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Effects of Small-Scale Gold Dredging on Arsenic, Copper, Lead, and Zinc Concentrations in the Similkameen River

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Effects of Small-Scale Gold Dredging on Arsenic, Copper, Lead, and Zinc Concentrations in the Similkameen River

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Table of Contents

List of Appendices

List of Figures

List of Tables

Abstract

A field study was conducted to determine if small-scale gold dredges operating in the Similkameen River exacerbate current exceedances of the human health criteria for arsenic or result in violations of aquatic life criteria for arsenic, copper, lead, or zinc. Dredge effluents were analyzed from 14 sites on the river, and discharge plumes were sampled below three dredges. Data were also obtained on ambient metals concentrations, total suspended solids, and turbidity.

Results showed that the metals concentrations discharged from small-scale gold dredges are not a significant toxicity concern for aquatic life in the Similkameen River. Although this activity will exacerbate exceedances of arsenic human health criteria, it would take very large numbers of dredges to effect a 10% change in the river's arsenic levels, even at low-flow conditions.

Acknowledgements

The authors of this report thank the many miners who gave permission to sample the effluent from their gold dredges. We very much appreciate the cooperation and friendly reception Ecology personnel received at the 2004 Gold Dredge Rally in Oroville. Special thanks to Jim Creegan for his efforts to help us obtain samples and to Mark Erickson and Greg Christensen of the Resources Coalition for their support and cooperation in the sampling effort at the rally.

The authors also would like to acknowledge the good work of staff at the Ecology Manchester Environmental Laboratory in analyzing the samples for this project, especially Dean Momohara, Meredith Jones, Aileen Richmond, Sara Sekerak, Jamie Martin, and Sally Cull.

Samples for this study were collected with the assistance of Chris Coffin, Ray Latham, and Terry Wittmeier of the Ecology Central Regional Office.

Introduction

The Similkameen River is located in north-central Washington (Figure 1). During the public comment period on the *Lower Similkameen River Arsenic Total Maximum Daily Load* submittal report (Peterschmidt and Edmond, 2004), concerns were raised by the community and the Colville Confederated Tribes regarding the potential impact of small-scale gold dredging on arsenic concentrations in the river. An earlier laboratory simulation conducted by the Washington State Department of Ecology (Ecology) had concluded that arsenic and other metals would be rapidly diluted downstream of a dredge (Johnson, 1999). The applicability of these data to field conditions was called into question.

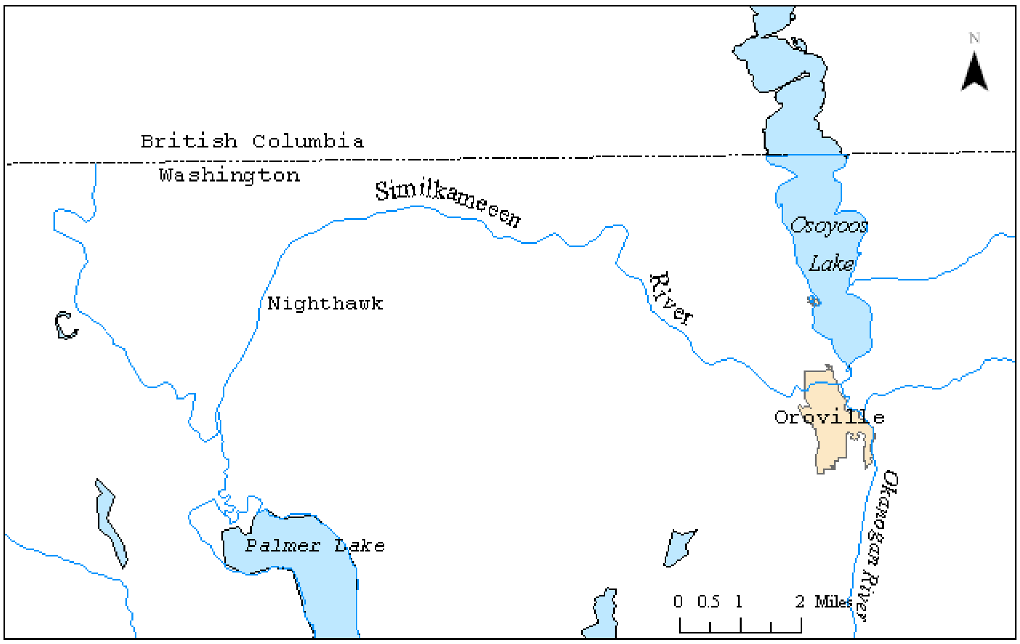


Figure 1. The Similkameen River

Dredging activities have been traditionally allowed on the Similkameen under mineral prospecting leases from the Washington State Department of Natural Resources (DNR). It is difficult to quantify the actual amount of dredging that occurs. The Ecology Central Regional Office (CRO) has observed up to 20 dredges on the river, although only some are in operation at any one time.

The dredging season is limited to July 1 through September 30, to protect salmon spawning. There are no restrictions on where dredging can be done along the length of the river. Dredging operations and high banking are limited to the wetted perimeter of the stream, or, with appropriate water rights, to within 200 feet inland of the ordinary high water mark.

The Washington Department of Fish and Wildlife (WDFW) is the lead agency regulating small-scale mining and prospecting. Their *Gold and Fish* pamphlet constitutes the Hydraulic Project

Approval (HPA) permit that small-scale prospectors and miners must comply with when conducting activities covered in the pamphlet. Exceptions to the pamphlet, authorization for other mining and prospecting activities, or use of other equipment types than authorized in *Gold and Fish* can be granted through issuance of a written HPA. Among other regulations, WDFW requires a minimum 200-foot separation between dredges. The role of Ecology in this activity is to administer water quality standards to prevent interferences with or harm to beneficial uses of state waters.

A typical commercially available dredge is pictured in Figure 2. A 4-inch diameter intake nozzle is the maximum currently allowed under authority of the *Gold and Fish* pamphlet and is most commonly used by small-scale prospectors and miners. Larger dredges can and have been permitted on the Similkameen River in the past.

Figure 2. A Small-scale Gold Dredge (http://www.keeneengineering.com/pamphlets/howdredge.html).

Review of Existing Metals Data

Except for arsenic, the level of chemical contamination in Similkameen River sediments is relatively low, both for metals and organic compounds (Johnson and Plotnikoff, 2000; Colville Confederated Tribes, unpublished data). Appendix A has a summary of Ecology's sediment chemistry data for the Similkameen.

Arsenic concentrations generally range from 10 – 50 mg/Kg[1] (Figure 3). Samples in the vicinity of Nighthawk and Oroville have exceeded a recently proposed Washington state sediment quality guideline of 20 mg/Kg for protection of aquatic life (Avocet Consulting, 2003). Most Washington rivers and streams have less than 10 mg/Kg arsenic in their sediments (Johnson, 2002a).

