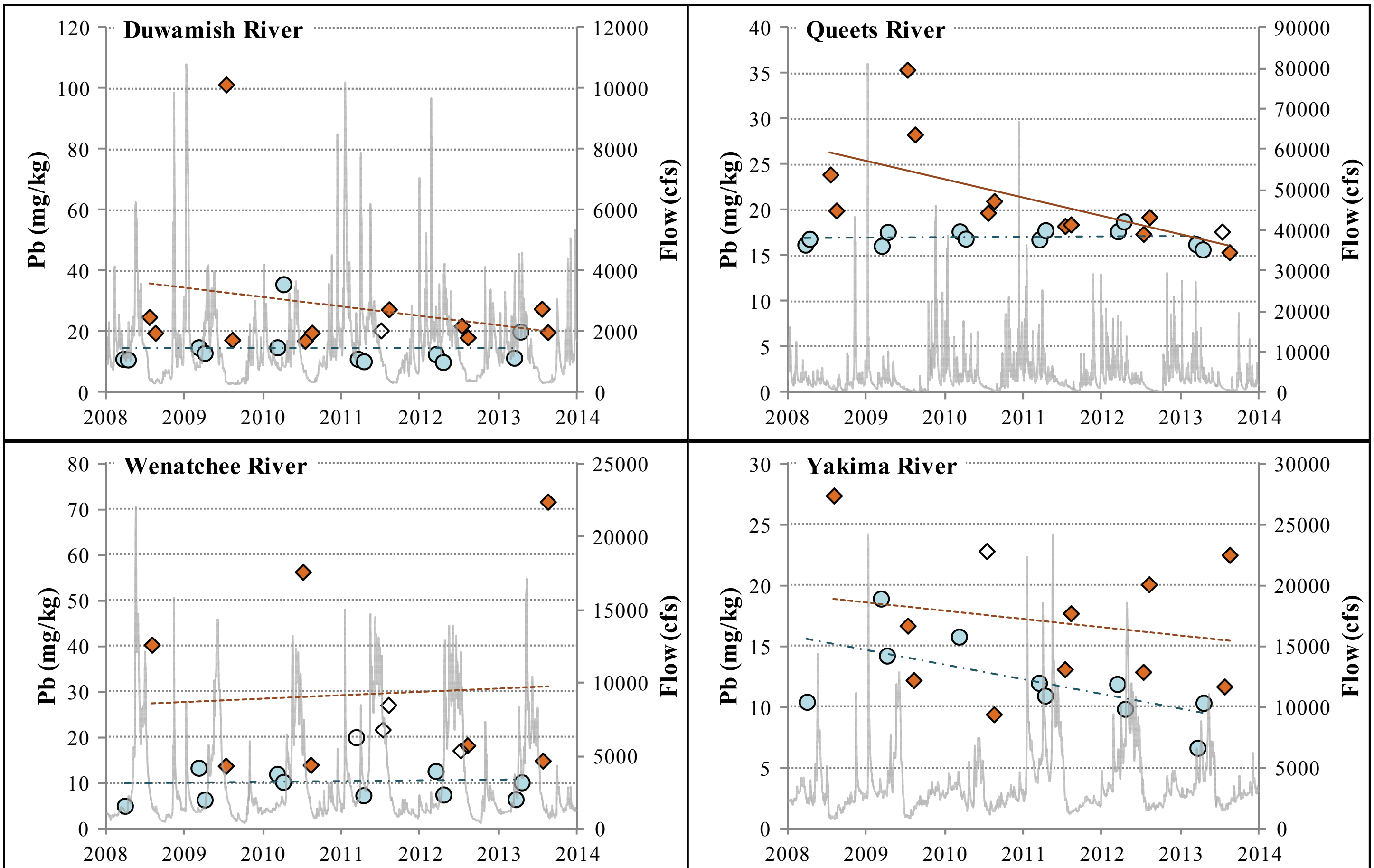


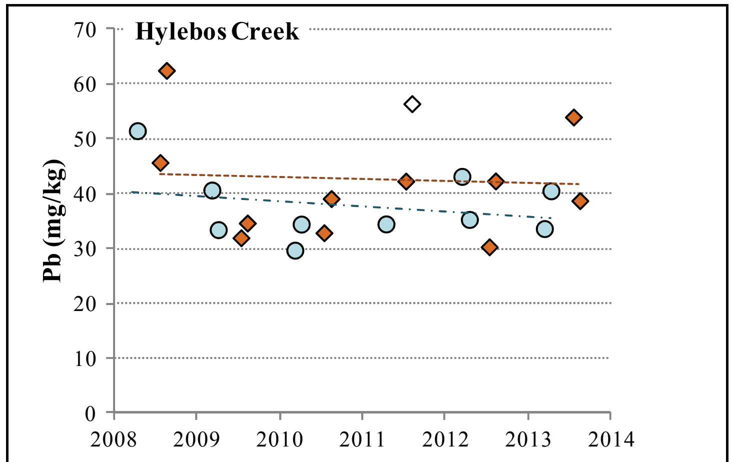
Figure 8. SPM-associated Lead Concentration (mg/kg) at Mid-sized River Sites, 2008 to 2013.

Note the different y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. Orange Solid Line=Fall Trendline significant at a 95% confidence interval. Flow data for the mid-sized rivers provided by the U.S. Geological Survey.

Small Streams

Lead concentrations in the three urban streams, Leach, Longfellow, and Thornton Creeks, were consistently higher than at the other monitoring sites, with the exception of the Spokane River. Lead concentrations in SPM collected from Hylebos Creek and Huge Creek were lower than levels in the three urban streams. Huge Creek acts as the small stream reference site and had the lowest lead concentrations of all sites sampled in 2013.

Figure 9 provides lead concentrations of the five small streams over the respective sampling periods. Concentrations at Hylebos, Leach, and Thornton Creeks have remained consistent throughout the 2008-2013 monitoring period. Longfellow Creek levels appear to be generally decreasing, but neither the Mann-Kendall test nor linear regression showed any significant changes.



