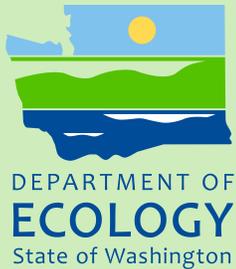




## **Mercury Levels in Gold Mining Reaches on Seven Washington Rivers and Creeks**

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Cover photo: Abandoned sluice box in the Sultan River (Michael Friese photo)

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# **Mercury Levels in Gold Mining Reaches on Seven Washington Rivers and Creeks**

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by

Art Johnson, Michael Friese, and Kristin Carmack

Environmental Assessment Program  
Washington State Department of Ecology  
Olympia, Washington 98504-7710

## Waterbody Numbers:

WA-07-1170 and -1180 Sultan River  
WA-39-1400 and -1420 Swauk Creek  
WA-45-1013 and -1014 Peshastin Creek  
WA-49-1030 Similkameen River  
WA-52-1220 Strawberry Creek  
WA-62-3500 Slate Creek  
(no number) Mary Ann Creek

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## Abstract

The use of mercury in historical gold mining operations is a significant environmental hazard, particularly in the western United States. In this study, historic gold mining reaches on seven Washington rivers and creeks were screened for evidence of mercury contamination. Mercury was analyzed in the water column, suspended sediments, streambed sediments, benthic invertebrates, and fish. Although mercury was moderately elevated in some samples, the levels overall do not appear to represent a significant concern for aquatic life, wildlife, or human health.

# Acknowledgements

The authors of this report thank the following people for their contribution to this study:

- Fritz Wolf of the Washington State Department of Natural Resources provided valuable information on mining sites of potential interest for this study.
- Biologists from the Confederated Tribes of the Colville Reservation collected most of the fish samples for this study. The help of Patti Bailey, Sheri Sears, Dennis Moore, Chris Fisher, and other tribal biologists is greatly appreciated.
- Washington State Department of Ecology staff:
  - This study was originally proposed by Greg Caron of the Central Regional Office. Greg also advised on study design, assisted with the field work, and reviewed the final report.
  - Casey Deligeannis, Jenna Durkee, and Evan Newell of the Environmental Assessment Program assisted with the sample collections.
  - The good work of the Manchester Environmental Laboratory in analyzing project samples is very much appreciated. Special thanks to Nancy Rosenbower, Leon Weiks, and Dean Momohara's Inorganic Chemistry Unit.
  - This report benefitted from review by Dale Norton and Callie Meredith of the Environmental Assessment Program Toxics Studies Unit.
  - Jean Maust, Joan LeTourneau, Cindy Cook, and Gayla Lord formatted the final report.

# Introduction

Miners historically used mercury (quicksilver) to recover gold from placer deposits in rivers and streams throughout the western United States. Placer gold tends to concentrate in places of slackened water velocity, such as bars on the inner sides of curves and where streams emerge from rapids into quiet water. The word “placer” is derived from the Spanish for “sandbank”.

Mercury was added to sluice boxes to recover gold as an amalgam. The high density of mercury caused the gold-mercury amalgam to sink while sand and gravel passed through the sluice. This practice began in the 1850s and was the main gold recovery technique in placer mining until the 1940s.

Finer gold and mercury particles were washed out of sluice boxes. In California, millions of pounds of mercury were lost to the environment in this way (Churchill, 2000). Fish from reservoirs and streams in California mining areas have accumulated sufficient mercury to pose a human health risk (May et al., 2000; Klasing and Brodberg, 2003). Mercury contamination from historical gold mining is thus a significant environmental hazard (USGS, 2005).

Overall, the value of placer deposits in Washington state is comparatively low (Moen and Hunting, 1975). The first discovery of gold in Washington was in 1853 (Stevens, 1860). Some of the earliest areas to be mined included Ruby Creek (Whatcom County), the Sultan River (Snohomish County), Swauk Creek and Peshastin Creek (Chelan County), the Cle Elum River (Yakima County), and the Similkameen and Okanogan Rivers (Okanogan County). By 1990, most of the state’s placers had been found and largely worked out.

DNR was advising on how mercury could be used by miners to recover gold as recently as 1975, although adding strict cautions as to the health hazard (Moen and Hunting, 1975). The Washington State Department of Ecology (Ecology) Hazardous Waste and Toxics Reduction Program (HWTR) has been working with miners to dispose of elemental mercury they find in Washington rivers and streams. In 2003, the Legislature passed the Mercury Education Reduction Act, initiating a program for safe mercury disposal. Since then, HWTR contacts within mining clubs and individuals have resulted in the recovery of nearly 500 pounds of mercury.

HWTR wondered if old placer mines could be acting as potential point sources of mercury and was concerned that methylmercury could be entering the food web at these locations. Mining sites offered targeted areas for investigation. Therefore, in response to a request from HWTR, selected reaches on rivers and creeks where gold mining has occurred were screened for evidence of mercury contamination during 2009-2010.

## Project Description

The objective of this project was to determine if mercury levels at selected historic gold mining areas on Washington rivers and creeks have the potential to adversely affect aquatic life and wildlife, or represent a potential human health risk for fish consumers. Placer mining reaches in seven watersheds were selected for investigation. Mercury levels were measured in the water column, suspended sediments, streambed sediments, benthic invertebrates, and fish.

Field work was initiated in August 2009 and completed in June 2010. The study was conducted by the Ecology Environmental Assessment Program (EA Program), with sample analysis by Ecology's Manchester Environmental Laboratory (MEL). The study followed a quality assurance project plan (Johnson, 2009).

# Mercury Assessment Criteria

Quality criteria that apply to mercury in freshwater environments are summarized in Tables 1 through 4. These values were used to assess the significance of mercury concentrations found in mining areas during the present study.

Washington's water quality standards establish criteria for protection of aquatic life and human health (Table 1). The aquatic life criteria for chronic and acute exposure to mercury are 0.012 and 2.1 ug/L (parts per billion), respectively. The chronic criterion is a 4-day average concentration not to be exceeded more than once every three years on average. The acute criterion is for a 1-hour average concentration not to be exceeded more than once every three years on average. Washington's human health criteria for consumption of fish and water are set out in the EPA National Toxics Rule (NTR). The mercury human health water quality criterion is 0.14 ug/L.

Table 1. Washington State Water Quality Criteria for Mercury (ug/L, total mercury).

Aquatic Life*		Human Health†
Chronic	Acute	0.14
0.012	2.1	

\*WAC 173-201A

†EPA National Toxics Rule (40 CFR 131.36)

Washington has not established criteria to protect wildlife from the effects of mercury or other toxic chemicals. EPA (1997) has derived fish tissue concentrations of methylmercury that would not be expected to have adverse effects on fish-eating birds and mammals (Table 2). Essentially all the mercury in biological tissues is in the form of methylmercury.

Table 2. EPA Wildlife Criteria for Mercury\* (ug/Kg, wet weight).

Fish Tissue Methylmercury Concentrations	
Trophic Level 3	Trophic Level 4
77	350

\*EPA (1997)

For trophic level 3 and 4 fish species, EPA proposed criteria of 77 ug/Kg and 350 ug/Kg (parts per billion), respectively. Level 3 species are herbivores and omnivores such as carp and perch. Level 4 are predatory species such as bass. Other studies have similarly concluded that mercury levels in excess of 100 to 300 ug/Kg are associated with adverse effects (Wolfe et al., 1998; Lazorchak et al, 2003). The present report therefore uses a benchmark value of 200 ug/Kg as an indicator of potential for increased hazard to wildlife due to elevated mercury levels.

EPA has developed a range of mercury human health criteria for fish consumers (Table 3). The criteria differ due to assumptions about consumption rates, toxicity, and other factors.

Table 3. EPA Human Health Criteria for Mercury in Fish Tissue (ug/Kg, wet weight).

National Toxics Rule*	Methyl Mercury†	Screening Values**	
		Subsistence	Recreational
770	300	49	400

\*EPA National Toxics Rule (40 CFR 131.36)

†EPA (2001)

\*\*EPA (2000)

In EPA (2000), screening values (SVs) were developed for toxic substances to aid in prioritizing areas that may present risks to people consuming fish. The SVs are for guidance only and are not regulatory thresholds. The SVs for mercury are 49 ug/Kg for subsistence fishing and 400 ug/Kg for recreational fishers.

The NTR human health water quality criterion can be translated into an equivalent fish tissue concentration using EPA bioaccumulation factors. Ecology uses this approach to identify water quality limited lakes, rivers, and streams that pose a health risk for fish consumers. The NTR human health water quality criterion for mercury (0.14 ug/L) equates to a fish tissue criterion of 770 ug/Kg, using the EPA bioaccumulation factor of 5,500 L/Kg.

EPA’s current recommended human health criterion for methylmercury is 300 ug/Kg (EPA, 2001). This is the maximum advisable concentration in fish to protect consumers among the general population. EPA expects the criterion to be used as guidance by states and authorized tribes in establishing or updating water quality standards for waters of the United States. The 300 ug/Kg criterion is used to assess the significance of findings in the present study.

Washington currently has regulatory sediment quality criteria for marine waters only. Table 6-3 in U.S. Army Corps of Engineers et al. (2009) has the most recent interim freshwater sediment quality values being used by Ecology as guidance for assessing freshwater sediments for dredging and disposal. This report recommends sediment quality screening levels (SL) for mercury and other toxic substances in freshwater sediments. Toxic effects to benthic organisms due to mercury would not be expected to occur at or below the SL1 of 280 ug/Kg. Minor adverse benthic effects would be anticipated at the mercury SL2 of 750 ug/Kg.

Table 4. Interim Freshwater Sediment Quality Values for Mercury\* (ug/Kg, dry weight).

Screening Level 1	Screening Level 2
280	750

\*USACE et al. (2009)

# Waterbodies Investigated

Seven rivers and creeks with a history of mining for placer gold were selected for study, based on recommendations from HWTR and the Washington State Department of Natural Resources (DNR) (Figure 1).

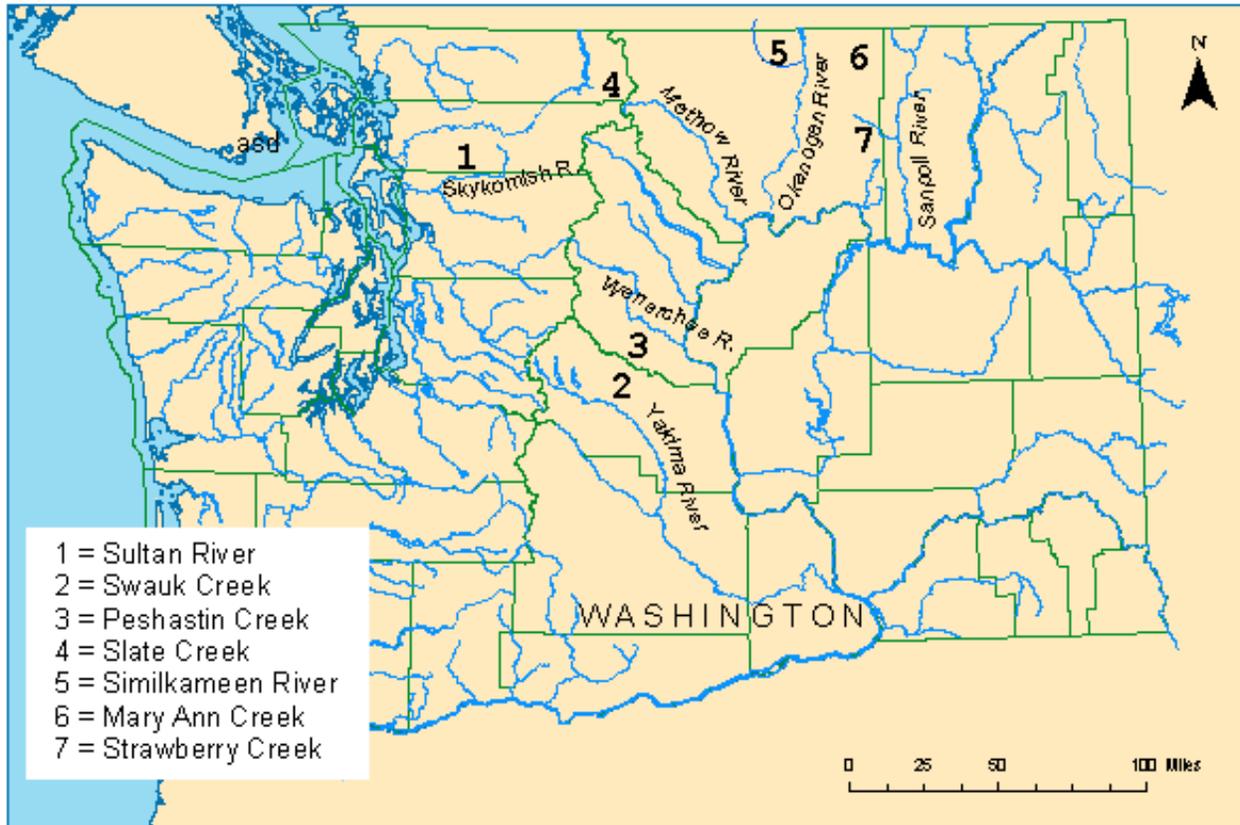


Figure 1. Approximate Location of Waterbodies Screened for Mercury Contamination, Showing Major Rivers to Which They Discharge.

*Mary Ann Creek (#6) is a tributary of Myers Creek, which flows into British Columbia.*

Reaches within these drainages that have seen substantial gold mining activity are depicted in Figures 2a-g. These locations were delineated on paper maps provided by Fritz Wolf of the DNR Division of Geology and Earth Resources. Some small-scale gold mining continues to varying extents at all of these sites.

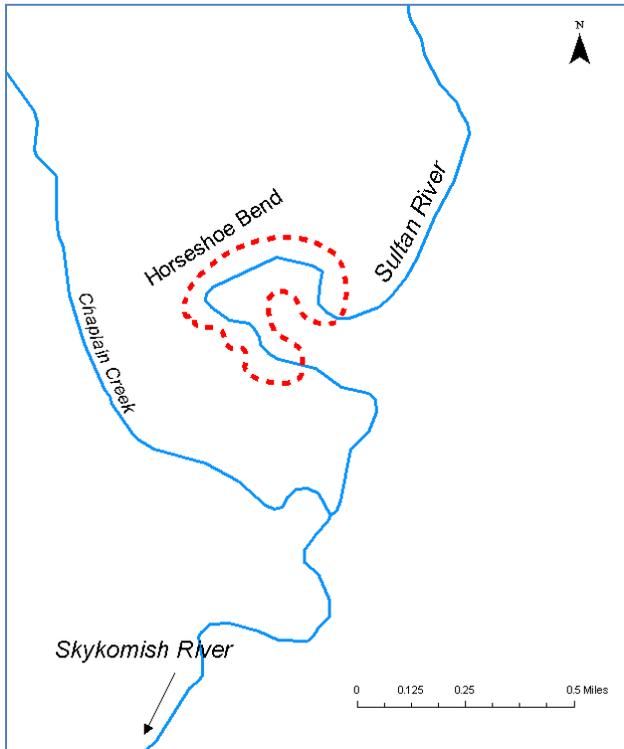


Figure 2a. Placer Mining Area on the Sultan River, Snohomish County.

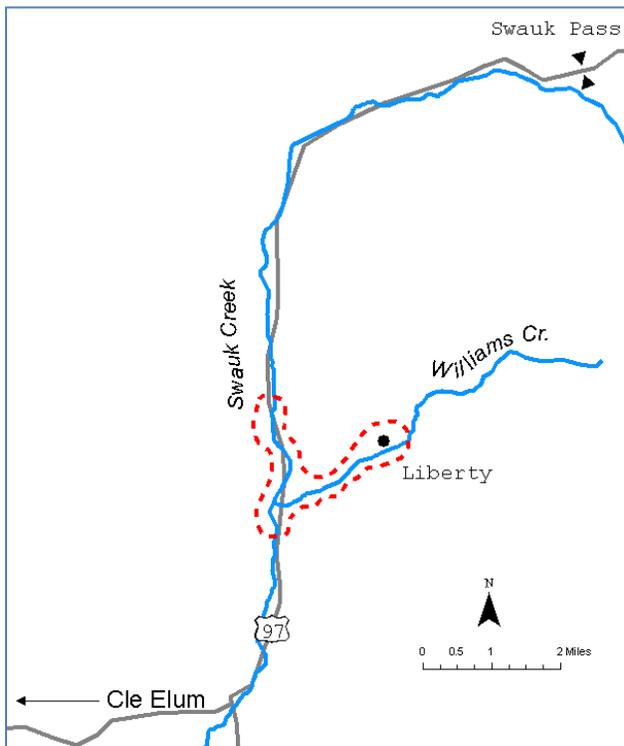


Figure 2b. Placer Mining Area in the Swauk Creek Drainage, Kittitas County.