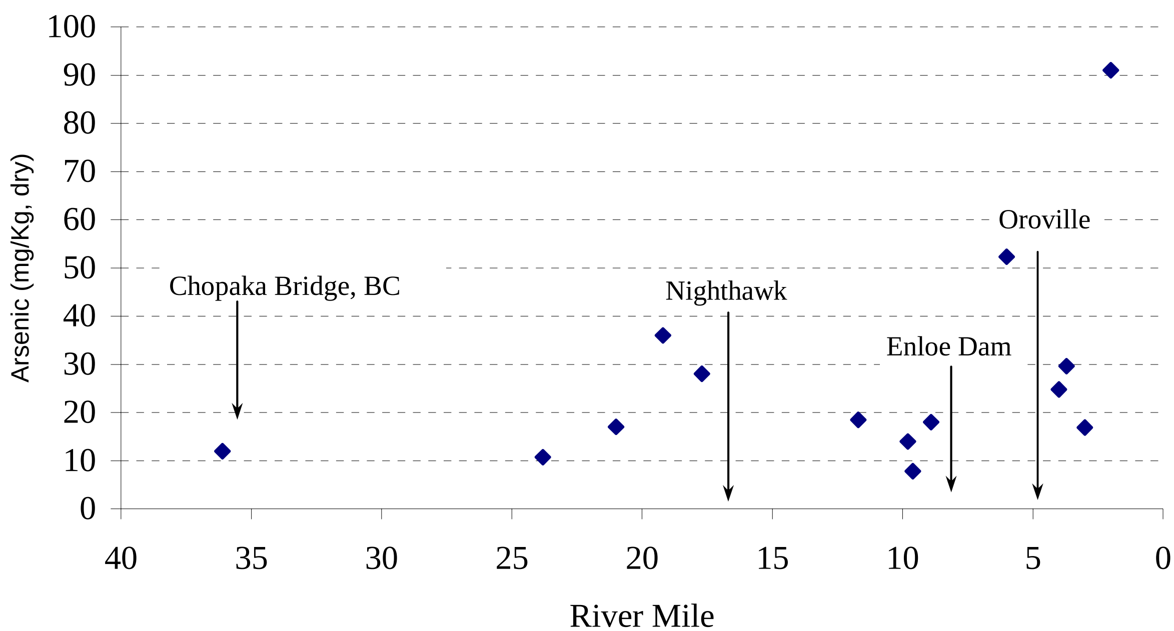


Figure 3. Arsenic Concentrations in Similkameen River Sediments (from Johnson, 2002a)

Arsenic is also elevated in the Similkameen water column, with concentrations of 1.0 - 5.0 ug/L[2] typically being encountered (Johnson, 2002a). Most Washington rivers have arsenic concentrations ranging from 0.2 – 1.0 ug/L (Johnson, 2002b). Other metals are not substantially elevated in the Similkameen River. Appendix B has Similkameen River metals data for 1995 - 2004 from Ecology's routine monitoring station at Oroville.

[1] mg/Kg = parts per million
[2] ug/L = parts per billion

A technical study conducted for the Similkameen River arsenic TMDL concluded that the major source of the higher arsenic concentrations was tailings from historical mining activity in British Columbia (Johnson, 2002a). Resuspension of contaminated sediments was identified as a potentially important source of arsenic to the water column.

Water quality criteria for metals being analyzed in the present study are shown in Table 1. Like most Washington rivers, the natural background concentration of arsenic in the Similkameen exceeds the very low human health criteria of 0.018 and 0.14 ug/L. Washington's human health criteria are from the EPA National Toxics Rule and are based on a one-in-one million excess cancer risk from consuming fish and water, or fish only. There are no equivalent human health criteria for copper, lead, or zinc. The aquatic life criteria shown below for arsenic, copper, lead, and zinc are not exceeded in the Similkameen River.

Table 1. Applicable Washington State Water Quality Criteria for Metals (ug/L)

	Aquatic Life Criteria*		Human Health Criteria	
Metal	Acute	Chronic	Fish + Water Consumption	Fish Consumption
Arsenic	360	190	0.018†	0.14†
Copper**	9.2	6.5	- -	- -
Lead**	31	1.2	--	- -
Zinc**	66	60	- -	- -

WAC 173-201A
*applies to dissolved metals
†applies to total inorganic arsenic
**criteria adjusted for 52 mg/L hardness (lowest recorded during present study)

Arsenic has been shown to increase going downstream from Chopaka, B.C. (river mile 36) to Oroville (Figure 4). This is primarily due to the Palmer Lake outlet at r.m. 19.5, a major arsenic source to the lower river. Palmer Lake has been contaminated by inflows from the Similkameen River and may have additional local sources of arsenic. (Johnson, 2002)

The previously mentioned dredging simulation study conducted by Ecology involved mixing predetermined amounts of Similkameen River water and sediment to approximate a dredged material slurry (the Elutriate Test described in Plumb (1981)). After shaking for 30 minutes, the supernatant from the mixture was allowed to settle, then filtered and analyzed. The samples used in this test were obtained near Eagle Rock (r.m. 11.7) and just above Enloe Dam (r.m. 8.9), areas where dredging was either underway or planned. Arsenic concentrations were 14 - 18 mg/Kg in the bulk sediments and 3.9 ug/L in the river water.

Results of the simulation showed that arsenic, copper, lead, and zinc were the metals of primary interest. Arsenic concentrations in the elutriate were 5 – 10 times higher than the river water used in the test. Copper and lead exceeded aquatic life criteria by factors of 2 – 4. Zinc approached half its aquatic life criteria values. A point source dilution model applied to these data suggested that at least a five-fold dilution would occur immediately downstream of a dredge during low-flow conditions. It was concluded that water quality concerns were probably negligible for metals, at least with respect to individual dredges.

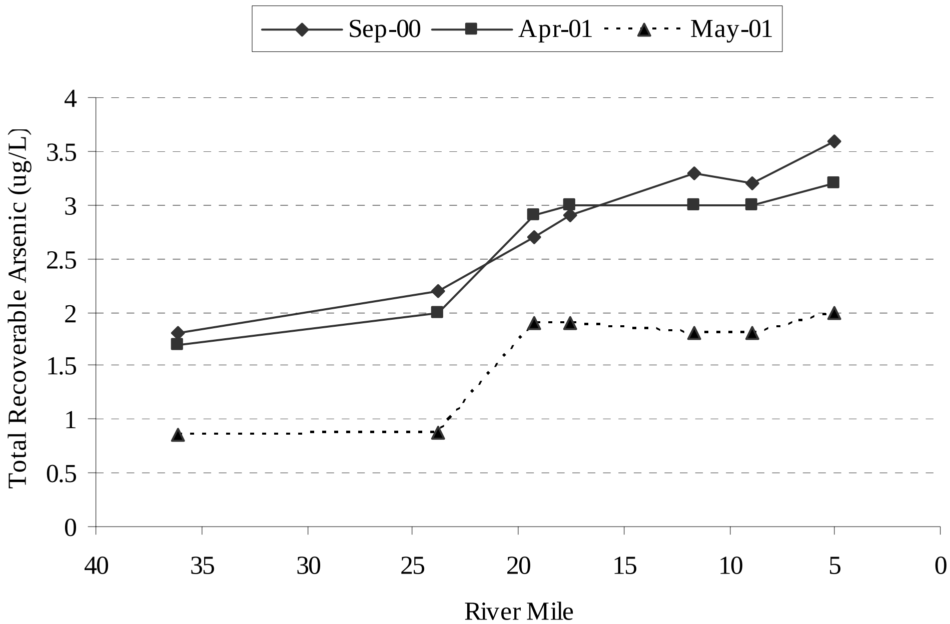


Figure 4. Arsenic Concentrations in Similkameen River Water Samples (from Johnson, 2002a).