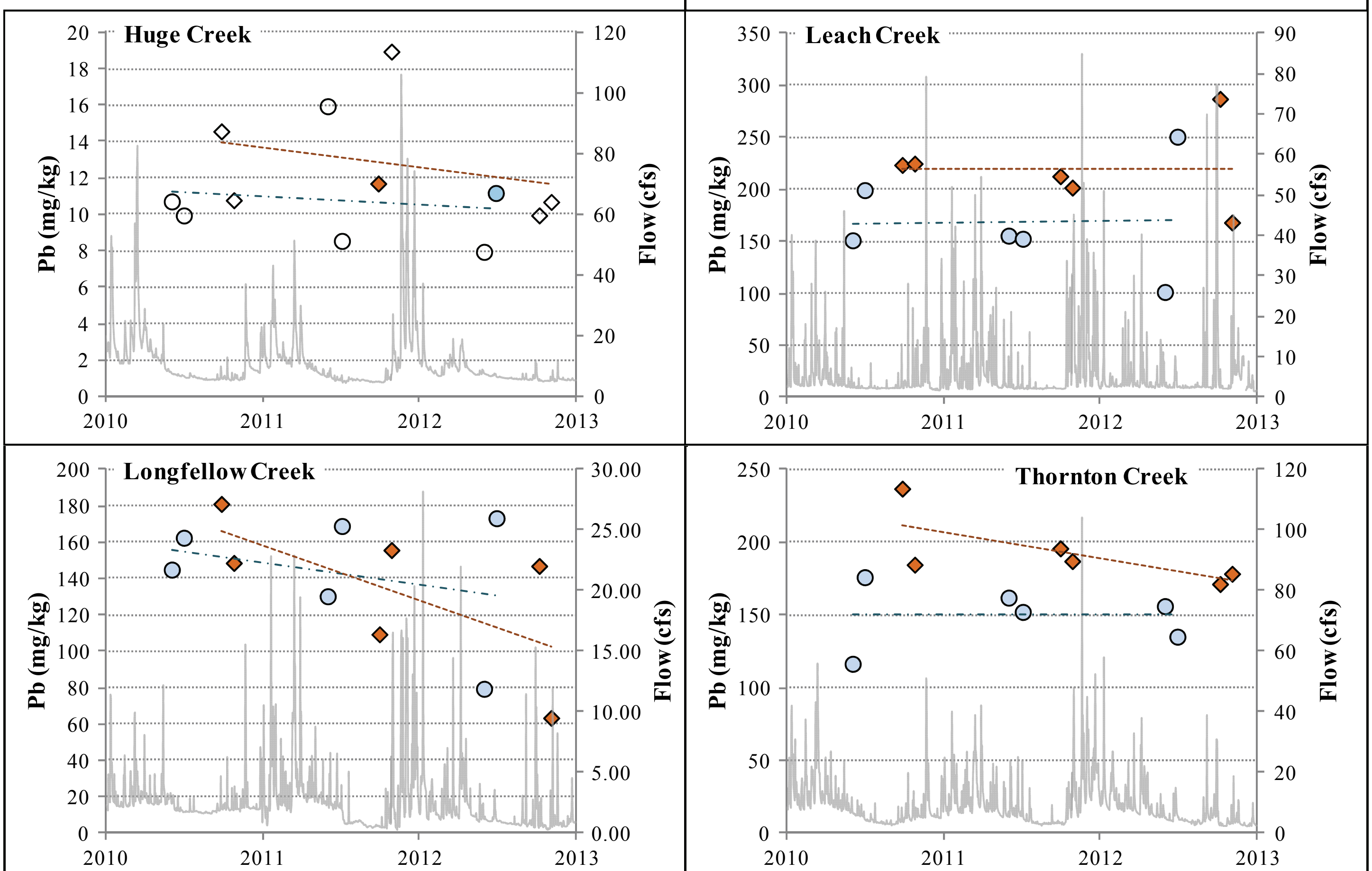


Figure 9. SPM-associated Lead Concentration (mg/kg) at Small Streams, 2008 to 2013.

Note the different y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. The R^2 values are shown parallel to each trendline. Bold R^2 values are significant at the 95% confidence interval. Flow data for the mid-sized rivers provided by the U.S. Geological Survey. No flow data are available for Hylebos Creek.

Conclusions

This report summarizes results from the sixth year of a long-term study to evaluate temporal trends in environmental lead concentrations in selected Washington State rivers and streams. A total of 58 suspended particulate matter (SPM) samples from 15 sites were analyzed for lead in 2013. Results include the following:

- Lead concentrations ranged from below detection limits to 2,150 mg/kg, with a median of 51.2 mg/kg.
- Samples collected from the Spokane River at the Idaho border contained the highest concentrations, followed by the Spokane River at Nine Mile.
- Lead concentrations were also elevated in the Upper Columbia River and the three urban streams compared to concentrations at other sampling sites.
- Six out of 58 samples (10%) contained lead concentrations above (not meeting) Ecology's freshwater Sediment Cleanup Objective (SCO) of 360 mg/kg. All samples collected from the Spokane River at the Idaho border, and both spring samples from the Spokane River at Nine Mile, were above the SCO for lead.
- Mann-Kendall tests revealed no significant trends for any of the monitoring sites from 2008 to 2013. Linear regressions showed fall samples from the Queets River generally decreased, and spring samples from the Columbia River at Rock Island Dam increased.
- The Lower Columbia River site had the highest particulate lead loading, ranging from 30-147 kg/day. This site also had the highest flows. The Upper Columbia River, near the Canada border, had the next highest lead loads, followed by the two Spokane River sites.

Recommendations

The authors of this report should consider changes to the sampling design of the lead monitoring program. The following changes may be considered:

- Add more urban streams to the monitoring site list. The lead concentrations in small, urban streams are likely to be the most dynamic as chemical action plan (CAP) reduction strategies are implemented. Increasing the frequency of small-stream sampling should also be considered.
- Discontinue sampling at most river monitoring sites, as no significant trends have been detected after six years of monitoring. Lead concentrations measured from the mid-sized river sites were low and reflective of baseline conditions; therefore, trends are not likely to be seen.
- Continue monitoring the Upper Columbia River and Spokane River sites because lead levels continue to be elevated, despite the lack of apparent trend.
- Research other methods, such as sediment traps, for collecting SPM that would integrate time and allow for collecting larger sample material size.

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