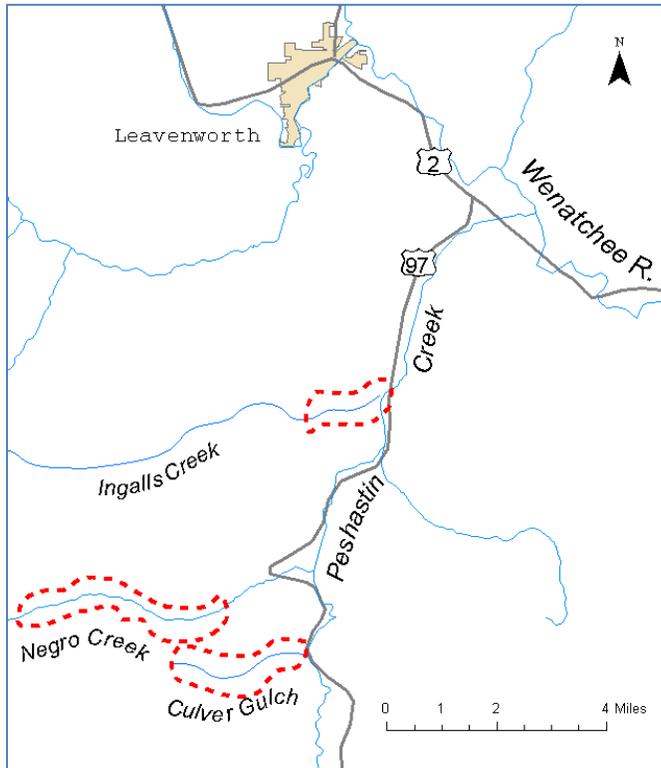


Figure 2c. Placer Mining Areas in the Peshastin Creek Drainage, Chelan County.

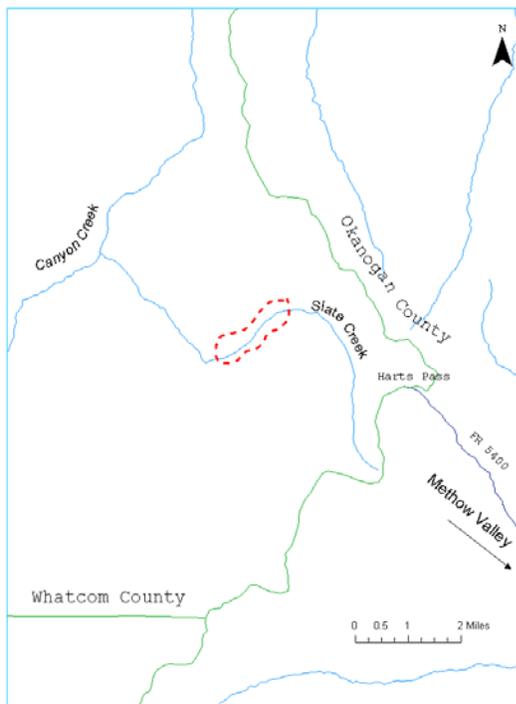


Figure 2d. Placer Mining Area on Slate Creek, Whatcom County.

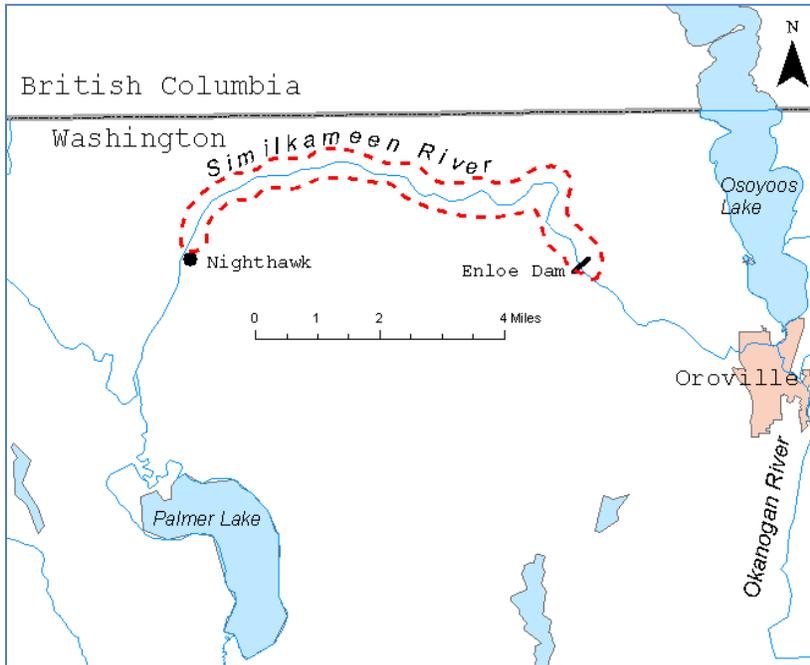


Figure 2e. Placer Mining Area on the Similkameen River, Okanogan County.

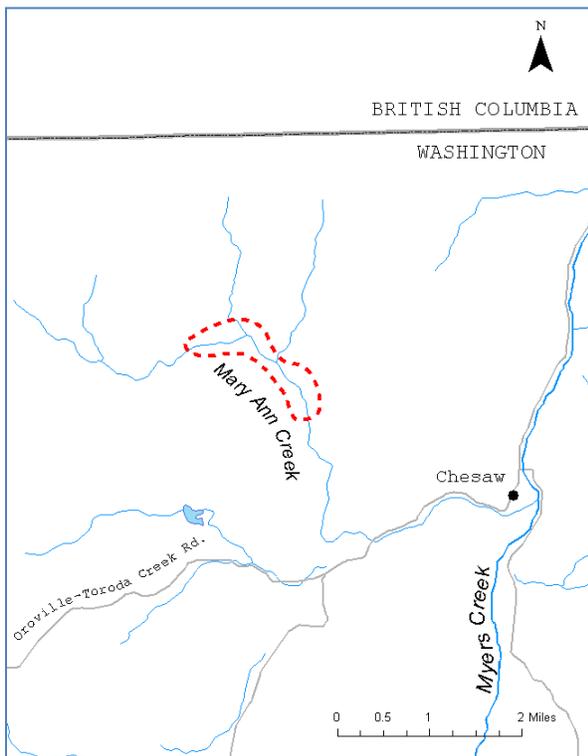


Figure 2f. Placer Mining Area on Mary Ann Creek, Okanogan County.

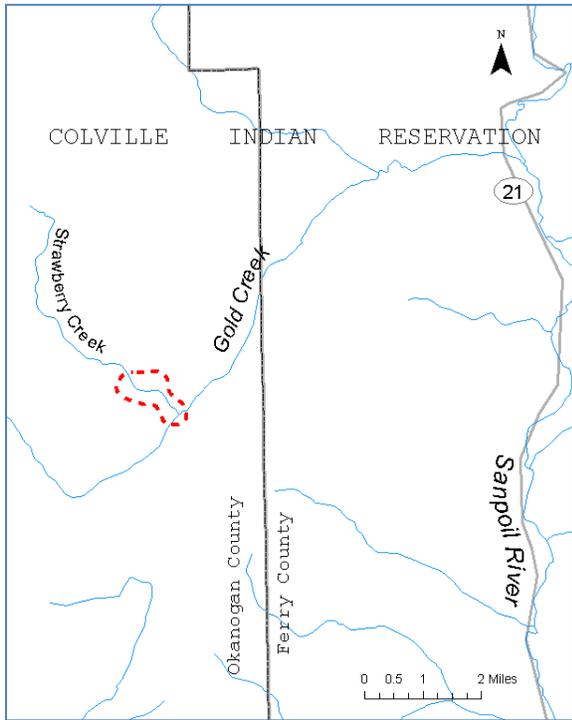


Figure 2g. Placer Mining Area on Strawberry Creek, Okanogan County.

# Sampling Design

Water column, suspended sediment, bed sediment, and biological samples were analyzed for evidence of mercury contamination. USGS and others have identified mercury "hot spots" by similar reconnaissance-level sampling at mining sites in other states (e.g., Alpers et al., 2005). Results were compared to the environmental mercury criteria, benchmarks, and standards previously described. A weight-of-evidence approach was used to conclude if significant contamination exists.

For various reasons, including but not limited to access, streamflow, and habitat conditions, the number and type of samples that could be collected varied from waterbody to waterbody. Water and bed sediments were sampled at all sites. Suspended sediment and tissue samples were obtained at about half the sites.

## Water Column

The annual flow patterns of the Sultan River, Swauk Creek, Peshastin Creek, and Similkameen River are depicted in Figure 3. Mercury transport out of reaches contaminated from mining operations would be expected to be greatest during runoff events when bottom material is re-suspended. The highest flows in these waterbodies are either in the early winter (Sultan River) or spring (Peshastin Creek, Swauk Creek, and Similkameen River). Flow data were not available for Slate, Mary Ann, or Strawberry Creek, but they would also have their highest flows in the spring, similar to other eastern Washington streams.

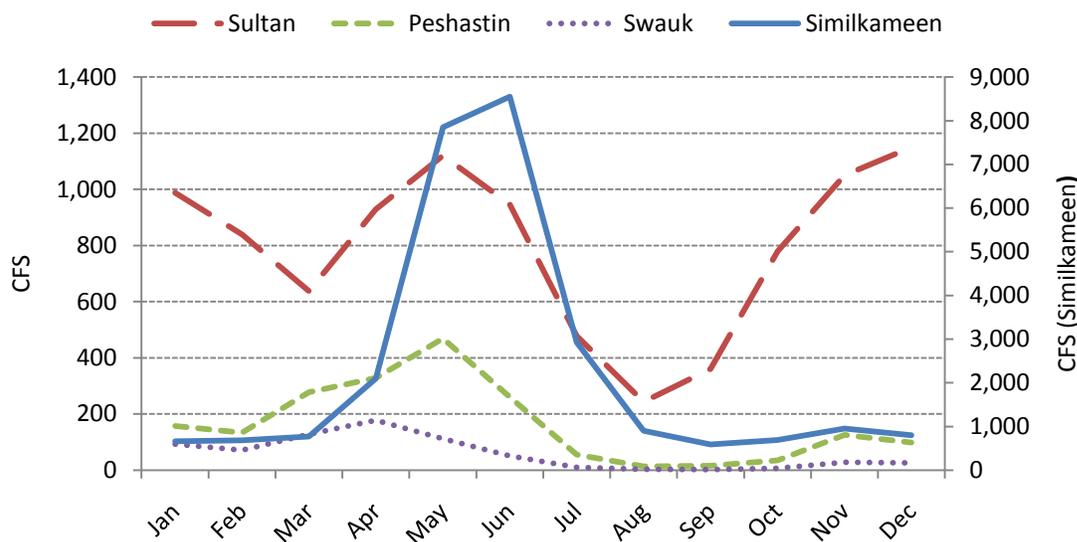


Figure 3. Flow Patterns in the Sultan River, Peshastin Creek, Swauk Creek, and Similkameen River (monthly averages).

<http://waterdata.usgs.gov/wa/nwis/sw> and [http://ecy.wa.gov/programs/eap/flow/shu\\_main.html](http://ecy.wa.gov/programs/eap/flow/shu_main.html)

Based on these patterns, water column samples were collected during November through January in the Sultan River and from April through June in the six eastern Washington rivers and creeks. A set of baseline samples was also obtained from each waterbody during summer low-flow conditions (August/September). Slate Creek was not accessible in the spring due to snow.

The timing and number of the water samples collected is shown in Table 5. To the extent possible, the winter and spring water samples coincided with rising flows when scouring is the greatest.

Table 5. Timing and Number of Water Samples, 2009-2010.

Drainage	Low Flow		Winter Runoff				Spring Runoff					Total samples
	A	S	O	N	D	J	F	M	A	M	J	
Sultan River	2	1		2	1	1						7
Swauk Creek*	2								3	3	3	11
Peshastin Creek†	4								4	4	4	16
Slate Creek	4								[inaccessible]			4
Similkameen River	1								2	2	2	7
Mary Ann Creek	1									2		3
Strawberry Creek	1								1	2		4
Total samples =	15	1		2	1	1			10	13	9	52

\*Includes samples from Williams Creek.

†Includes samples from Ingalls Creek, Negro Creek, and Culver Gulch.

Water sampling sites were located within and downstream of the mining areas shown in Figure 2. The samples were analyzed for total mercury and total suspended solids (TSS). Low-level analytical methods (0.002 ug/L reporting limit) were used for mercury so that results could be compared to Washington’s chronic water quality criterion of 0.012 ug/L.

## Suspended Sediment

Water samples provided an instantaneous measurement of mercury concentrations. For those areas where water velocity was relatively low and depth sufficient, suspended sediment traps were used to give a long-term assessment of mercury re-suspension and transport.

Sediment traps were installed downstream of the mining areas on the Sultan River, Swauk Creek, Peshastin Creek, Similkameen River, and Strawberry Creek. The traps were set out during October (Sultan) or April-May (Swauk, Peshastin, Similkameen, and Strawberry) and retrieved two to seven weeks later. The material retained in the traps was centrifuged and analyzed for total mercury at a reporting limit of approximately 5 ug/Kg, dry weight. The water was too shallow to deploy traps in Mary Ann Creek and Slate Creek.

## Streambed

Streambed samples were collected within each of the placer mining areas. One to four samples were obtained at each site, except for Peshastin Creek and Negro Creek where the bottom was rocky. The samples were taken from deposits of fine material accessed during summer low flow. Total mercury and grain size were analyzed. The reporting limit for mercury was approximately 5 ug/Kg, dry weight.

## Biological Samples

Benthic invertebrates have been shown to accumulate mercury in rivers and streams impacted by mining and other anthropogenic sources. Order of magnitude differences in mercury levels have been observed in invertebrates collected above and below contaminated sites (Eisler, 1987). Unlike fish, benthic invertebrates have limited mobility and thus may be more representative of site-specific conditions.

Caddisflies, being abundant and relatively large, were selected for benthic invertebrate samples to achieve sufficient weights for mercury analysis. Two to three caddisfly composites each were collected in the Sultan, Peshastin, and Swauk drainages. The samples were taken in the late summer or fall. Caddisflies were not found or were uncommon at the four other study areas. The entire animal minus the casing was analyzed for total mercury, using composites of approximately 30 to 70 individuals each.

Adverse human health effects due to consuming fish with elevated mercury levels was also a concern addressed in this study. Total mercury was analyzed in fillets from one to four fish species collected in the vicinity of the mining areas on the Sultan River, Similkameen River, and Strawberry Creek. Fish could not be obtained from the other sites due to poor habitat or endangered species concerns.

The fish were collected during late summer, which afforded the best access and fishing success. Several researchers have recommended that fish be sampled for mercury during the summer or fall when uptake is most rapid and methylmercury production greatest (e.g., Cope et al., 1990; Slotton et al., 1995). Tissue turnover times for mercury are multiple years for top predators and months to years for forage fish (Chasar et al., 2009).

The reporting limit for mercury in tissue was approximately 20 ug/Kg, wet weight.

## Summary of Sampling Design

The types and numbers of samples analyzed for this investigation are summarized in Table 6.

Table 6. Types and Numbers of Samples Analyzed.