Project Description

In response to the concerns expressed by the community and Tribe, Ecology conducted a field study to obtain water samples in the vicinity of small-scale gold dredges operating in the Similkameen River during the summer of 2004. The objectives of the study were to determine if dredging: 1) exacerbates current exceedances of the human health criteria for arsenic, or 2) results in violations of the aquatic life criteria for arsenic, copper, lead, or zinc. The study was not designed to assess compliance with the state turbidity standard or to determine the effect of dredging on total suspended solids (TSS) concentrations in the river.

Three types of water samples were collected for the study: Ambient samples were collected in the upper river to determine background concentrations for the metals and other parameters of interest. Effluents were sampled from dredges operating at 14 sites along the river to represent a range of substrates and associated metals concentrations. Finally, the turbidity plumes downstream of three dredges were sampled at selected distances to gage the downstream extent of the impacted area.

Clean sampling techniques and low-level analytical methods were used to analyze arsenic, copper, lead, and zinc. TSS, turbidity, and hardness were also measured. Hardness was needed to calculate the water quality criteria for copper, lead, and zinc. Some data were also obtained on effluent flow rates and stream velocities in the vicinity of the dredges. River discharge was determined from the gaging station operated by the U.S. Geological Survey (USGS) at Nighthawk (http://nwis.waterdata.usgs.gov/usa/nwis/discharge).

Field work was conducted once each month during the July 1 – September 30 period when dredging is permitted. The study was conducted by the Ecology Environmental Assessment Program with field assistance provided by CRO. The samples were analyzed by the Ecology Manchester Environmental Laboratory.

Study Design

Samples for the gold dredge study were collected on June 30 - July 1, August 18 - 19, and September 21 - 22, 2004. Monthly average river flow during this period typically ranges from 3,029 cfs (July) to 616 cfs (September).

The first set of samples corresponded to the July 1 opening of the mineral prospecting work window. The second sample set was collected during a Resources Coalition dredge rally held in Oroville on August 18 - 22, an event designed to generate interest and improve understanding of small-scale gold dredging. The third sample set was intended to assess dredging impacts during September low flow.

Ambient Samples

Background concentrations for the metals and other parameters of interest were determined by analyzing water samples collected in the Similkameen River approximately 3 ½ miles below Nighthawk (Figure 5). This location is in the upper part of the reach where most dredgers work. The ambient samples were collected on June 30, the day before the opening of the dredging season, and again in the early morning of August 19 and September 22 before dredgers began working the river.

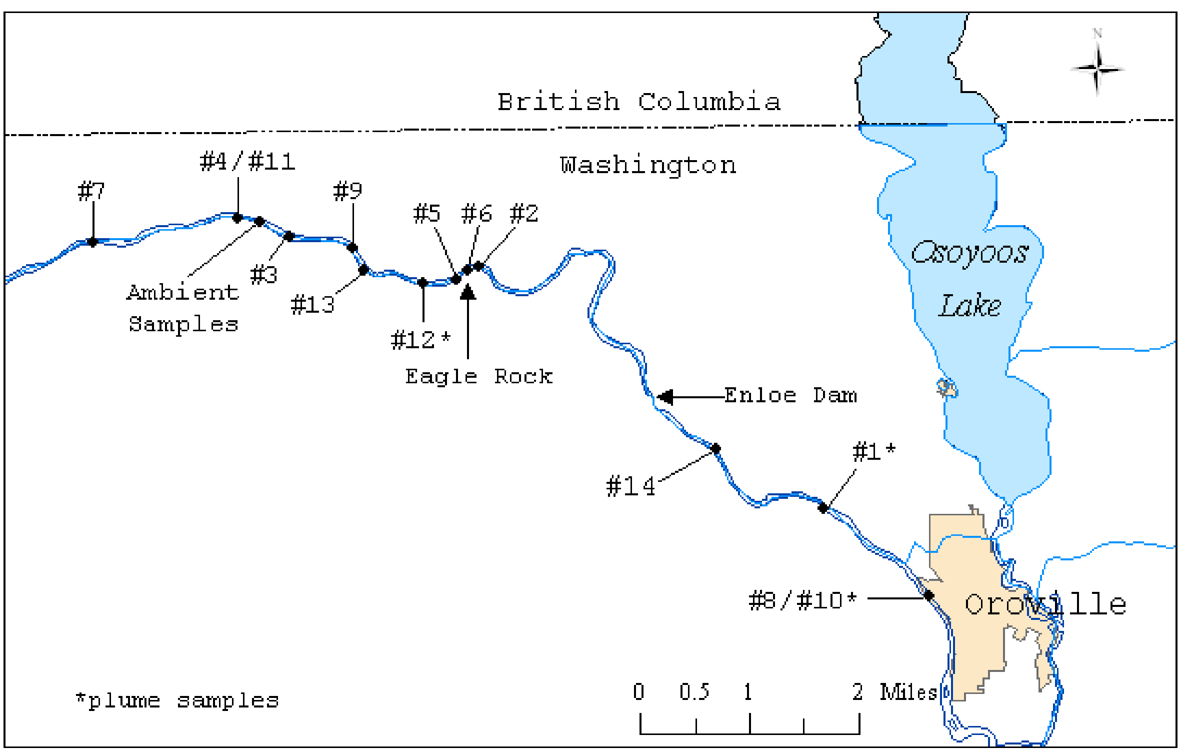


Figure 5. Locations of Gold Dredge Samples Collected in the Similkameen River during 2004

Three replicate samples were collected on each of the above dates and analyzed for total recoverable[3] and dissolved arsenic, copper, lead, and zinc, turbidity, and hardness. In addition to establishing background conditions, the results provided information on particulate vs. dissolved metals which was needed to evaluate the effluent data.

Effluent Samples

Dredging primarily occurs from a few miles below Nighthawk (r.m. 17.5) down to Oroville near the mouth of the river. Dredges operating at the 14 sites shown in Figure 5 were opportunistically sampled. An attempt was made to distribute the sampling effort equally up and down the river. No samples were obtained in the reservoir behind Enloe Dam as dredges normally do not operate there.

A single sample was collected from each dredge at the point the discharge left the sluice box. For dredge operations where the turbidity plume was being sampled, three effluent samples were collected.

In an effort to obtain a representative time-dependent composite, the effluent samples were collected by filling a one-liter sample bottle in small increments over a five-to-ten minute period. The samples were allowed to settle for approximately one hour and then ½ liter decanted into sample containers. This procedure removed sand and other large particles that would normally settle out of the water column. A settling time of one hour was selected based on the settleable solids analysis in EPA Method 160.5.

The effluents were analyzed for total recoverable arsenic, copper, lead, and zinc.

For selected dredges, the effluent flow rate was estimated from discharge velocity measurements and the dimensions of the sluice box. River velocity and substrate characteristics were also recorded.

Detailed information on the location of the effluent sampling sites, dredge descriptions, flows, and substrate characteristics can be found in Appendix C.

Plume Samples

The plumes from three dredges operating under different flow regimes – one each in July, August, and September – were sampled to gage the downstream extent of the impacted area (Figure 5). Three samples each were collected at 10, 50, and 200 feet below the dredge, staggered over approximately a 30-minute period. A marked polyethylene line with a float at the far end was attached to the back of the dredge to locate downstream sampling points. The distance of the furthest downstream sample was based on the *Gold and Fish* pamphlet requirement that dredges be separated by 200 feet.

[3] Total recoverable metals refers to a laboratory procedure where a sample is subjected to strong acid digestion prior to analysis. A total metals analysis employs a more thorough digestion of the sample. A total recoverable analysis is typically done for surface water samples and, for present purposes, is essentially equivalent to total metals.

Three separate effluent samples were collected at the same time the plume was being sampled. A single sample was also collected immediately upstream of the dredge suction hose for comparison with the plume. The effluent was analyzed for total recoverable metals.

The upstream and plume samples were analyzed for total recoverable arsenic, dissolved copper, lead, and zinc, TSS, turbidity, and hardness. Arsenic was analyzed as total recoverable for comparison to the human health standards, which are based on inorganic arsenic. Most of the arsenic in the Similkameen River water is in inorganic form (Johnson, 2002a). Measuring inorganic arsenic directly would have significantly increased the cost of the study. Total recoverable arsenic can reasonably be compared to the dissolved aquatic life criteria, since they differ only slightly from the older total recoverable criteria on which they are based. Copper, lead, and zinc were analyzed as dissolved for direct comparison with the aquatic life standards.

Number of Samples

The number and type of samples collected for this project are summarized in Table 2.

Table 2. Number and Type of Samples Collected for the 2004 Similkameen River Gold Dredge Study

Sample Type	No. of Sites	Samples per Site	Sub-total	Analyses
Ambient River	1	9	9	TR As, Cu, Pb, Zn; Diss Cu, Pb, Zn; TSS; turbidity; hardness
Above Dredge	14	1	14	TR As; Diss Cu, Pb, Zn; TSS; turbidity; hardness
Dredge Effluent	14	1-3	20	TR As, Cu, Pb, Zn
Dredge Plume	3	9	27	TR As; Diss Cu, Pb, Zn; TSS; turbidity; hardness
Bottle Blanks	1	3	3	TR As, Cu, Pb, Zn
Filter Blanks	1	3	3	Diss As, Cu, Pb, Zn
		Total =	76	

TR = total recoverable
Diss = dissolved

Methods

Field Procedures

Table 3 lists the sample size, container, preservation, and recommended holding time for each study parameter. Sample containers were obtained from Manchester Laboratory. Metals sampling procedures followed the guidance in EPA (1995) *Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels*. All samples were taken as simple grabs or grab composites.

Table 3. Sample Containers, Preservation, and Holding Times for Water Samples

Parameter	Minimum Quality Required	Container	Preservative*	Holding Time
Metals	250 mL	500 mL Teflon bottle	HNO_3 to pH<2, 4°C	6 months
Hardness	100 mL	125 mL poly bottle	H_2SO4 to pH<2, 4°C	6 months
TSS	1,000 mL	1,000 mL poly bottle	Cool to 4°C	7 days
Turbidity	100 mL	500 mL poly bottle	Cool to 4°C	48 hours

*dissolved metals samples filtered in the field (0.45 micron)

Metals samples were collected directly into pre-cleaned 500 mL (plume and ambient samples) or 1 L (effluent samples) Teflon bottles. The effluent samples were allowed to settle and were then decanted, as previously described. Samples for dissolved metals were filtered in the field through a pre-cleaned 0.45 um Nalgene filter unit (#450-0045, type S). The filtrate was transferred to a new pre-cleaned 500 mL Teflon bottle. The whole water and filtered water samples were preserved to pH <2 with sub-boiled 1:1 nitric acid, carried in small Teflon vials. Teflon sample bottles, Nalgene filters, and Teflon acid vials were cleaned by Manchester, as described in Kammin et al. (1995), and sealed in plastic bags. Non-talc nitrile gloves were worn by personnel filtering the samples. Filtering was done in a glove box constructed of a PVC frame and polyethylene cover.

Flow was measured with a Marsh-McBirney meter and top-setting rod. A hand-held GPS was used to record sampling locations. All samples were placed in polyethylene bags, held on ice for transport to Ecology HQ, and then taken by courier to Manchester Laboratory within one to two days of collection. Chain-of-custody procedures were followed (Manchester Environmental Laboratory, 2003).

Laboratory Procedures

Table 4 shows the analytical methods used in this project.

Table 4. Laboratory Procedures

Analyte	Sample Matrix	Sample Prep Method	Analytical Method
Arsenic, Copper, Lead, Zinc	whole water	HNO_3/HCl digest	EPA 200.8
Copper, Lead, Zinc	filtered water	analyze directly	EPA 200.8
Hardness	whole water	N/A	EPA 200.7
TSS	whole water	N/A	EPA 160.2
Turbidity	whole water	N/A	EPA 180.1

N/A = not applicable

Data Quality

Manchester Laboratory prepared written quality assurance reviews on the quality of the chemical data for this project. The reviews include an assessment of sample condition on receipt at the laboratory, compliance with holding times, instrument calibration, procedural blanks, laboratory control samples, matrix spike and matrix spike duplicate recoveries, and duplicate sample analyses. No significant problems were encountered that compromise the accuracy, validity, or usefulness of the data. The quality assurance reviews and complete chemical data for this project are available from the author.

The precision of the data reported here can be assessed from results of duplicate analyses conducted on selected samples (Appendix D). Dissolved metal determinations agreed within 10%. Total recoverable metals agreed within approximately 20%, except 36% for zinc in one sample. Results for TSS, turbidity, and hardness were also in close agreement.

Field blanks were analyzed to detect metals contamination arising from sample containers or the filtration procedure. Bottle blanks were prepared at Manchester Laboratory by filling the Teflon sample bottles with deionized water. Filter blanks were prepared by filtering half the contents of a bottle blank. The field blanks were treated the same as samples.

Bottle and filter blanks were analyzed on three occasions during the project (Appendix E). There was a trace amount of zinc in the filter blanks (0.56 – 1.1 ug/L). The other metals were not detected in either type of blank. This demonstrates that the sample collection, preservation, and filtration procedures were not contributing significant amounts of metals to the samples.

Results and Discussion

River Flow

Figure 6 compares historical average flow in the Similkameen River with the flows encountered when samples were collected for the 2004 gold dredge study. The data are from USGS monitoring station #12442500 at Nighthawk.