Waterbody	Water	Bed Sediments	Suspended Sediment	Caddisflies	Fish Tissue
Sultan River	7	3	1	2	1
Swauk Creek Drainage	11	2	1	3	
Peshastin Drainage	16	1		2	
Similkameen River	7	3	1		5
Strawberry Creek	7	1			2
Mary Ann Creek	3	1			
Slate Creek	4	4			

# Field Methods and Sample Preparation

Sample containers, preservation, and handling for this project are shown in Table 7.

Table 7. Sample Containers and Preservation.

Media/Analysis	Container	Preservation	Holding Time
<b>Water</b>			
Total Mercury	500 mL Teflon*	HNO <sub>3</sub> to pH<2, ≤ 6°C	28 days
Total Suspended Solids	1000 mL poly bottle	Cool to ≤ 6°C	7 days
<b>Sediment</b>			
Total Mercury	8 oz. glass†	Cool to ≤ 6°C	28 days
Grain Size	8 oz. plastic	Cool to ≤ 6°C	6 months
<b>Tissue</b>			
Total Mercury	4 oz. glass†	Freeze	28 days

\*Cleaned as described in Manchester Laboratory Clean Room Standard Operating Procedure.

†Cleaned as per OSWER protocol #9240.0-05.

## Water

Sampling procedures for mercury in water followed the guidance in EPA Method 1669 *Sampling Ambient Water for Trace Metals at EPA Water Quality Levels*. All samples were taken as simple grabs and placed on ice immediately upon collection.

The mercury samples were collected directly into pre-cleaned 500 mL Teflon bottles. TSS samples were collected in one-liter poly bottles. The Teflon bottles were acid-cleaned by MEL, as described in SOP 720005 v3.0 and sealed in plastic bags. The mercury samples were preserved to pH <2 after receipt at the laboratory.

Streamflow was either measured at the time of sample collection or obtained through USGS or Ecology flow monitoring programs.

## Suspended Sediment

The sediment traps used in this study consisted of a simple 4-inch diameter Plexiglas cylinder, weighted in a concrete slab, and extending either 6 or 12 inches above the streambed. The cylinder was pre-cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, and deionized water. The cylinder mouth was covered with aluminum foil for transport into the field.

The traps were deployed in areas of low-to-moderate stream velocity for two to seven weeks, depending on the anticipated rate of sediment accumulation. After retrieval, the sediment in the cylinder was allowed to settle and overlying water decanted. The remaining slurry was passed through a 2 mm screen into priority pollutant cleaned ½ gallon glass jars with Teflon lid liners and stored on ice in coolers.

Sample processing consisted of decanting off additional overlying water and centrifuging the remaining material in a pre-weighed, 16-oz glass jar at 1,000 rpm for ten minutes to isolate the sediment fraction. After centrifuging, the overlying water was decanted and the centrifuged sediment scraped into a pre-cleaned 8 oz. glass jar with Teflon lid liner and stored at <4°C until analyzed.

## **Streambed Sediments**

Sediment collection and handling followed the EA Program SOP for freshwater sediment samples (Blakley, 2008). The samples were composites of multiple grabs taken with a stainless steel scoop.

The sediments were passed through a 2 mm screen to remove rocks, sticks, and other debris, and homogenized in a stainless steel bowl by stirring. Subsamples of the homogenized sediment were put into pre-cleaned 8 oz. glass jar with Teflon lid liner and stored at <4°C until analyzed.

Stainless steel implements used to collect and manipulate the sediments were cleaned prior to use by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, and deionized water. The equipment was air dried and wrapped in aluminum foil for transport into the field.

## **Caddisflies**

Caddisflies were collected by hand from riffle habitats. The casings were removed with acid-cleaned forceps and the animals placed in pre-cleaned 4 oz. glass jars with Teflon lid liners. Each sample analyzed consisted of between 30 and 70 individual organisms, with wet weights ranging from approximately 5 to 10 grams.

The caddisflies were freeze-dried at MEL and ground to uniform color and consistency in a mortar and pestle. The mortar and pestle were pre-cleaned using similar procedures as for the sediment samples.

## **Fish**

Fish were collected by electroshocking or hook and line. To the extent possible, only those fish large enough to reasonably be retained for consumption were taken.

Fish selected for analysis were killed by a blow to the head. The fish were put in plastic bags and placed on ice or frozen for transport to Ecology headquarters, where the samples were held frozen pending preparation of tissue samples.

Tissue samples were prepared following the EA Program SOP for resecting finfish (Sandvik, 2006). Techniques to minimize potential sample contamination were used. Staff preparing the samples wore non-talc nitrile gloves and worked on heavy duty aluminum foil or a polyethylene cutting board. The gloves and foil were changed between samples; the cutting board was cleaned between samples as described below.

The fish were thawed enough to remove the foil wrapper, given a unique identifying number, and their length and weight recorded (Appendix A). The fish were then rinsed with tap water and deionized water to remove any adhering debris. The entire fillet from one or both sides of each fish was removed with stainless steel knives and homogenized in a Kitchen-Aid blender. The fillets were scaled and analyzed skin-on. Due to their small size, the fish from Strawberry Creek were analyzed whole. The sex of each fish was recorded (Appendix A).

Two to five individual fish were used for each composite sample. To the extent possible, the length of the smallest fish in a composite was no less than 75% of the length of the largest fish. The composites were prepared using equal weights from each fish. The pooled tissues were homogenized to uniform color and consistency, using three passes through the blender. The homogenates were placed in pre-cleaned 4 oz. glass jars with Teflon lid liners. The tissue samples were refrozen for later shipment to MEL.

Cleaning of resecting instruments, cutting boards, and blender parts was done by washing in tap water with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, de-ionized water, and pesticide-grade acetone. The items were then air-dried on aluminum foil in a fume hood before use.

## **General Field Procedures**

Field activities were recorded in a bound notebook of waterproof paper. A GPS was used to record sampling locations. All field samples were placed in polyethylene bags and held on ice for transport to Ecology headquarters. The water and streambed samples were held in a secure cooler and transported to MEL within one to two days of collection. The suspended sediment and biological samples were processed in the EA Program cleaning room at Ecology headquarters before being transported to MEL. In all cases, chain-of-custody procedures were followed.

# Laboratory Methods

Project samples were analyzed by MEL, except for grain size which was analyzed by Columbia Analytical Services, a MEL contractor. The following methods were used.

Table 8. Laboratory Methods.

Media/Analysis	Reporting Limit	Sample Preparation Method	Analytical Method
<b>Water</b>			
Total Mercury	0.002 ug/L	acid digest	CVAA, EPA 245.7
Total Suspended Solids	1 mg/L	--	SM2540D
<b>Sediment</b>			
Total Mercury	0.005 mg/Kg dw	acid digest	CVAA, EPA 245.5
Grain Size	0.1%	--	PSEP, 1986
<b>Tissue</b>			
Total Mercury	0.005 mg/Kg ww	acid digest	CVAA, EPA 245.6

\*Includes field blanks

CVAA = Cold Vapor Atomic Absorption

PSEP = Puget Sound Estuary Program

## Data Quality

MEL prepared written case narratives assessing the quality of the data collected for this project. The reviews include a description of analytical methods and an assessment of holding times, calibration, method blanks, laboratory control samples, duplicate samples, and matrix spike/matrix spike duplicates. No significant problems were encountered in analyzing these samples and the data are usable as qualified. The complete case narratives and data reports are available from the author on request.

Transfer blanks or bottle blanks were analyzed on four occasions during the water sample collections to detect mercury contamination arising from sample containers or sample handling. Mercury was not detected in any of these blanks at or above 0.002 ug/L.

Selected water, sediment, and tissue samples were analyzed in duplicate (splits) to provide estimates of analytical variability. Results agreed within 10% or better for mercury and within 20% or better for TSS and grain size.

Overall, the analytical data met the data quality objectives identified in the Quality Assurance Project Plan for this study (Johnson, 2009).

# Results

## Sultan River

### Placer Description

The mining area investigated on the Sultan River was Horseshoe Bend. Moen and Huntting's *Handbook for Gold Prospectors in Washington* (1975) describes the major placer deposits in Washington. They characterize the Horseshoe Bend Placer as follows:

“Loc: Sec. 8, (28-8E), on Sultan River 5 miles north of the town of Sultan. Prop: 157 acres of patented ground. Ore: Coarse gold. Assays: Average values of 25 to 40 cents per yard at \$20 gold<sup>1</sup>. Prod: Several thousand dollars.”

### Samples Analyzed

The types and locations of samples analyzed in the Horseshoe Bend area are shown in Figure 4. Samples were collected at two locations in the lower part of the Bend and approximately two miles further downstream near the Jackson Power Plant. Appendix B has detailed descriptions of each sampling site for the study.

Water, bed sediment, and caddisflies were sampled from these sites during low-flow conditions in August. Two or three samples of each type were collected in total.

Fish sampling was conducted in September. Mountain whitefish were caught by electrofishing in the vicinity of the power plant. Efforts to collect additional fish along a ¼ mile reach upstream of the plant were unsuccessful. No attempt was made to electrofish within Horseshoe Bend because the steep terrain made access difficult.

Three suspended sediment traps were deployed just above the power plant in mid-October. One of the three was successfully retrieved in early December yielding a single sample spanning a 49-day period.

Additional water samples were collected just above the power plant during high flow conditions in the winter. One or two samples were taken each month from November through January.

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<sup>1</sup> Assay values and production figures in Moen and Huntting (1975) are based on gold prices at \$35 per troy ounce, unless otherwise noted. Gold is currently over \$1,000/ounce.

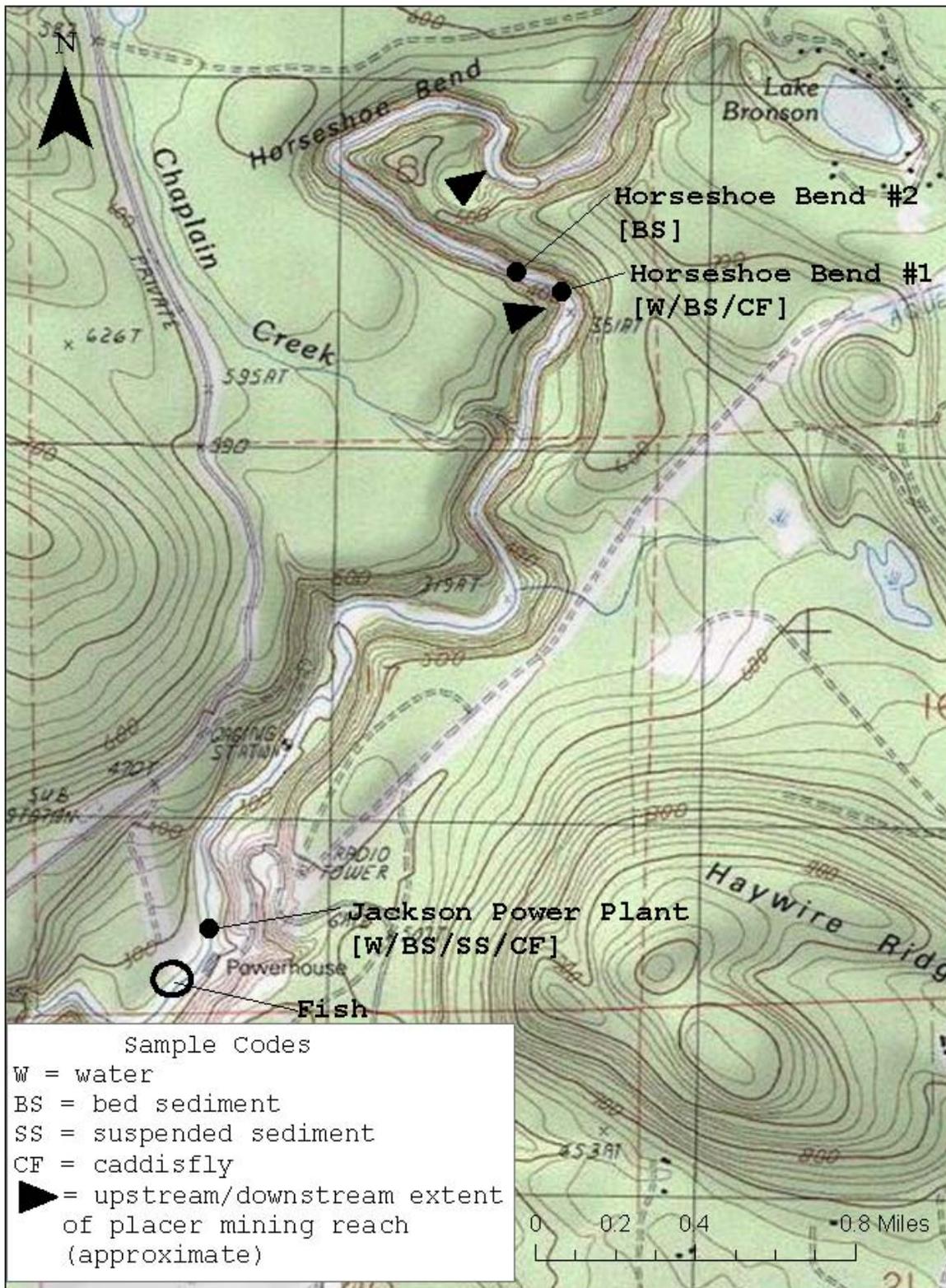


Figure 4. Types and Locations of Samples Collected in the Sultan River

Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

## Results

Results for the Sultan River samples are summarized in Table 9.

Mercury concentrations were at or below the 0.002 ug/L reporting limit in the low-flow water samples (310-358 cfs). Concentrations increased by factors of two to four or more with higher flows during the winter months (784-1,930 cfs). The highest mercury concentrations recorded, 0.0048 to 0.0082 ug/L, remained within Washington's chronic aquatic life criterion of 0.012 ug/L.<sup>2</sup>

Total suspended solids (TSS) ranged from 1 to 42 mg/L. There was a strong positive correlation between mercury and TSS in the water samples ( $R^2=0.89$ , log transformed data).

Bottom sediment samples from this area had mercury concentrations of 25 to 144 ug/Kg. Mercury levels increased with the amount of fine material in the samples. The single suspended sediment sample collected at the downstream end of this reach had a mercury concentration of 74 ug/Kg, which is consistent with findings for the streambed. These concentrations are well below the interim screening level of 280 ug/Kg for adverse biological effects of mercury in freshwater environments in Washington.

The two caddisfly samples analyzed had mercury concentrations of 55 and 89 ug/Kg. A higher concentration of 101 ug/Kg was measured in mountain whitefish fillets. Mountain whitefish feed on caddisflies and other aquatic insects. These concentrations do not exceed the 200 ug/Kg benchmark for protection of fish-eating birds and mammals. The whitefish did not approach EPA's current recommended human health criterion of 300 ug/Kg for methylmercury.

## Other Mercury Data

No other mercury data were located for the Sultan River.

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<sup>2</sup> Environmental criteria for mercury criteria are described on pages 9-11.

Table 9. Mercury Concentrations in Water, Sediment, and Biological Samples Collected from the Sultan River during 2009-2010.

<b>1. Water</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS	Flow
					(mg/L)	(cfs)
Horseshoe Bend #1	0908054-01	10-Aug-09	0.002	U	1	310
Jackson Power Plant	0908054-06	10-Aug-09	0.002	U	2	310
	0910061-01	19-Sep-09	0.0023		3	358
	0911034-01	4-Nov-09	0.002	U	1	1,500
	0911054-01	20-Nov-09	0.0048		13	1,930
	0919046-01	17-Dec-09	0.0065		9	784
	0912050-01	5-Jan-10	0.0082		42	1,660
<b>2. Bed Sediment</b>						
Sample Site	Sample No.	Collection	Mercury	Fines		
		Date	(ug/Kg, dry)	(%)		
Horseshoe Bend #1	0908054-03	10-Aug-09	25	1.4		
Horseshoe Bend #2	0908054-04	10-Aug-09	144	56		
Jackson Power Plant	0908054-07	10-Aug-09	34	5.6		
<b>3. Suspended Sediment</b>						
Sample Site	Sample No.	Collection Dates	Mercury (ug/Kg, dry)			
Jackson Power Plant	1001040-01	19-Oct-09 to 7-Dec-09	74			
<b>4. Caddisfly (soft parts)</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, wet)			
Horseshoe Bend #1	0910050-01	10-Aug-09	55			
Jackson Power Plant	0910050-02	10-Aug-09	89			
<b>5. Fish (fillets)</b>						
Sample Site/Species	Sample No.	Collection Date	Mercury (ug/Kg, wet)			
Jackson Power Plant Mountain Whitefish	0910051-1	14-Sep-09	101			

U = not detected at or above reported value.