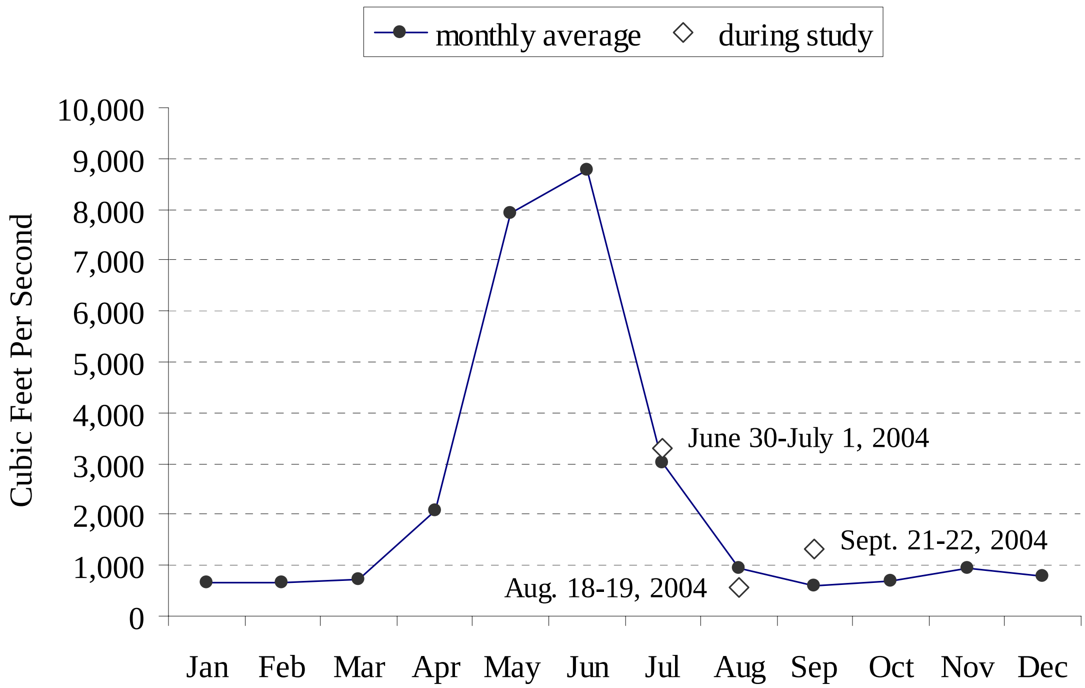


Figure 6. Monthly Average Flow in the Similkameen River, Showing Flows When Gold Dredge Samples were Collected (USGS station 12442500, 1928 – 2002).

As shown in Figure 6 and summarized below, river flows during gold dredge sampling were representative of the range of summer flows normally encountered in the Similkameen. Dry August weather resulted in low-flow conditions that were not anticipated to occur until the following month. Wet weather caused higher than normal discharge during the September sample collection.

Month	Average Flow	
	Historical	During Sampling
July	3,029 cfs	3,300 cfs
August	936 cfs	581 cfs
September	616 cfs	1,320 cfs

Ambient Water Quality

Ambient levels of TSS, turbidity, metals, and hardness measured in the Similkameen during the 2004 dredging season are summarized in Table 5. As previously described, these samples were collected in the upper part of the reach where dredging is done, but when no dredges were operating. Each data point represents results from three replicate samples. Variability within each sample set was minimal.

Table 5. Ambient Water Quality Conditions in the Similkameen River During the 2004 Gold Dredging Season [mean ± standard deviation of three replicates collected at river mile 14.0; no dredges operating]

Parameter	June 30	August 18	September 21	Overall Mean*
TSS (mg/L)	10 ± 0	3 ± 0.5	5 ± 0	6
Turbidity (NTU)	4.2 ± 0.4	2.2 ± 0.1	2.4 ± 0.05	2.9
Tot. Rec. Arsenic (ug/L)	3.9 ± 0.1	4.2 ± 0	2.2 ± 0.1	3.4
Dissolved Arsenic (ug/L)	2.7 ± 0.1	4.2 ± 0	1.8 ± 0	2.9
Tot. Rec. Copper (ug/L)	2.3 ± 0.2	1.2 ± 0	1.4 ± 0	1.6
Dissolved Copper (ug/L)	0.82 ± 0.05	0.84 ± 0.01	0.97 ± 0.1	0.88
Tot. Rec. Zinc (ug/L)	1.7 ± 0.1	<1.0	1.2 ± 0.1	1.3
Dissolved Zinc (ug/L)	0.92 ± 0.1	1.1 ± 0.1	2.2 ± 1.5	1.4
Tot. Rec. Lead (ug/L)	0.14 ± 0.02	<0.10	0.18 ± 0.01	0.14
Dissolved Lead (ug/L)	<0.02	<0.10	0.09 ± 0.05	0.07
Hardness (mg/L)	52 ± 0.4	82 ± 0.1	61 ± 0.02	65

*detection limit used for non-detects

TSS, turbidity, and total recoverable zinc, copper, and lead varied directly with flow. The levels were highest in July (September for lead) and lowest in August. The highest total recoverable arsenic concentrations were in August. Hardness varied inversely with flow, reflecting the relatively greater contribution of groundwater when river discharge is low.

TSS and turbidity ranged from 3 - 10 mg/L and 2.2 - 4.2 NTU, respectively. Concentrations of total recoverable metals ranged from 2.4 - 4.2 ug/L for arsenic, 1.2 - 2.3 ug/L for copper, <1.0 - 1.7 ug/L for zinc, and <0.10 - 0.18 ug/L for lead. Total recoverable zinc and lead were below detection limits during the low flows of August.

Dissolved metals concentrations were 1.8 - 4.2 ug/L for arsenic, 0.82 - 0.97 ug/L for copper, 0.92 - 2.2 ug/L for zinc, and <0.02 - 0.09 ug/L for lead. Because of a zinc background in the filtration procedure, the dissolved results slightly exceeded total recoverable in most of the August and September samples. Trace zinc contamination is frequently encountered when analyzing at the low ppb level.

These results are consistent with historical data on the Similkameen River (Appendix B; Johnson 1997, 2002a). At the time of the gold dredge study, ambient levels of dissolved arsenic, copper, lead, and zinc were one to two orders of magnitude lower than the aquatic life criteria (see Table 1). Total recoverable arsenic exceeded the more restrictive human health criteria by one to two orders of magnitude. As discussed earlier in this report, arsenic concentrations in most rivers and streams naturally exceed the EPA human health criteria, although to a lesser extent than in the Similkameen. There are no human health criteria for copper, lead, or zinc.

Dredge Effluents

Metals concentrations measured in effluents from gold dredges operating in the lower Similkameen River are shown in Table 6. These data are for total recoverable metals.