## Swauk Creek

### Placer Description

The mining area investigated in the Swauk Creek drainage centered around its confluence with Williams Creek. The Swauk and Williams Creek placers are described by Moen and Hunting (1975) as follows:

Swauk Creek Placer: “Loc: Along Swauk Creek between the mouths of Baker and First Creeks. Deposit: Gravel from a few feet to 70 or 80 feet in thickness. Pay gravels are found on and near bedrock. Assays: Gravel varies from a few cents to \$40 per yard. Prod: Considerable.”

Williams Creek Placer: “Loc: Along Williams Creek near Liberty and at its junction with Swauk Creek. Deposit: Good pay gravel is found within 3 or 4 feet of bedrock and 70 or 80 feet below present stream level. Prod: Considerable.”

Moen and Hunting additionally note that “The largest nuggets yet found in Washington are from the Swauk district in Kittitas County. A 73-troy-ounce nugget was found in 1900 at the Elliott Placer on Williams Creek, and a 77-troy-ounce nugget on a bench of Swauk Creek near the mouth of Baker Creek.”

### Samples Analyzed

Sample collection sites in the Swauk Creek drainage included Swauk Creek above Williams Creek (near Baker Creek), the mouth of Williams Creek, and Swauk Creek about one mile below Williams Creek (Figure 5).

A similar set of samples was collected as in the Sultan River, except that no attempt was made to collect fish due to low water levels. As for other eastern Washington streams, runoff conditions were monitored during the spring snowmelt period (April, May, and June). A suspended sediment sample was obtained from the lower Swauk Creek site representing a 43-day period from mid-April through late May.

### Results

Results for the Swauk and Williams Creek samples are summarized in Table 10.

Mercury concentrations in the water samples followed a pattern similar to the Sultan River. Concentrations were at or below reporting limits during low flow, with higher concentrations occurring during spring runoff.

Williams Creek tended to have higher mercury concentrations than Swauk Creek, where mercury was inconsistently detected. There was only one instance (May) where concentrations increased from upstream to downstream in Swauk Creek - from 0.0022 to 0.0032 ug/L - corresponding to when the maximum concentration was recorded in Williams Creek, 0.0049 ug/L. As in the

Sultan River, mercury was correlated with TSS in Williams Creek ( $R^2 = 0.79$ ). Both Swauk and Williams Creek consistently met Washington's chronic water quality criterion.

Relatively low mercury levels were found in the sediment samples, 34 ug/Kg in Williams Creek and 55 ug/Kg in Swauk Creek downstream of Williams Creek. A two to three times higher concentration of 97 ug/Kg was measured in the suspended sediment sample collected at the lower Swauk Creek site in the spring, suggesting enhanced mercury transport during this period. No exceedances of the 280 ug/Kg interim sediment quality screening level were observed.

Mercury concentrations in caddisfly samples ranged from 68 to 112 ug/Kg. Concentrations were higher in Williams Creek and lower Swauk Creek compared to upper Swauk Creek. The caddisflies from lower Swauk Creek had almost twice the concentration as in upper Swauk Creek, a further indication of a possible impact from mining in this reach. All caddisfly samples were less than the 200 ug/Kg benchmark for adverse effects of mercury on wildlife.

## Other Mercury Data

During 1999-2000, Ecology monitored mercury and other metals every other month in Swauk Creek near its confluence with the Yakima River (Johnson, 2000). The objective was to verify 303(d) listings<sup>3</sup> based on historical data. The sampling site was approximately 10 miles below Williams Creek. Mercury was detected intermittently at low concentrations of 0.002 to 0.004 ug/L.

In a 1997 study by Ecology and DNR, metals were analyzed in water and sediment from Swauk Creek and Williams Creek in connection with hard rock mining (Raforth et al., 2000). One set of water samples each was collected during low flow and high flow in upper and lower Williams Creek, and in Swauk Creek above and below Williams Creek. Mercury was not detected at or above 0.002 ug/L. Sediment samples from these sites showed mercury concentrations of 30 to 50 ug/Kg, which is in close agreement with findings from the present study.

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<sup>3</sup> Section 303(d) of the Clean Water Act requires the states to prepare list of waterbodies that do not meet standards; see [www.ecy.wa.gov/programs/wq/303d/index.html](http://www.ecy.wa.gov/programs/wq/303d/index.html).

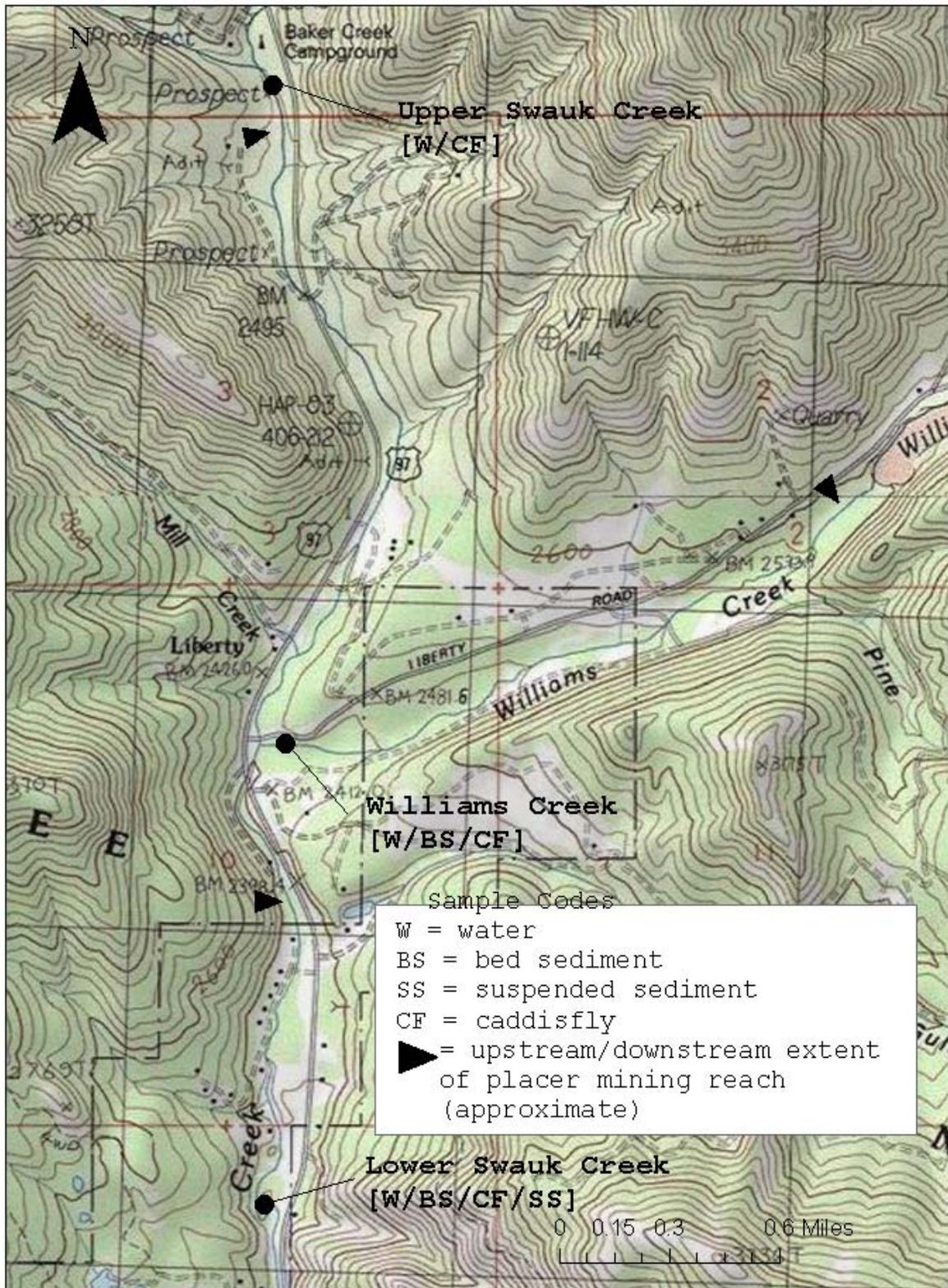


Figure 5. Types and Locations of Samples Collected in the Swauk Creek Drainage.

Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

Table 10. Mercury Concentrations Measured in Water, Sediment, and Biological Samples Collected from the Swauk Creek Drainage during 2009-2010.

<b>1. Water</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS (mg/L)	Flow (cfs)
Williams Cr. at mouth	0908055-14	24-Aug-09	0.0023		1	1.3
Swauk Cr. below Williams Cr.	0908055-11	24-Aug-09	0.0023		1 U	2 est.
Swauk Cr. above Williams Cr.	1004043-03	12-Apr-10	0.002	U	2	--
Williams Cr. at mouth	1004043-02	12-Apr-10	0.0020		3	12
Swauk Cr. below Williams Cr.	1004043-01	12-Apr-10	0.002	U	3	46
Swauk Cr. above Williams Cr.	1005083-03	24-May-10	0.0022		6	--
Williams Cr. at mouth	1005083-02	24-May-10	0.0049		16	--
Swauk Cr. below Williams Cr.	1005083-01	24-May-10	0.0032		8	--
Swauk Cr. above Williams Cr.	1006080-03	21-Jun-10	0.002	U	4	--
Williams Cr. at mouth	1006080-02	21-Jun-10	0.0024		9 J	30
Swauk Cr. below Williams Cr.	1006080-01	21-Jun-10	0.002	U	6	75
<b>2. Bed Sediment</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, dry)		Fines (%)	
Williams Cr. at mouth	0908055-15	24-Aug-09	34		4.6	
Swauk Cr. below Williams Cr.	0908055-12	24-Aug-09	55		5.0	
<b>3. Suspended Sediment</b>						
Sample Site	Sample No.	Collection Dates	Mercury (ug/Kg, dry)			
Swauk Cr. below Williams Cr.	1006085-01	12-Apr-10 to 25-May-10	97			
<b>4. Caddisfly (Soft Parts)</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, wet)			
Swauk Cr. above Williams Cr.	0910050-03	24-Aug-09	68			
Williams Cr. at mouth	0910050-05	24-Aug-09	90			
Swauk Cr. below Williams Cr.	0910050-04	24-Aug-09	112			
<b>5. Fish (Fillets)</b>		[No Samples Collected]				

U = not detected at or above reported value

J = estimated value

# Peshastin Creek

## Placer Description

The mining area investigated in the Peshastin Creek drainage included Peshastin, Negro, and Ingalls Creeks. Placer deposits on these creeks are described in Moen and Hunting (1975) as follows:

Peshastin Creek Placers: “Loc: On upper reaches of Peshastin Creek. Deposit: Placer gold found in best concentration on bedrock below gravels. Assays: Gold is of high purity.”

Negro Creek Placers: “Loc: Secs. 2 and 3 (22-17E), from mouth of Negro Creek upstream for 2 miles. Assays: 10 cents to \$1.20 per yard. Prod: \$1,100 prior to 1897.

Ingalls Creek Placer: “Loc: Sec. 25 (23-17E), on Peshastin Creek, at the mouth of Ingalls Creek.”

## Samples Analyzed

Sampling sites in the Peshastin drainage included upper Peshastin Creek, the mouths of Negro Creek and Ingalls Creek, and Peshastin Creek just below Ingalls Creek (Figure 6). Samples were planned for Culver Gulch – which had been identified by DNR as a mining area (see Figure 2c) – but it was consistently found to be dry. While Moen and Hunting mention the upper Peshastin among major placer deposits in Washington, it was not one of the sites DNR mapped out for investigation. It is uncertain how the location of the upper Peshastin sampling site for the present study relates to placer mining activity in this part of the creek.

Water samples in the Peshastin drainage were collected during low flow and on three occasions in the spring. Due to the rocky stream bed and fast, shallow water, sediment and biological samples were limited. Caddisflies were obtained in upper Peshastin Creek, and a sediment and a caddisfly sample were collected at the mouth of Ingalls Creek. Caddisflies were not encountered or were rare elsewhere.

Two suspended sediment samplers were placed in lower Peshastin Creek in the spring, but were washed away by high flows. Fish were not collected due to fast water and endangered species concerns (juvenile Chinook).

Flow data were not obtained for the Peshastin Creek drainage during spring because of hazardous conditions. A monthly average discharge of 260-470 cfs has been measured in Peshastin Creek in April, May, and June (Figure 3).

## Results

Table 11 summarizes the results for samples from the Peshastin drainage.

Mercury concentrations were consistently low in water samples from Peshastin, Negro, and Ingalls Creeks. Of the fifteen samples analyzed, 13 were below the 0.012 ug/L reporting limit. The two detections were at 0.0025 and 0.0030 ug/L.

A low mercury concentration of 11 ug/Kg was measured in the sediment sample from Ingalls Creek, the only sediments analyzed for the study. A caddisfly sample from this site also had a relatively low mercury concentration, 37 ug/Kg.

Caddisflies from upper Peshastin Creek showed evidence of significant mercury contamination. The concentration in this sample was 556 ug/Kg which substantially exceeds the 200 ug/Kg wildlife benchmark. Water was the only other type of sample analyzed from this site and concentrations were consistently low. TSS was 6 mg/L or less, indicating little scouring of the streambed was occurring.

## Other Mercury Data

Raforth et al. (2004) reports data on mercury and other metals in water and sediment collected at hard rock mines located in the Peshastin drainage, but did not collect samples within Peshastin, Negro, or Ingalls Creeks.

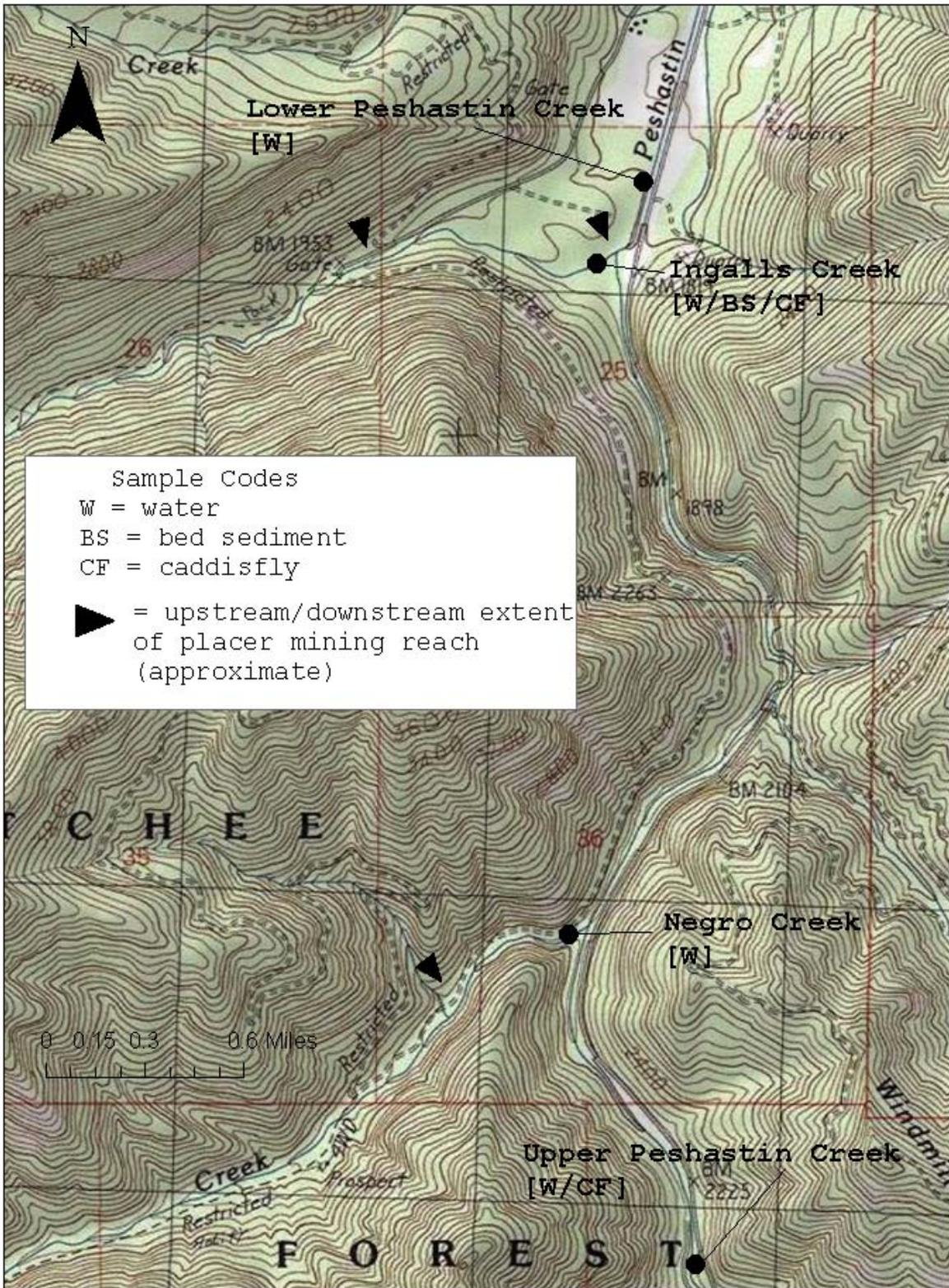


Figure 6. Types and Locations of Samples Collected in the Peshastin Creek Drainage.  
 Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

Table 11. Mercury Concentrations Measured in Water, Sediment, and Biological Samples Collected from the Peshastin Creek Drainage during 2009-2010.