Table 6. Metals Concentrations in Effluent Samples from Gold Dredges Operating in the Similkameen River During 2004 [ug/L, total recoverable]

Site No.	Date	Arsenic	Copper	Zinc	Lead
#1	July 1	3.8	2.3	1.9	0.23
#2	July 1	6.2	6.1	5.2	0.69
#3	August 18	6.4	4.7	9.1	0.67
#4	August 18	6.6	9.3	9.4	0.97
#5	August 18	6.6	8.3	7.3	1.1
#6	August 18	6.3	5.1	4.2	1.3
#7	August 18	4.6	2.4	1.8	0.16
#8	August 18	7.4	4.4	3.3	0.47
#9	August 19	5.6	3.3	3.0	0.39
#10	August 19	7.3	3.7	4.4	0.46
#11	August 19	8.0	5.4	7.4	0.75
#12	September 21	2.6	2.9	2.0	0.47
#13	September 21	3.3	4.7	3.6	0.62
#14	September 22	2.6	2.0	1.8	0.26
	mean =	5.5	4.6	4.6	0.61
	minimum =	2.6	2.0	1.8	0.16
	maximum =	8.0	9.3	9.4	1.3

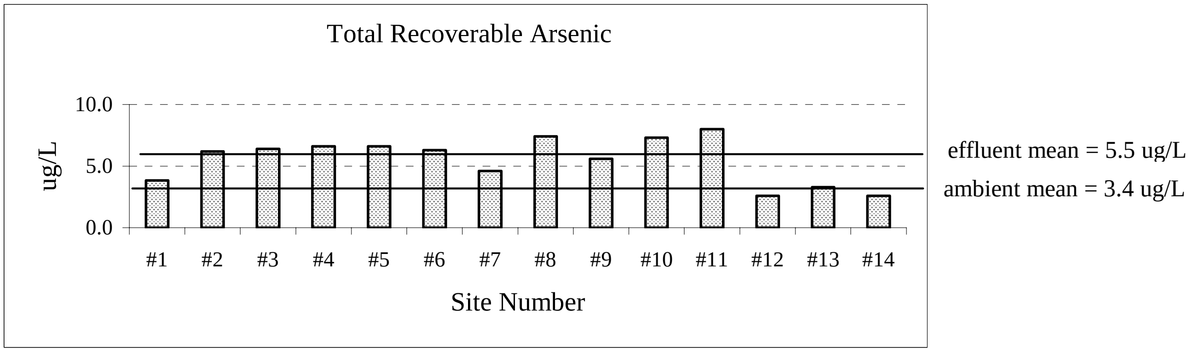
Although collected at 14 different locations and at varying stages in the dredging process, metals concentrations in the effluents did not differ greatly between sites. Minimum and maximum concentrations were within a factor of 2 for arsenic, factors of 4 - 5 for copper and zinc, and a factor of 8 for lead. Average concentrations were 5.5 ug/L arsenic, 4.6 ug/L copper, 4.6 ug/L zinc, and 0.61 ug/L lead. As described earlier, these samples were decanted, so did not include sand and other particles that would rapidly settle out of the water column following discharge.

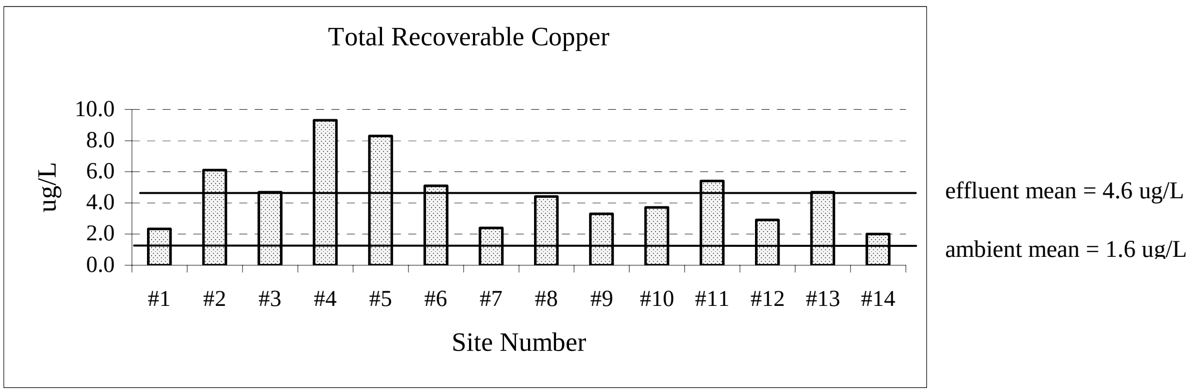
Most of the effluent data are based on single samples composited over a five-to-ten minute period. Three separate composites were analyzed in conjunction with turbidity plume sampling at sites #1, #10, and #12. These samples were collected over a period of approximately 30 minutes (i.e., three five-to-ten minute composites per site) and also showed a low level of variability (Table 7). The average of the three composites is shown in Table 6.

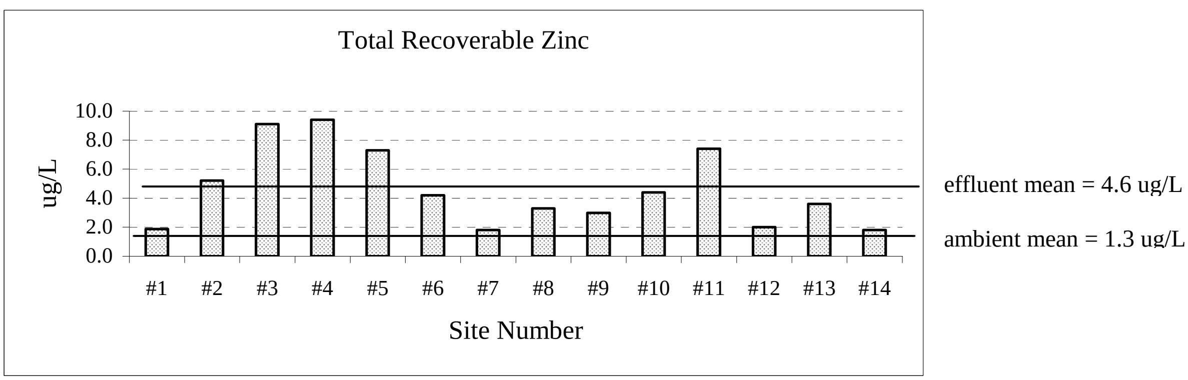
Table 7. Variability of Replicate Gold Dredge Effluent Samples [ug/L, total recoverable]

Site No	Date	Time	Arsenic	Copper	Zinc	Lead
#1	July 1, 2004	115-1125	5.0	2.5	1.9	0.26
"	"	1335-1345	3.2	2.3	2.1	0.21
"	"	1155-1205	3.3	2.2	1.6	0.23
		mean ± s.d.=	3.8 ± 0.8	2.3 ± 0.1	1.9 ± 0.2	0.23 ± 0.02
#10	Aug 18, 2004	1513-1518	7.1	3.2	3.8	0.41
"	"	1523-1528	7.8	4.9	5.5	0.58
"	"	1538-1543	7.0	3.0	3.9	0.38
		mean ± s.d.=	7.3 ± 0.4	3.7 ± 0.9	4.4 ± 0.8	0.46 ± 0.1
#12	Sept 21, 2004	1330-1335	2.6	2.9	2.1	0.56
"	"	1338-1343	2.7	3.2	2.0	0.48
"	"	1345-1350	2.5	2.6	1.9	0.38
		mean ± s.d.=	2.6 ± 0.1	2.9 ± 0.2	2.0 ± 0.1	0.47 ± 0.1

A perspective on the potential these effluents have to affect metals concentrations in the river can be gained from a comparison with the ambient data (Figure 7). Zinc and lead appear to be the metals of greatest potential concern, with effluent concentrations being up to approximately 10 times higher than ambient levels. Arsenic, on the other hand, exceeded background by a factor of 2 or less, suggesting a minimal impact. These data indicate that the potential for these metals to be increased due to dredging in the Similkameen River is, in decreasing order, zinc, lead, copper, and arsenic.