<b>Water</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS (mg/L)		Flow (cfs)
Upper Peshastin Creek	0908055-19	24-Aug-09	0.0025		1	U	--
Negro Creek at mouth	0908055-04	24-Aug-09	0.002	U	2	U	3.3
Ingalls Creek at mouth	0908055-01	24-Aug-09	0.002	U	1	U	24
Lower Peshastin Creek	0908055-18	24-Aug-09	0.002	U	1	U	15 est.
Upper Peshastin Creek	1004043-04	12-Apr-10	0.002	U	1	U	--
Negro Creek at mouth	1004043-08	12-Apr-10	0.002	U	1	U	--
Ingalls Creek at mouth	1004043-05	12-Apr-10	0.002	U	1	U	--
Lower Peshastin Creek	1004043-06	12-Apr-10	0.002	U	1	U	--
Upper Peshastin Creek	1005083-04	24-May-10	0.002	U	3		--
Negro Creek at mouth	1005083-05	24-May-10	0.002	U	4		--
Ingalls Creek at mouth	1005083-06	24-May-10	0.002	U	3		--
Lower Peshastin Creek	1005083-07	24-May-10	0.0030		4		--
Upper Peshastin Creek	1006080-06	21-Jun-10	0.002	U	2		--
Negro Creek at mouth	1006080-04	21-Jun-10	0.002	U	2		--
Ingalls Creek at mouth	1006080-05	21-Jun-10	0.002	U	6	J	--
Lower Peshastin Creek	1006080-07	21-Jun-10	0.002	U	4		--
<b>Bed Sediment</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, dry)		Fines (%)		
Ingalls Creek at mouth	0908055-02	24-Aug-09	11		1.0		
<b>Suspended Sediment</b>	[No Samples Collected]						
<b>Caddisfly (Soft Parts)</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, wet)				
Upper Peshastin Creek	0910050-07	24-Aug-09	556				
Ingalls Creek at mouth	0910050-06	24-Aug-09	37				
<b>FISH (Fillets)</b>	[No Samples Collected]						

U = not detected at or above reported value

J = estimated value

## Slate Creek

### Placer Description

The mining area investigated on Slate Creek extends for about two miles downstream from Harts Pass. Moen and Hunting (1975) mention Slate Creek among the major placer deposits in Washington, but they provide no further information.

### Samples Analyzed

Due to snow, Slate Creek is only accessible in the fall. Water and bed sediments were sampled in late September at four locations where mining has historically been concentrated (Figure 7).

No caddisflies were found in Slate Creek and it has no fish populations. A suspended sediment sampler was not deployed for this study.

### Results

Table 12 has the results from analyzing the Slate Creek samples.

Mercury was not detected in the water samples. Three of the four sediment samples had low mercury concentrations ranging from 11 – 20 ug/Kg. Due to interferences encountered in the fourth sample, reporting limits were high (67 ug/Kg) and mercury was not detected.

### Other Mercury Data

Additional mercury data could not be located for Slate Creek. Raforth et al. (2002) investigated nearby Bonita Creek and did not find evidence of significant mercury contamination.

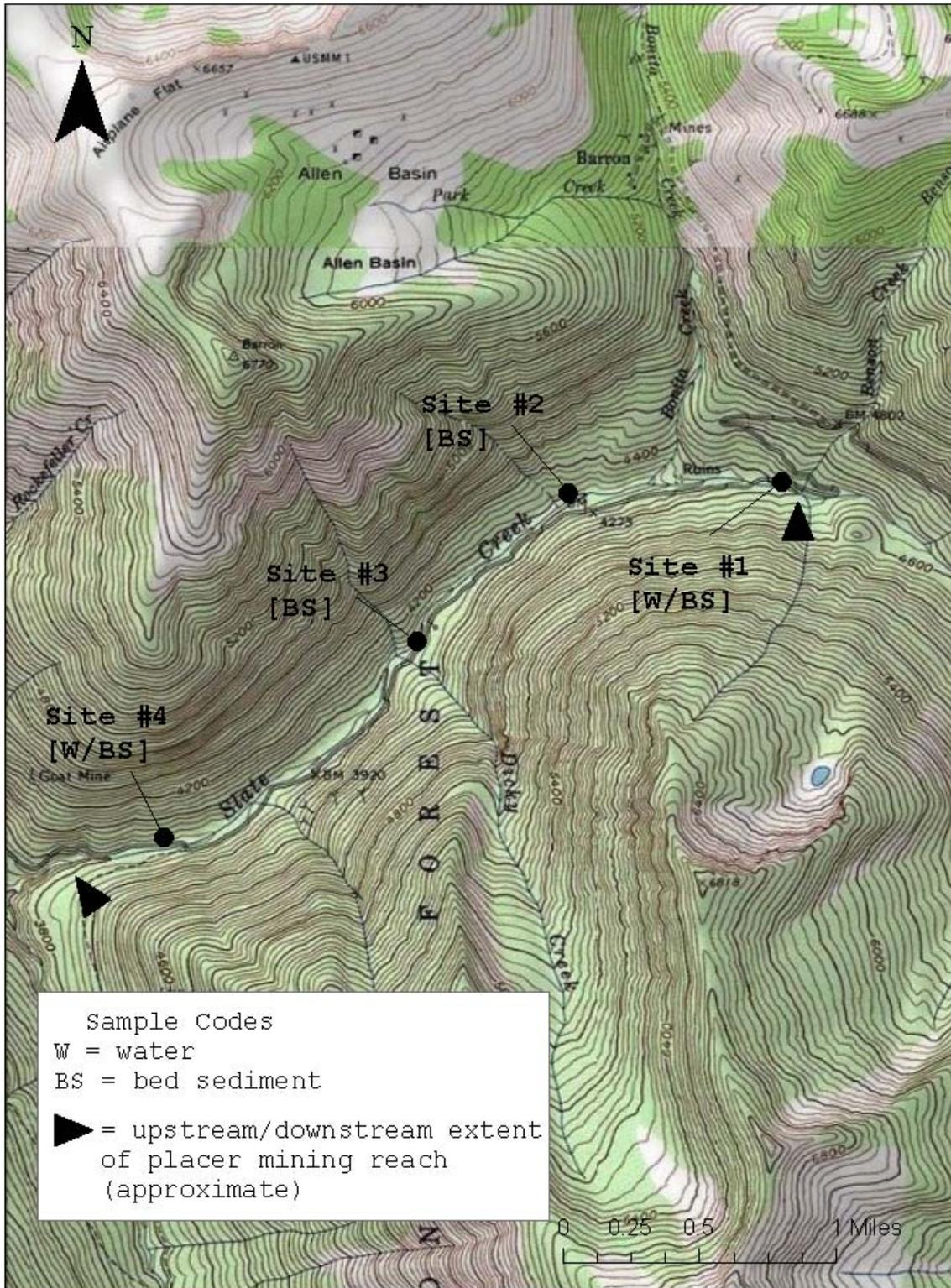


Figure 7. Types and Locations of Samples Collected in Slate Creek.  
Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

Table 12. Mercury Concentrations Measured in Water and Sediment Samples Collected from Slate Creek in 2009.

<b>1.. Water</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS (mg/L)		Flow (cfs)
#1 (upper)	0909089-01	22-Sep-09	0.002	U	1	J	--
#1 (upper) - replicate	0909089-02	"	0.002	U	1	J	--
#4 (lower)	0909089-06	30-Sep-09	0.002	U	2	U	1.7
#4 (lower) - replicate	0909089-07	"	0.002	U	1	U	--
<b>2. Bed Sediment</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, dry)		Fines (%)		
#1 (upper)	0909089-03	22-Sep-09	63	U	0.9		
#2	0909089-04	"	15		0.4		
#3	0909089-05	"	11		0.8		
#4 (lower)	0909089-08	30-Sep-09	20		4.2		
<b>3. Suspended Sediment</b>	[No Samples Collected]						
<b>4. Caddisfly (Soft Parts)</b>	[No Samples Collected]						
<b>5. Fish (Fillets)</b>	[No Samples Collected]						

U = not detected at or above reported value

J = estimated value

# Similkameen River

## Placer Description

The mining area investigated on the Similkameen River extends about 17.5 miles from the mouth near Oroville to the community of Nighthawk. Enloe Dam forms a small reservoir about 9 miles above Oroville. The river is free-flowing from the reservoir up into British Columbia.

Moen and Huntting (1975) give this description of the Similkameen River Placers: “Loc: Along the Similkameen River between Oroville and Nighthawk. Deposit: Gold found as flake gold, shot gold, and nuggets in the river bars and lower terraces. Prod: Reportedly \$500,000 in the few years following 1859. Intermittent to 1955.”

## Samples Analyzed

Figures 8a and 8b show where sampling was conducted in the Similkameen. Water samples were collected immediately above Enloe Dam, in the free-flowing reach just above the reservoir, and at Nighthawk bridge. Sediments were sampled near Enloe Dam, at the upper end of the reservoir, and at Eagle Rock, roughly midway between the reservoir and Nighthawk.

Two suspended sediment samplers were placed at the upper end of the reservoir in the spring, one of which was successfully retrieved. The deployment period was cut short to 17 days in view of extremely high and turbid flows in early May.

Fish samples were obtained through the courtesy of the Colville Confederated Tribes. Fish were caught by hook and line in Enloe Reservoir, at Nighthawk, and in the vicinity of Sinlahekin Creek (Palmer Lake outlet) above Nighthawk. Rainbow trout, mountain whitefish, smallmouth bass, and northern pikeminnow were collected. Efforts to find caddisflies in this reach of the Similkameen met with no success.

## Results

Results for the Similkameen River samples are in Table 13.

As in several of the other waterbodies investigated, mercury concentrations in the Similkameen increased with flow and were correlated with TSS ( $R^2 = 0.85$ ). Maximum concentrations of 0.0102 to 0.0113 ug/L were recorded in April, closely approaching the chronic criterion of 0.012 ug/L. High TSS levels, 119-140 mg/L, were encountered in April and May.

Most of the mercury and TSS loads appeared to originate above Nighthawk. Upstream mines in Washington and, more especially, British Columbia are known sources of metals loading to the upper Similkameen River (Johnson, 2002).

The elevated mercury levels seen in the water column were not reflected in the sediment samples. Bed sediments had low mercury concentrations of <6 to 13 ug/Kg. The suspended sediment sample was slightly higher at 37 ug/Kg.

A wide range of mercury concentrations were measured in fillets from the five fish species analyzed. The highest concentrations were in smallmouth bass and the larger size class of northern pikeminnow, 149 and 379 ug/Kg, respectively. These upper trophic level predatory species are known accumulators of mercury. Similar levels can be found in predatory fish from other Washington waterbodies that have no anthropogenic mercury sources (Furl et al., 2009). Lower concentrations were seen in small northern pikeminnow (96 ug/Kg) demonstrating an age/size effect. The lowest concentrations were found in rainbow trout and mountain whitefish, 54 and 67 ug/Kg, respectively, which feed at a lower trophic level.

Northern pikeminnow exceeded the 300 ug/Kg methylmercury criterion recommended by EPA. This species is generally not considered to be a food fish.

## Other Mercury Data

Several Ecology datasets provide evidence of a modest increase in mercury concentrations through the placer mining reach of the Similkameen River:

- Ecology's River and Stream Water Quality Monitoring network has mercury data for the Similkameen River @ Oroville from 1996 to 2008 ([www.ecy.wa.gov/programs/eap/fw\\_riv/rv\\_main.html#4](http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html#4)). Out of the 27 water samples analyzed, 26 were in the range 0.001 – 0.004 ug/L. An elevated concentration of 0.010 ug/L is reported for a single sample collected during a high flow event in June 2008. A sample collected at Nighthawk on the same day had a slightly lower mercury concentration of 0.007 ug/L. These results are comparable to the higher mercury concentrations encountered in the present study.
- An earlier water quality monitoring effort in 1995-96 also showed a slight downstream increase in mercury concentrations in water samples collected above and below the placer mining reach in April (Johnson, 1997). Concentrations in duplicate samples averaged 0.003 ug/L at Nighthawk vs. 0.005 ug/L at Oroville. Mercury was non-detect (<0.001 ug/L) at both locations under low-flow conditions.
- Johnson and Plotnikoff (2000) reviewed Ecology's sediment quality data for the Similkameen River. Mercury results were available for seven sediment samples collected in or above the mining reach during 1995 and 1998. Concentrations were slightly higher in the mining reach (up to 30 ug/Kg) than further upstream (<10-10 ug/Kg).

Ecology's Washington State Toxics Monitoring Program recently analyzed chemical contaminants in a fillet composite from mountain whitefish collected near the mouth of the Similkameen River in 2008 (Seiders and Deligeannis, 2009). The mercury concentration in this sample was 73 ug/Kg, which agrees closely with the whitefish analyzed for the present study.

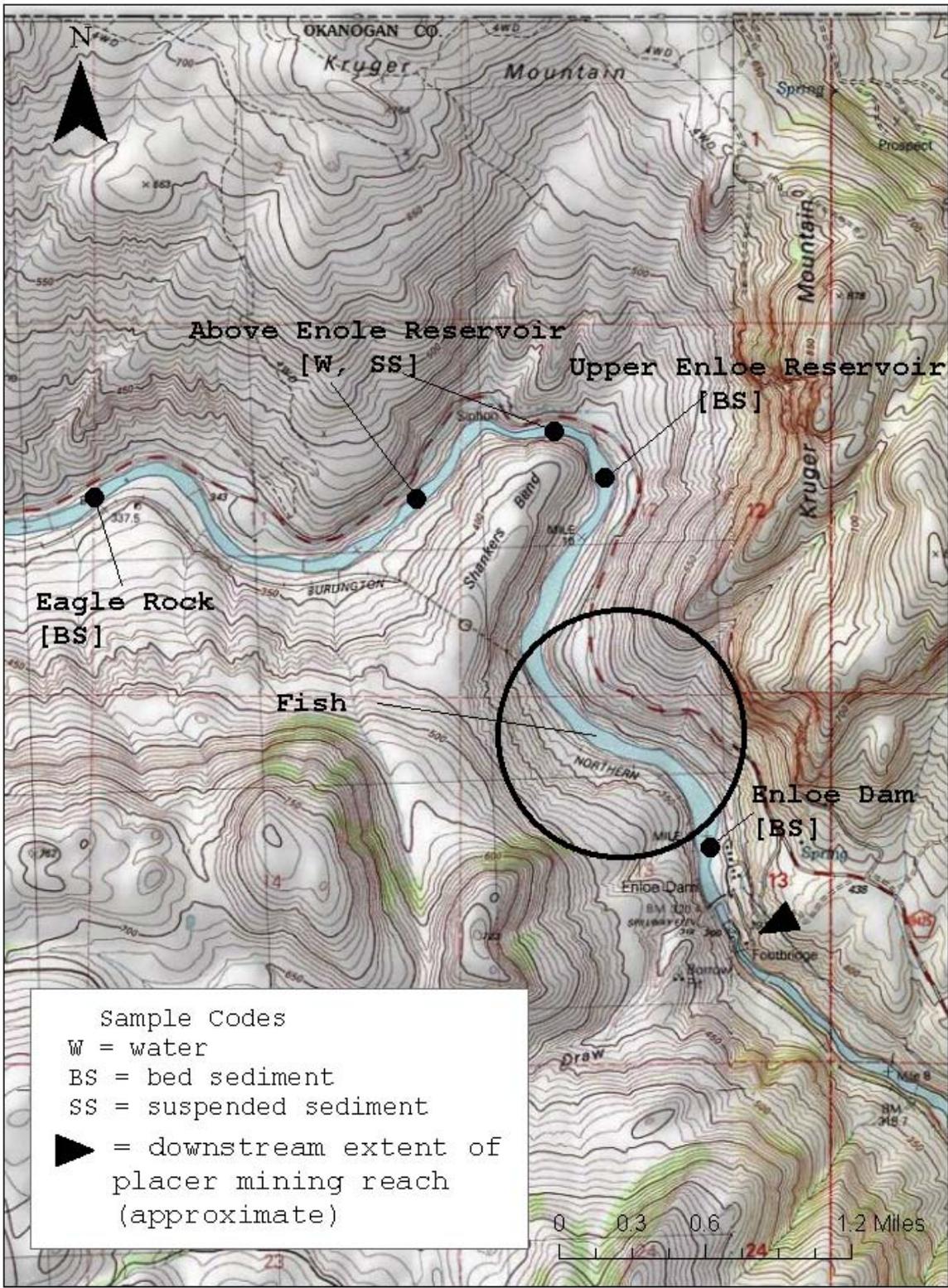


Figure 8a. Types and Locations of Samples Collected in the Lower Similkameen River.  
 Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

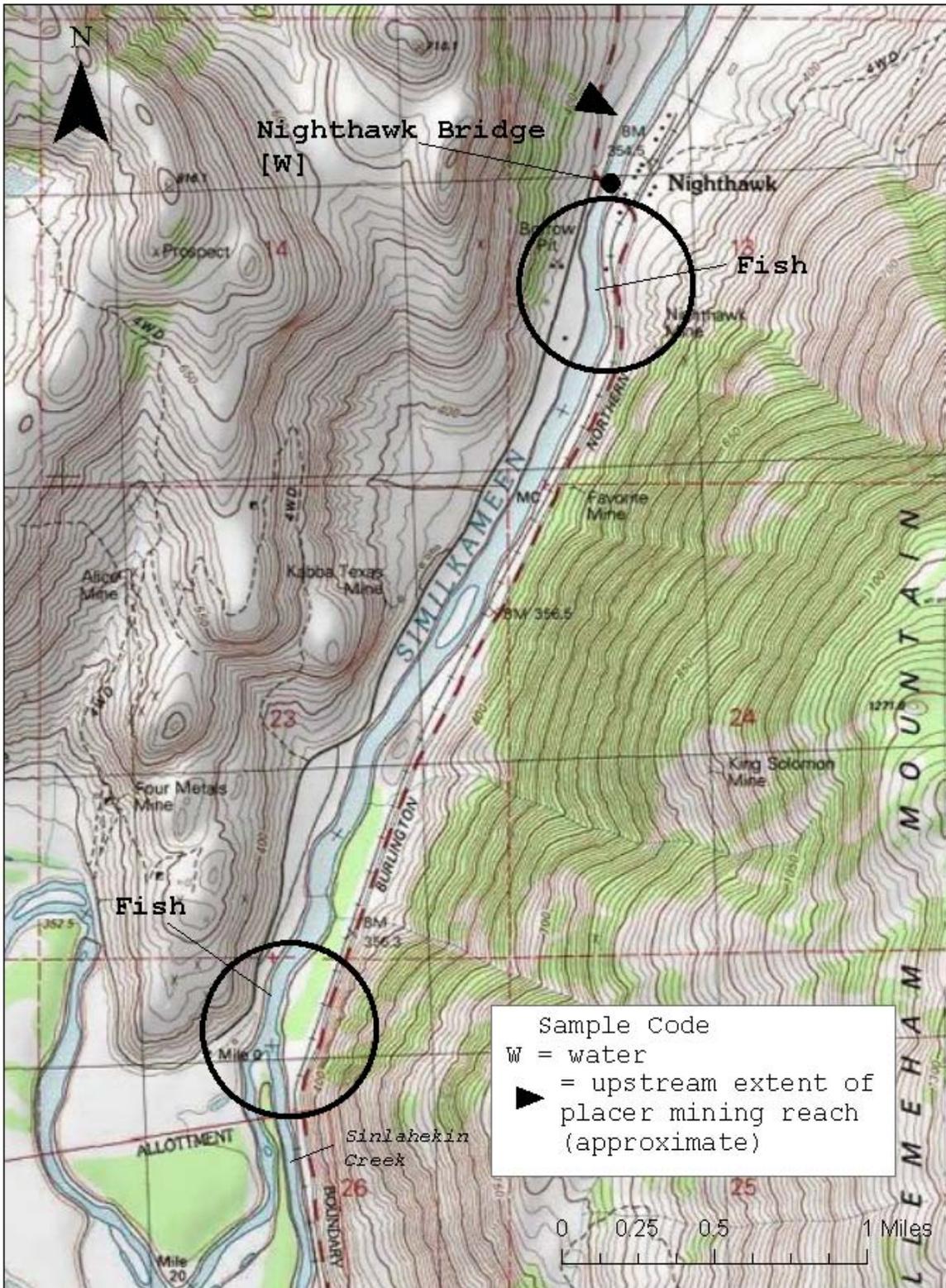


Figure 8b. Types and Locations of Samples Collected in the Upper Similkameen River. Mountain whitefish collected Sinlahekin Creek to Stateline. *Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.*

Table 13. Mercury Concentrations Measured in Water, Sediment, and Biological Samples Collected from the Similkameen River during 2009-2010.

<b>1. Water</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS (mg/L)	Flow (cfs)
Above Enloe Reservoir	0909068-03	14-Sep-09	0.002	U	2	536
Nighthawk bridge	1004065-02	21-Apr-10	0.0102		80	3,750
Above Enloe Reservoir	1004065-01	21-Apr-10	0.0113		119	--
Nighthawk bridge	1005068-02	8-May-10	0.0020		12	J 2,830
Above Enloe Reservoir	1005068-03	8-May-10	0.0020		9	--
Nighthawk bridge	1005083-08	20-May-10	0.0080		140	J 10,800
Above Enloe Reservoir	1005083-09	20-May-10	0.0085		106	J --
<b>2. Bed Sediment</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, dry)		Fines (%)	
At Enloe Dam	0909068-01	14-Sep-09	16	J	17	
Above Enloe Reservoir	0909068-02	14-Sep-09	6	U	1.8	
Eagle Rock	0909068-05	14-Sep-09	13		14	
<b>3. Suspended Sediment</b>						
Sample Site	Sample No.	Collection Dates	Mercury (ug/Kg, dry)			
Upper Enloe Reservoir	1006085-02	21-Apr-10 to 8-May-10	37			
<b>4. Caddisfly (Soft Parts)</b>	[No Samples Collected]					
<b>5. Fish (Filletts)</b>						
Sample Site/Species	Sample No.	Collection Date	Mercury (ug/Kg, wet)			
Enloe Reservoir Pikeminnow (small)	0910051-5	11-Sep-09	96			
Pikeminnow (large)	0910051-8	11-Sep-09	379			
Nighthawk Smallmouth bass	0910051-7	11-Sep-09	149			
Sinlahekin confluence Rainbow trout	0910051-4	11-Sep-09	54			
Stateline - Sinlahekin Mountain whitefish	0910051-6	11-Sep-09	67			

U = not detected at or above reported value

J = estimated value

## Mary Ann Creek

### Placer Description

Mary Ann Creek is an intermittent stream. The placer is described in Moen and Huntting (1975) as follows:

“Loc: Secs. 13 and 24, (40-29E) on Mary Ann Creek. Deposit: Gold occurs from grass roots downward to bedrock. 7-inch clay seam 4 feet above bedrock acts as false bedrock, and values are richer above the clay than elsewhere. Prod. \$40,000 in the 1880s.

### Samples Analyzed

Mary Ann Creek was sampled at its mouth and approximately 2 miles above the mouth, near the downstream end of the placer deposits. It was dry when first visited in September to collect low-flow samples. There was a small discharge during April and May, at which time two water samples and one sediment sample were obtained (Figure 9).

### Results

Results for the Mary Ann Creek samples are summarized in Table 14. Mercury concentrations were uniformly low in the few water and sediment samples analyzed.

### Other Mercury Data

No other mercury data could be located for Mary Ann Creek.

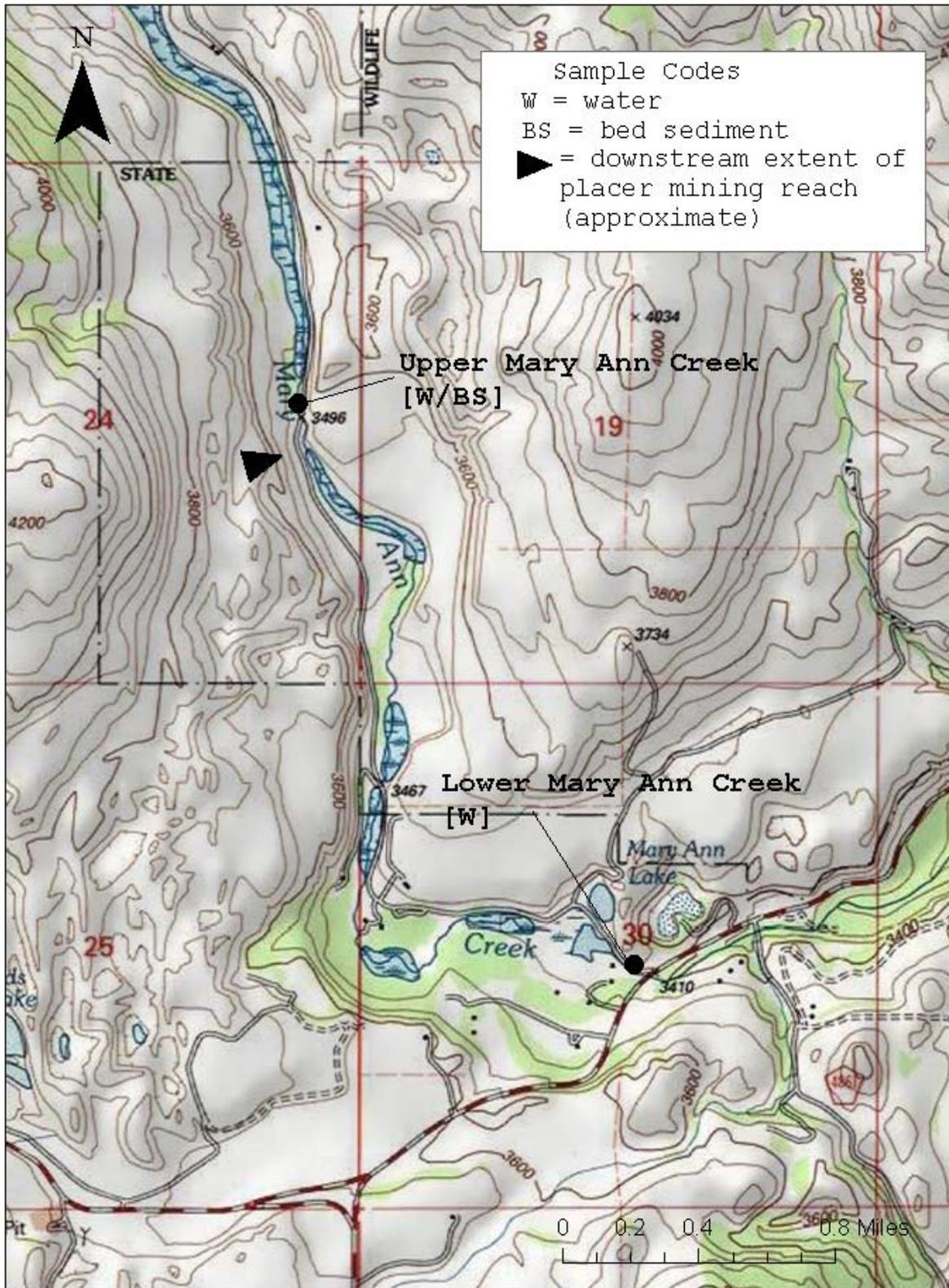


Figure 9. Types and Locations of Samples Collected in Mary Ann Creek.  
 Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

Table 14. Mercury Concentrations Measured in Water and Sediment Samples Collected from Mary Ann Creek during 2009-2010.

<b>1. Water</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS (mg/L)		Flow (cfs)
~1 mi. ab. Oroville-Toroda Rd.	- -	14-Sep-09	[dry]				
Oroville-Toroda Road	1004065-05	21-Apr-10	0.002	U	NA		trickle
~1 mi. ab. Oroville-Toroda Rd.	1005068-01	8-May-10	0.002	U	1	U	0.82
~1 mi. ab. Oroville-Toroda Rd.	1005083-10	20-May-10	0.0021		1		1.0
<b>2. Bed Sediment</b>							
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, dry)		Fines (%)		
~1 mi. ab. Oroville-Toroda Rd.	1005068-05	8-May-10	32		43		
<b>3. Suspended Sediment</b>	[No Samples Collected]						
<b>4. Caddisfly (Soft Parts)</b>	[No Samples Collected]						
<b>5. Fish (Fillets)</b>	[No Samples Collected]						

U = not detected at or above reported value

NA = not analyzed

## Strawberry Creek

### Placer Description

The mining area on Strawberry Creek extends about one mile upstream from the mouth.

Moen and Huntting (1975) describe the placer as follows: “Loc. On Strawberry Creek in S1/2 sec. 35, (34-31E). Ore min: Gold, magnetite, ilmenite. Deposit: Flats from 20 to 200 feet wide along the stream are underlain by a shallow layer of coarse gravel. Dev: Small pits. Assays: 2 pans of gravel from the layer next to bedrock yielded 1 cent in Au and 1 oz. of more of black sand. Prod: Reportedly \$100 worth of gold at \$20 gold.”

### Samples Analyzed

Sampling on Strawberry Creek was restricted to the mouth due to difficult access further upstream. Water and sediment samples were obtained during September low flow (Figure 10). Two additional water samples were collected in the spring (April and May). A suspended sediment sampler was deployed in April, but, of necessity, was located in a high velocity environment and was full of gravel when retrieved and therefore not analyzed.

Rainbow trout and brook trout samples were obtained by biologists with the Colville Confederated Tribes. They were collected at the mouth of the creek in September. Due to their relatively small size, these fish were analyzed whole. Caddisflies were not observed at this site.

### Results

Mercury concentrations in the water samples ranged from <0.002 to 0.0059 ug/L, with the higher levels detected in the spring. Mercury was not detected in the sediment sample (<5.9 ug/Kg) and concentrations in the fish samples were low (37-64 ug/Kg). No water, sediment, or tissue criteria were exceeded.

### Other Mercury Data

No other mercury data could be located for Strawberry Creek.