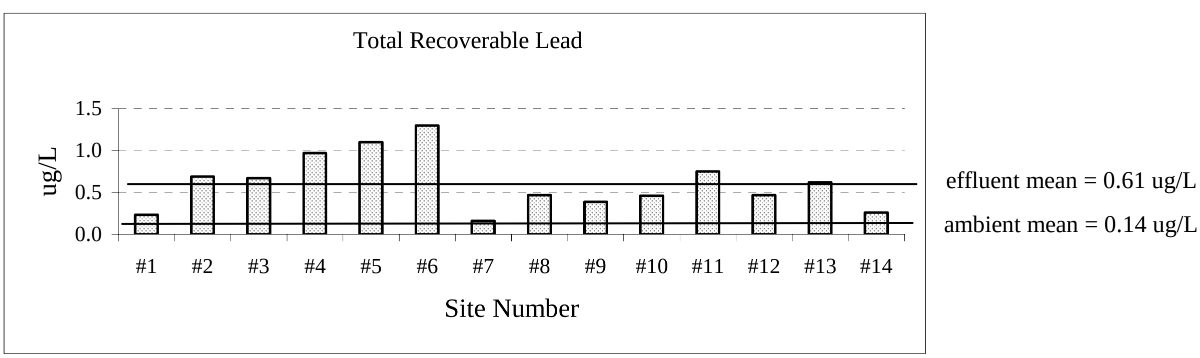


Figure 7. Metals Concentrations in Similkameen River Gold Dredge Effluents

Dredge Plumes

Turbidity plumes were sampled behind three gold dredges, one each at sites #1, #10, and #12. The results are summarized in Table 8. Each data point represents results from three replicate samples taken over approximately a 30-minute period. The effluent data are for total recoverable metals, while the plume and upstream data are for dissolved metals, except for total recoverable arsenic. (See Study Design for an explanation of analyzing total recoverable vs. dissolved metals.)

Table 8. Results from Sampling Gold Dredge Effluent Plumes in the Similkameen River During 2004 [mean ± standard deviation of three samples, except a single sample collected above each dredge]

Parameter	Turbidity (NTU)	TSS (mg/L)	Diss. Zinc (ug/L)	Diss. Copper (ug/L)	Diss. Lead (ug/L)	T.R. Arsenic (ug/L)	Hardness (mg/L)
Site #1, July 1							
Above dredge	4.3	10	<0.50	1.0	<0.02	3.7	52
Dredge effluent*	N/A	N/A	1.9 ± 0.2	2.3 ± 0.1	0.23 ± 0.02	3.8 ± 0.8	N/A
10 ft. downstream	10 ± 3.0	86 ± 45	1.1 ± 0.2	0.83 ± 0.02	<0.02**	9.8 ± 5.1	54 ± 1
50 ft. downstream	7.6 ± 3.0	68 ± 23	1.1 ± 0.2	0.83 ± 0.02	<0.02†	9.4 ± 5.4	54 ± 2
200 ft. downstream	5.2 ± 1.0	20 ± 3	0.6 ± 0.1	0.87 ± 0.09	<0.02	5.0 ± 0.7	53 ± 0.1
Site #10, August 18							
Above dredge	0.8	1	0.68	0.76	<0.10	5.3	88
Dredge effluent*	N/A	N/A	4.4 ± 0.8	3.7 ± 0.8	0.46 ± 0.09	7.3 ± 0.4	N/A
10 ft. downstream	12 ± 0.5	32 ± 7	2.0 ± 0.7	0.86 ± 0.01	<0.10	9.8 ± 1.9	90 ± 0.3
50 ft. downstream	3.6 ± 1.0	7 ± 2	1.3 ± 0.1	0.81 ± 0.01	<0.10	6.0 ± 0.1	89 ± 0.4
200 ft. downstream	1.4 ± 0.2	3 ± 0.5	1.1 ± 0.2	0.81 ± 0.01	<0.10	5.4 ± 0	88 ± 0.3
Site #12, September 21							
Above dredge	3.0	7	<0.50	0.94	0.032	2.2	59
Dredge effluent*	N/A	N/A	2.0 ± 0.08	2.9 ± 0.2	0.47 ± 0.07	2.6 ± 0.1	N/A
10 ft. downstream	11 ± 0.5	44 ± 9	0.88 ± 0.1	0.99 ± 0.01	0.039 ± 0.001	4.0 ± 0.4	60 ± 0
50 ft. downstream	6.9 ± 0.1	23 ± 3	2.8 ± 0.9	1.1 ± 0.1	0.040 ± 0.003	2.8 ± 0.1	59 ± 0
200 ft. downstream	4.0 ± 0.9	8 ± 2	0.93 ± 0.3	0.94 ± 0.01	0.035 ± 0.002	2.4 ± 0.1	59 ± 0

N/A = not analyzed
*dredge effluent data are total recoverable metals
**one detection at 0.028 ug/L
†one detection at 0.027 ug/L

River flows at the time of sample collection were 3,300 cfs (site #1), 581 cfs (site #10), and 1,320 cfs (site #12). Current velocities at the dredge sites ranged from 1.5 to 2.5 feet per second, and water depths were between 1.5 and 4 feet. The substrates were cobble with varying amounts of sand and gravel.

Downstream changes in the plume can be better visualized in Figure 8 which plots average TSS, turbidity, and metals concentrations. Zinc was below detection limits in the August and September upstream samples, and lead was below detection limits in most of the July and August samples. The detection limit was plotted where these metals were not detected.

Table 9 compares the upstream TSS, turbidity, and metals concentrations with the average concentrations measured in the furthest downstream samples 200 feet below the dredge. The differences between the three sites illustrate the variability inherent in a dredge plume mixing under different conditions of river flow and turbulence.

Table 9. Percent Increases in TSS, Turbidity, and Metals Concentrations Measured 200 Feet Below Three Gold Dredges in the Similkameen River

Site No.	TSS (mg/L)	Turbidity (NTU)	Tot. Rec Arsenic (ug/L)	Dissolved Copper (ug/L)	Dissolved Zinc (ug/L)	Dissolved Lead (ug/L)
#1	100	21	35	0	20	ND
#10	200	75	2	7	62	ND
#12	14	33	9	0	86	9
mean =	100	43	15	2	56	9

ND = not detected

At 200 feet, complete mixing with the river had not occurred. On average, TSS concentrations 200 feet downstream of the dredges were twice as high (100% increase) as upstream of the dredges. Turbidity and dissolved zinc levels at 200 feet were half again as high as upstream (43 – 56% average increase). There was only a modest increase in arsenic, copper, and lead (2 – 15%).