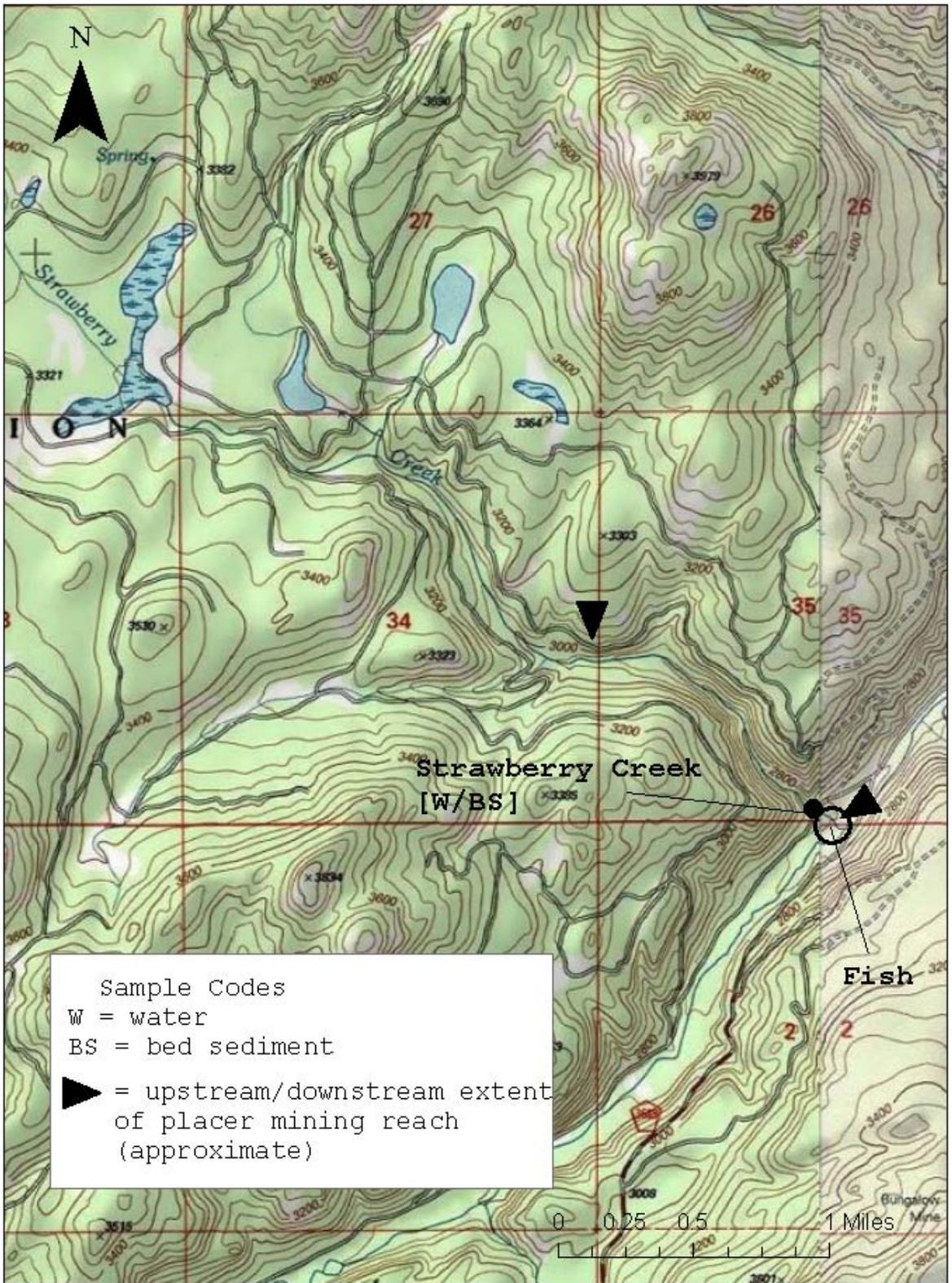


Figure 10. Types and Locations of Samples Collected in Strawberry Creek.  
Base map credit: ESRI ArcGIS Online and data partners including USGS and © 2007 National Geographic Society.

Table 15. Mercury Concentrations Measured in Water, Sediment, and Biological Samples Collected from Strawberry Creek during 2009-2010.

<b>1. Water</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/L)		TSS (mg/L)	Flow (cfs)
Mouth	0909068-11	15-Sep-09	0.002	U	2	U 0.5 est.
Mouth	1004065-03	22-Apr-10	0.0059		7	8.48
Mouth	1005068-04	9-May-10	0.0033		1	U 16
Mouth	1005083-11	21-May-10	0.0032		1	7.14
<b>2. Bed Sediment</b>						
Sample Site	Sample No.	Collection Date	Mercury (ug/Kg, dry)		Fines (%)	
Mouth	0909068-12	15-Sep-09	5.9	U	2.7	
<b>3. Suspended Sediment</b>	[No Samples Collected]					
<b>4. Caddisfly (Soft Parts)</b>	[No Samples Collected]					
<b>5. Fish (Whole Body)</b>						
Sample Site/Species	Sample No.	Collection Date	Mercury (ug/Kg, wet)			
Near Mouth Rainbow trout	0910051-2	2-Sep-09	37			
Brook trout	0910051-3	"	64			

U = not detected at or above reported value

## Comparison of Mining Areas

The data obtained on mercury in water, bed sediments, and caddisflies allow some comparisons to be made among mining areas. Spatial coverage of the fish and suspended sediment samples was too limited to compare across sites.

Figure 11 shows the mercury concentrations in water samples collected from mining reaches during runoff periods. Data from the most downstream site in each waterbody were used. Low-flow data were excluded because samples were few and concentrations uniformly low. As shown in the figure, the highest mercury concentrations tended to occur in the Similkameen River, Sultan River, Strawberry Creek, and Williams Creek, in descending order.

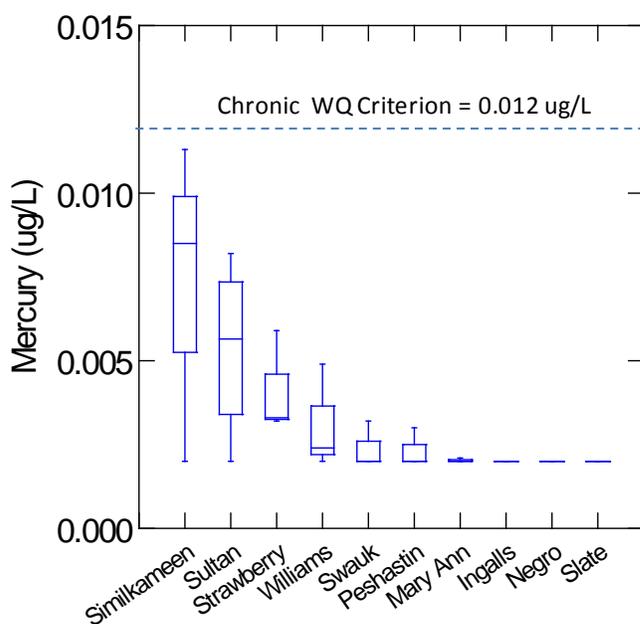


Figure 11<sup>4</sup>. Comparison of Mercury Concentrations in Water Samples. (*non-detects plotted at the reporting limit*)

The bed sediment data are plotted in Figure 12. One Slate Creek sample was not included due to a high reporting limit (63 ug/Kg vs. 5 ug/Kg). The Sultan River and Williams Creek again show some of the highest levels. Swauk Creek ranks higher in this comparison than it did for water samples.

Similkameen River and Strawberry Creek had low mercury concentrations in sediment compared to water. As previously noted, results from water sampling suggest the major source of mercury to the Similkameen River lies upstream of the placer mining reach. The low mercury concentration in Strawberry Creek sediments may be a function of the coarse grain size of the sample analyzed.

<sup>4</sup> In these plots, the box includes 50% of the values, with the median shown as a horizontal line. The “whiskers” extend to the maximum and minimum values.

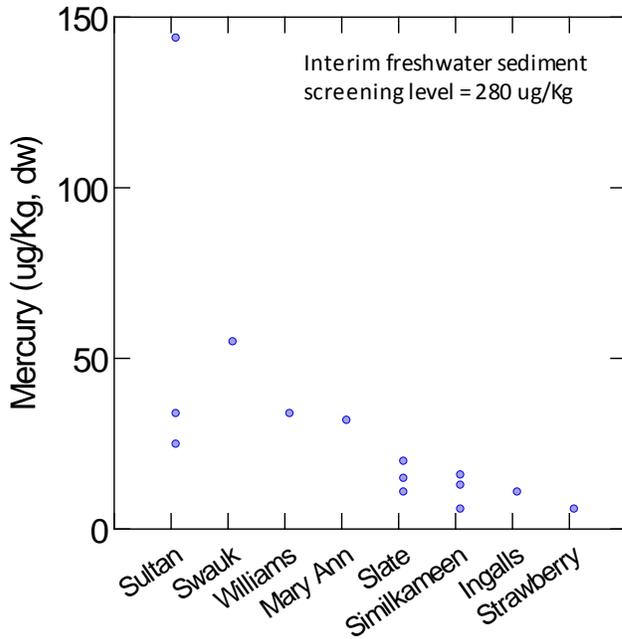


Figure 12. Mercury Concentrations in Bed Sediment Samples.

Only a single sediment sample was obtained for some of these areas. There is the potential, therefore, that the results are not representative. Supporting information is provided by the caddisflies collected in the vicinity of five of the sediment sampling sites. As shown in Figure 13, there was close agreement between the caddisfly and sediment samples as to the relative levels of mercury at these locations.

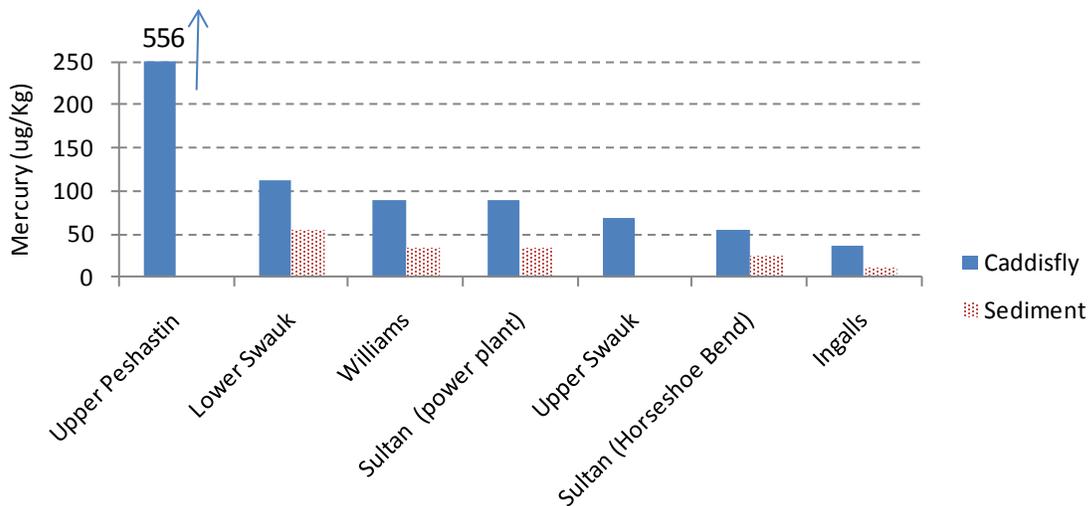


Figure 13. Mercury Concentrations in Caddisfly Samples Compared to Bed Sediments Collected in Same Vicinity.

*Sediment not collected at Upper Peshastin Creek and upper Swauk Creek.*

## Statewide Perspective

This study did not find frequent exceedances of water quality criteria or other environmental benchmarks for mercury. Elevated concentrations were, however, observed in some instances. This raises questions about what mercury levels are typically encountered in other Washington rivers and streams.

Hallock (2010) reviewed the 1994 – 2009 metals data from Ecology’s River and Stream Water Quality Monitoring network. Hallock notes that, of the 95 stations where metals were analyzed, “Few, if any, were selected for monitoring because of suspected metals contamination.”

Mercury levels tend to be higher in western Washington rivers and streams, with only one of the highest dozen concentrations being from eastern Washington (Walla Walla River, February 1997, 0.038 ug/L). The highest mercury result recorded was 0.098 ug/L from the Nisqually River (February 1999). High mercury concentrations tended to be patchy, with no station exhibiting chronically high levels. Only 14 out of the 845 water samples analyzed (1.7%) exceeded the chronic water quality criterion (0.012 ug/L), with just four results more than double the criterion.

The mercury data for western and eastern Washington are plotted separately in Figure 14, with an overlay of the mining reach data. The distribution of these values suggests that the higher mercury concentrations recorded for reaches where mining has occurred are, in fact, elevated over what is typically seen in eastern Washington, but not particularly elevated compared to western Washington.

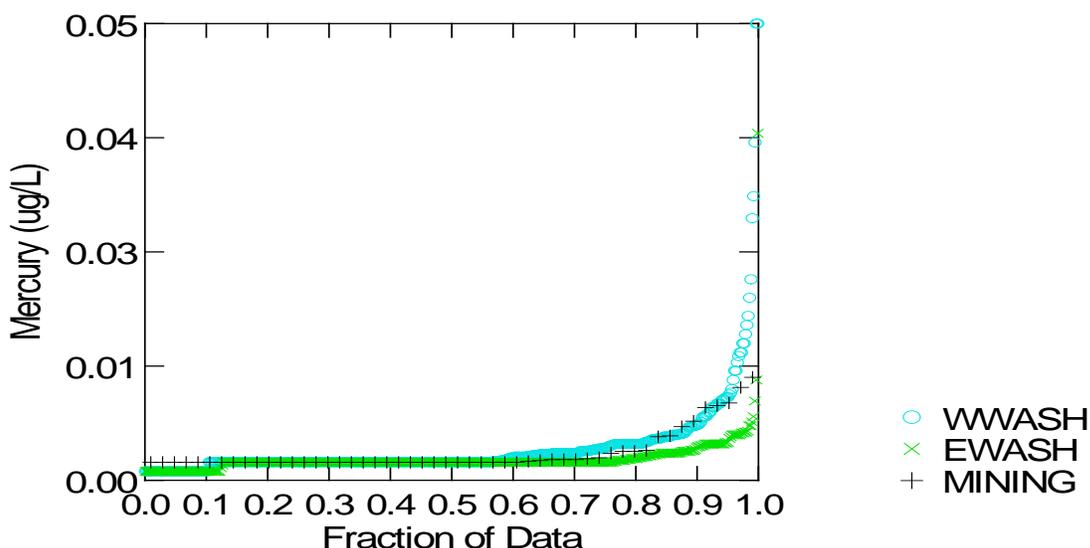


Figure 14. Mercury Concentrations in Water Samples from Washington Rivers and Streams: Statewide Results Compared to Mining Reaches.

*Maximum value for western Washington (0.098 ug/L) not plotted for reason of scale.*

A statewide soils study provides a similar perspective on the sediment samples. San Juan (1994) reports metals data for “natural background” soils collected throughout Washington. The state was divided into 24 distinct regions based on geology, soils, and climate. Twelve of the regions and four urban areas (Puget Sound, Clark County, Yakima, and the Spokane Basin) were then selected for soil sampling. Mercury and other metals exhibited higher concentration in Western Washington soils, on average, which is consistent with the water quality monitoring data, previously discussed.

Table 16 has a statistical summary of the mercury data on background soils and mining reach sediments. In terms of the 90th percentile, median, and minimum, sediments from mining areas are intermediate between soils in eastern and western Washington. This conclusion mirrors results from comparing the water quality data.

Table 16. Mercury Concentrations in Background Soils and Mining Reach Sediments. (ug/Kg, dry)

	Background Soils*		Mining Reach Sediments†
	Western WA	Eastern WA	
90 <sup>th</sup> percentile	80	40	60
Median	36	14	20
Minimum	9	4	6
Maximum	185	312	144
N=	86	80	15

\*San Juan (1994)

†Present study

San Juan concluded that population, geology, climate, and vegetation of Western Washington were the primary reasons for the east-west variation in metals concentrations.

# Summary and Conclusions

Indicators for mercury contamination were analyzed from seven Washington rivers and creeks with a history of mining for placer gold. Sample types included water, suspended sediment, streambed sediments, benthic invertebrates (caddisflies), and fish (fillets). Low-level analytical methods were used for mercury.

The waterbodies investigated were:

- In western Washington: the Sultan River.
- In eastern Washington: Swauk Creek and tributary Williams Creek, Peshastin Creek and tributaries Ingalls Creek and Negro Creek, Slate Creek, the Similkameen River, Mary Ann Creek, and Strawberry Creek.

Noteworthy findings are as follows:

- Although mercury was moderately elevated in some types of samples, the levels overall do not appear to represent a significant concern for aquatic life, wildlife, or human health, based on comparison with water quality criteria and other environmental benchmarks and standards
- Most waterbodies exhibited a substantial increase in mercury levels in water during runoff periods in the winter or spring. Mercury was consistently at or below reporting limits during low flow.
- Mercury concentrations increased with the amount of total suspended solids in the water column and with percent fines in the bed sediments.
- Hazardous accumulations of mercury were not observed in benthic invertebrates or edible fish tissue.
- The Sultan River, Swauk Creek, and Williams Creek had some of the highest mercury concentrations across several types of samples.
- Williams Creek appeared to be a mercury source to Swauk Creek.
- The predominant source of mercury to the Similkameen River lies upstream of the placer mining reach (Oroville to Nighthawk). Mining operations, particularly in British Columbia, are suspected.
- A very high mercury concentration was measured in caddisflies from upper Peshastin Creek. No corroborating data were obtained.
- A comparison with statewide water and soils data suggests that reaches where mining has occurred have elevated mercury levels compared to other rivers and streams in eastern Washington, but are not particularly elevated compared to western Washington.

# Recommendations

## Sampling Design

For purposes of identifying mercury contamination from historic gold mining operations on Washington rivers and streams, water and suspended sediment collected during periods of increasing discharge are useful samples to collect. Drawbacks to targeting bed sediments and fish include a paucity of fine sedimentary material in many free-flowing waterbodies, and movements of fish in and out of study areas. Sufficient numbers of representative samples can be hard to collect in both cases.

Caddisflies, although not available from all habitats, proved to be good mercury indicators, with consistently higher concentrations than nearby bed sediments. The suspended sediment trap design employed here was simple, effective in low-to-moderate velocity environments, and provided a time-integrated sample over periods of weeks to more than a month.

## Follow-up Sampling

Additional sampling should be conducted to confirm the existence of mercury contamination in upper Peshastin Creek.

A focused study is recommended to better characterize excursions of mercury and other mining-related metals during the spring freshet in the Similkameen River.

Although the Sultan River, Swauk Creek, and Williams Creek had some elevated mercury concentrations, the concentrations did not reach levels of concern. Past studies on Swauk and Williams Creek had similar findings. Follow-up investigation into mercury contamination therefore appears to be a low priority for these areas.

## References

- Alpers, C.N., M.P. Hunerlach, J.T. May, R.L. Hothem, H.E. Taylor, R.C. Antweiler, J.F. De Wild, and D.A. Lawler, D.A. 2005. Geochemical Characterization of Water, Sediment, and Biota Affected by Mercury Contamination and Acidic Drainage from Historical Gold Mining, Greenhorn Creek, Nevada County, California, 1999-2001: U.S. Geological Survey Scientific Investigations Report 2004-5251.
- Blakley, N. 2008. Standard Operating Procedure for Obtaining Freshwater Sediment Samples Version 1.0. EAP 040. Washington State Department of Ecology, Olympia, WA.  
[www.ecy.wa.gov/programs/eap/quality.html](http://www.ecy.wa.gov/programs/eap/quality.html)
- Chasar, L.C., B.C. Scudder, A. Robine Stewart, A.H. Bell, and G.R. Aiken. 2009. Mercury Cycling in Stream Ecosystems. 3. Trophic Dynamics and Methylmercury Bioaccumulation. *Environ. Sci. Technol.* 43(8):2733-39.
- Churchill, R.K. 2000. Contributions of mercury to California's environment from mercury and gold mining activities; Insights from the historical record, *in* Extended abstracts for the U.S. EPA sponsored meeting, Assessing and Managing Mercury from Historic and Current Mining Activities, November 28-30, 2000, San Francisco, Calif., p. 33-36 and S35-S48.
- Cope, W.G., J.G. Wiener, and R.G. Rada. 1990. Mercury accumulation in yellow perch in Wisconsin seepage lakes: Relation to lake characteristics. *Environmental Toxicology and Chemistry* 9:931-940.
- Eisler, R. 1987. Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service, Contaminant Hazard Reviews, Report No. 10. Patuxent Wildlife Research Center, Laurel, MD.
- EPA. 1997. Mercury Study Report to Congress, Volume VII: Characterization of Human Health and Wildlife Risks from Mercury Exposure in the United States. U.S. Environmental Protection Agency, Office of Air Quality Planning & Standards and Office of Research and Development. EPA-452/R-97-009.
- EPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Vol. 1. U.S. Environmental Protection Agency. EPA-823-B-00-007.
- EPA. 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C. EPA-823-R-01-001.
- Furl, C., C. Meredith, and M. Friese. 2009. Measuring Mercury Trends in Freshwater Fish in Washington State: 2008 Sampling Results. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-045. [www.ecy.wa.gov/biblio/0903045.html](http://www.ecy.wa.gov/biblio/0903045.html)
- Hallock, D. 2010. River and Stream Water Quality Monitoring Report: Water Year 2009. Washington State Department of Ecology, Olympia, WA. Publication No. 10-03-046.  
[www.ecy.wa.gov/biblio/1003046.html](http://www.ecy.wa.gov/biblio/1003046.html)

- Johnson, A. 1997. Survey of Metals Concentrations in the Similkameen River. Memorandum to Jim Milton. Washington State Department of Ecology, Olympia, WA. Publication No. 97-e10. [www.ecy.wa.gov/biblio/97e10.html](http://www.ecy.wa.gov/biblio/97e10.html)
- Johnson, A. 2000. Concentrations of 303(d) Listed Metals in the Upper Yakima River Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-024. [www.ecy.wa.gov/biblio/0003024.html](http://www.ecy.wa.gov/biblio/0003024.html)
- Johnson, A. and R. Plotnikoff. 2000. Review of Sediment Quality Data for the Similkameen River. Washington State Department of Ecology, Olympia, WA. Publication No 00-03-027. [www.ecy.wa.gov/biblio/0003027.html](http://www.ecy.wa.gov/biblio/0003027.html)
- Johnson, A. 2002. A Total Maximum Daily Load Evaluation for Arsenic in the Similkameen River. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-044. [www.ecy.wa.gov/biblio/0203044.html](http://www.ecy.wa.gov/biblio/0203044.html)
- Johnson, A. 2009. Quality Assurance Project Plan: Potential Impacts from Mercury Used in Historic Gold Mining on Six Rivers and Streams. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-123. [www.ecy.wa.gov/biblio/0903123.html](http://www.ecy.wa.gov/biblio/0903123.html)
- Klasing, S. and R. Brodberg. 2003. Evaluation of Potential Health Effects of Eating Fish from Selected Waterbodies in the Northern Sierra Nevada Foothills (Nevada, Placer, and Yuba Counties): Guidelines for Sport Fish Consumption. California Office of Environmental Health Hazard Assessment.
- Lazorchak, J. M., F.H. McCormick, T.R. Henry, and A.T. Herlihy. 2003. Contamination of fish in streams of the Mid-Atlantic Region: an approach to regional indicator selection and wildlife assessment. *Environmental Toxicology and Chemistry* 22: 545-553.
- May, J.T., R.L. Hothem, C.N. Alpers, and M.A. Law. 2000. Mercury Bioaccumulation in Fish in a Region Affected by Historic Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999. U.S. Geological Survey Open-File Report 00-367.
- Moen, W.S. and M.T. Huntting. 1975. Handbook for Gold Prospectors in Washington. Washington Department of Natural Resources, Division of Geology and Earth Resources. Information Circular 57.
- PSEP (Puget Sound Estuary Program). 1986. Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound. Prepared for U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA and Puget Sound Water Quality Authority, Olympia, WA by Tetra Tech, Inc., Bellevue, WA, 43 pp.
- Raforth, R., A. Johnson, and D. Norman. 2000. Screening Level Investigation of Water and Sediment Quality of Creeks in Ten Eastern Washington Mining Districts, with Emphasis on Metals. Washington State Department of Ecology and Washington State Department of Natural Resources. Ecology Publication No. 00-03-004. [www.ecy.wa.gov/biblio/0003004.html](http://www.ecy.wa.gov/biblio/0003004.html)

Raforth, R., D. Norman, and A. Johnson. 2002. Second Screening Investigation of Water and Sediment Quality of Creeks in Ten Washington Mining Districts, with Emphasis on Metals. Washington State Department of Ecology and Washington State Department of Natural Resources. Ecology Publication No. 02-03-024. [www.ecy.wa.gov/biblio/0203024.html](http://www.ecy.wa.gov/biblio/0203024.html)

Raforth, R., D. Norman, and A. Johnson. 2004. Third Screening Investigation of Water and Sediment Quality of Creeks in Ten Washington Mining Districts, with Emphasis on Metals. Washington State Department of Ecology and Washington State Department of Natural Resources. Ecology Publication No. 04-03-005. [www.ecy.wa.gov/biblio/0403005.html](http://www.ecy.wa.gov/biblio/0403005.html)

Sandvik, P. 2006. Standard Operating Procedures for Resecting Finfish Whole Body, Body Parts or Tissue Samples. Version 1.0. EAP007. Washington State Department of Ecology, Olympia, WA. [www.ecy.wa.gov/programs/eap/quality.html](http://www.ecy.wa.gov/programs/eap/quality.html)

San Juan, C. 1994. Natural Background Soil Metals Concentrations in Washington State. Washington State Department of Ecology, Olympia, WA. Publication No. 94-115. [www.ecy.wa.gov/biblio/94115.html](http://www.ecy.wa.gov/biblio/94115.html)

Seiders, K. and C. Deligeannis. 2009. Washington State Toxics Monitoring Program: Freshwater Fish Tissue Component, 2008. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-055. [www.ecy.wa.gov/biblio/0903055.html](http://www.ecy.wa.gov/biblio/0903055.html)

Slotton, D.G., J.E. Reuter, and C.R. Goldman. 1995. Mercury uptake patterns of biota in a seasonally anoxic northern California reservoir. *Water, Air, and Soil Pollution* 80:841–850.

Stevens, I.I. 1860. Reports of Explorations and Surveys to Ascertain the Most Practicable and Economic Route for a Railroad from the Mississippi River to the Pacific Ocean, made...in 1853-4. U.S. Pacific Railroad Explorations, V. 12, Book 1.

U.S. Army Corps of Engineers et al. 2009. Sediment Quality Evaluation Framework for the Pacific Northwest. USACE Portland District, Seattle District, Walla Walla District, and Northwestern Division. [www.nwp.usace.army.mil/environment/rset/sef/2009-Final\\_SEF.pdf](http://www.nwp.usace.army.mil/environment/rset/sef/2009-Final_SEF.pdf) [For sediment quality values Table 6-3 missing in original document see [www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=RSET](http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=DMMO&pagename=RSET)]

USGS. 2005. Fact Sheet: Mercury Contamination from Historic Gold Mining in California. USGS Fact Sheet FS-061-00.

WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington Washington State Department of Ecology, Olympia, WA. [www.ecy.wa.gov/laws-rules/ecywac.html](http://www.ecy.wa.gov/laws-rules/ecywac.html)

Wolfe, M.F., S. Schwarzbach, and R.A. Sulaiman. 1998. Effects of Mercury on Wildlife – A Comprehensive Review. *Environmental Toxicology and Chemistry* 17(2):146-160.

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# Appendices

## Appendix A. Biological Data on Fish Samples

Table A-1. Biological Data on Fish Samples.

Waterbody	Sample Site	Species	Date	Total Length (mm)	Weight (gm)	Sex
Sultan River	Jackson Power Plant	Mountain whitefish	14-Sep-09	233	135	m
				222	99	m
				230	113	m
				260	197	m
				180	64	f
Similkameen River	Sinlahekin confluence	Rainbow trout	11-Sep-09	290	256	f
				285	209	m
				258	163	f
				242	136	f
				237	146	f
	Enloe Reservoir	Pikeminnow - small		230	101	f
				254	130	m
				253	123	f
				240	106	ind
				228	82	ind
	Stateline - Sinlahekin	Mountain whitefish		462	1,061	f
				409	581	m
	Nighthawk	Smallmouth bass		311	259	f
				325	289	f
				321	289	f
Strawberry Creek	Mouth	Rainbow trout	2-Sep-09	136	28	ind
				91	9	ind
				92	8	ind
				78	7	ind
				81	5	ind
	Brook trout	144		31	ind	
		124		19	ind	
		121		19	ind	
		109		11	ind	
		91		7	ind	

ind = indeterminate

## Appendix B. Description of Sampling Sites

Table B-1. Location of Samples for Mercury Investigation of Gold Mining Reaches, 2009-2010 (NAD 83).

Waterbody	Sample Site Name	Site Description	Latitude	Longitude
Sultan River	Horseshoe Bend #1	Downstream end of pool at trail leading to access road	47.922	121.803
	Horseshoe Bend #2	Pool above trail leading to access road	47.923	121.803
	Jackson Power Plant	Immediately upstream of low concrete dam above power plant	47.909	121.814
	Jackson Power Plan (fish)	Pool downstream of low concrete dam	47.908	121.816
Swauk Creek	Above Williams Creek	Baker Creek campground*	47.382	120.696
	Below Williams Creek	About one mile below Williams Creek confluence, opposite gravel pit	47.230	120.697
Williams Creek	At mouth	Upstream side of Highway 97	47.244	120.697
Peshastin Creek	Upper	Unimproved campground about one mile above Negro Creek	47.431	120.657
	Lower	About 1/3 mile below Ingalls Creek	47.467	120.659
Negro Creek	At mouth	At mouth	47.444	120.662
Ingalls Creek	At mouth	At mouth	47.469	120.658
Slate Creek	#1	About 500 feet below Benson Creek	48.742	120.710
	#2	About 3/4 miles below Benson Creek	48.741	120.722
	#3	About 1 1/2 mile below Benson Creek	48.736	120.729
	#4		48.729	120.743
Similkameen	At Enloe Dam	Just upstream of warning cable	48.967	119.502
	Enloe Reservoir (fish)	Reservoir	48.972	119.510
	Upper Enloe Reservoir	Lower end of Shankers Bend	48.983	119.508
	Above Enloe Reservoir	Just upstream of Shankers Bend	48.983	119.518
	Eagle Rock	River mile 11.7	48.981	119.539
	Nighthawk	River mile 17.7	48.967	119.642
	Sinlahekin confluence (fish)	Near confluence with Sinlahekin Creek	48.94	119.658
	Sinlahekin - Stateline (fish)	Between Sinlahekin confluence and international border	48.962	119.702
Mary Ann Creek	Near mouth	Just above Oroville-Toroda Road	48.936	119.087
	~ 2 miles above mouth	Where creek flows under road	48.952	119.101
Strawberry Creek	At mouth	Immediately downstream of culvert	48.397	118.876
	Near mouth (fish)	Vicinity of Strawberry/Gold Creek confluence	48.396	119.702

\*Caddisfly sample was a composite from Baker Creek campground and three miles below campground.

## Appendix C. Acronyms, Abbreviations, and Units of Measurement

### Acronyms and Abbreviations

CFR	Code of Federal Regulations
DNR	Washington Department of Natural Resources
EA	Environmental Assessment (Ecology)
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
HWTR	Hazardous Waste and Toxics Reduction Program (Ecology)
MEL	Manchester Environmental Laboratory (Ecology)
NAD	North American Datum
NTR	National Toxics Rule
OSWER	Official Solid Waste and Emergency Response (EPA)
RM	River mile
RPD	Relative percent difference
SOP	Standard operating procedures
TSS	Total suspended solids
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

### Units of Measurement

cfs	cubic feet per second
dw	dry weight
ug/Kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
ww	wet weight