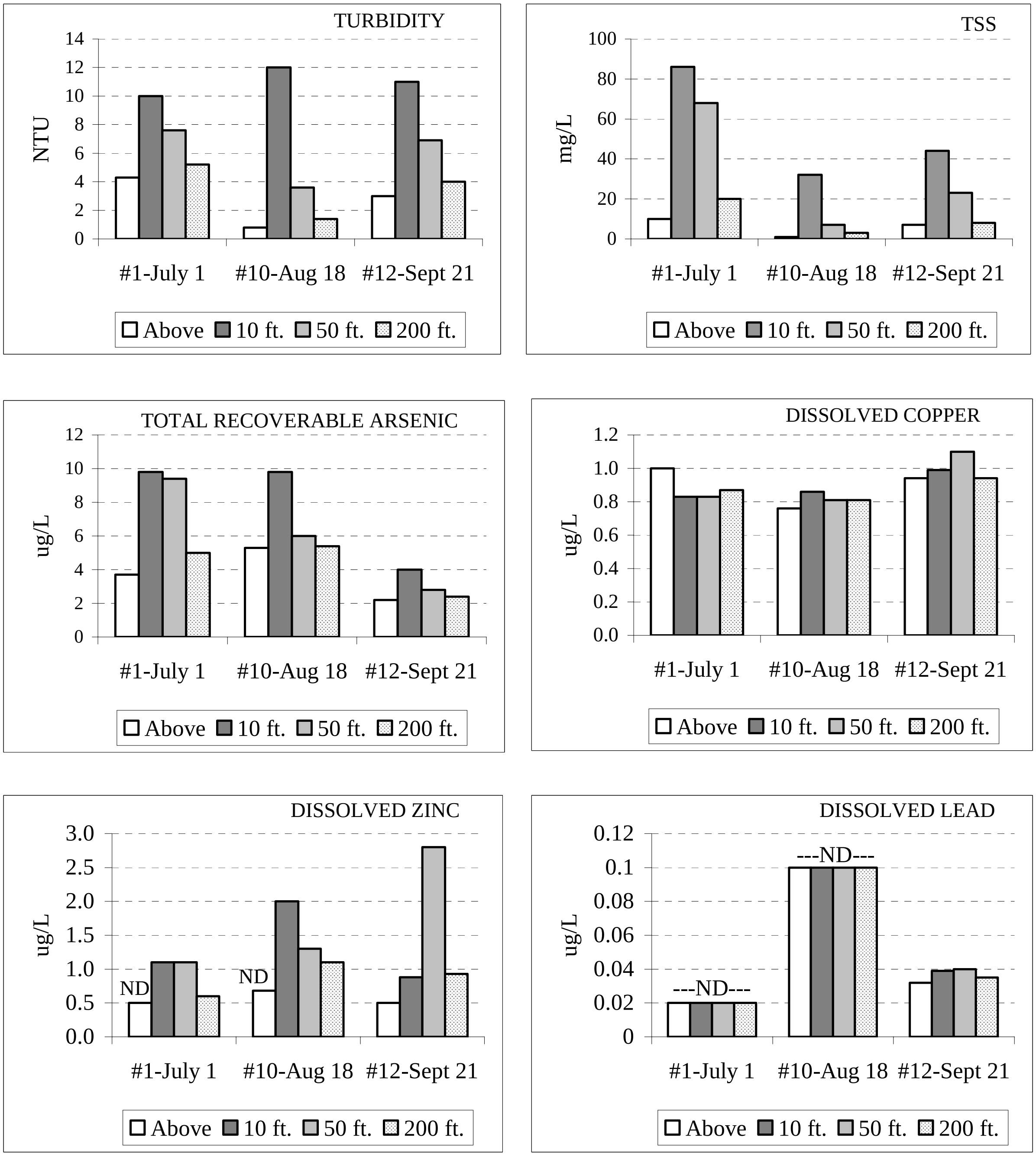


Figure 8. TSS, Turbidity, and Metals Concentrations Below Three Gold Dredges in the Similkameen River (mean of three grabs; ND = not detected).

Comparison with Water Quality Criteria

Table 10 compares the metals concentrations measured in Similkameen gold dredge effluents and dredge plumes with Washington state criteria for the protection of aquatic life. Copper, lead, and zinc toxicity varies inversely with hardness. The criteria were calculated for a hardness of 52 mg/L, the lowest recorded in the study.

Table 10. Metals Concentrations in Similkameen River Dredge Effluent and Plume Samples Compared to Criteria for Protection of Aquatic Life (ug/L)

	Arsenic	Copper	Lead	Zinc
Concentration Range in Effluents* (n=18)	2.6 - 8.0	2.0 - 9.3	0.16 - 1.3	1.8 - 9.4
Concentration Range Measured in Plume† (n=27)	2.3 - 17	0.79 - 1.2	<0.02 - 0.043	<0.5 - 4.1
Acute water quality criterion**	360	9.2	31	66
Chronic water quality criterion**	190	6.5	1.2	60

*total recoverable metals
†dissolved metals except total recoverable arsenic
**dissolved metals at 52 mg/L hardness (lowest recorded in study)

Based on analyzing 14 effluents and 27 plume samples, it appears that small-scale gold dredges have little or no potential to cause exceedances of aquatic life criteria in the Similkameen River. Arsenic and zinc concentration in dredge related samples were one to two orders of magnitude lower than criteria. Copper and lead concentrations were at or below criteria, except for one or two effluent samples that slightly exceeded (sites #4, #5, and #7).

The criteria comparison in Table 10 is a worst-case assessment in several respects:

1. Metals concentrations in the effluents and plumes would be subjected to further dilution in the river.
2. Subsamples for the effluent composites were only taken when the suction hose was in contact with the streambed. A true time-weighted composite would have included subsamples when the intake was lifted off the bottom – as periodically occurs – and only river water was being pumped through the dredge, resulting in lower average concentrations in the discharge.
3. Less restrictive water quality criteria would apply at other times of the dredging season when hardness levels are higher. For example, the acute criteria for copper increase from 6.5 to 9.6 ug/L going from a hardness of 52 mg/L (June 2004) to 82 mg/L (August 2004).
4. Once the effluents are discharged, the metals will partition into dissolved and particulate fractions. The dissolved fraction is the primary toxicity concern.

As previously described, ambient arsenic concentrations in the Similkameen River substantially exceed the Washington State human health criteria of 0.018 and 0.14 ug/L, due to natural conditions which have been exacerbated by historic land-based mining activity. The relative impact of dredge effluents on the already elevated arsenic concentrations in the river is assessed below.

Effect of Multiple Dredges

The metals concentrations measured in gold dredge effluents during the present study were at or below aquatic life criteria. Therefore, criteria exceedances would not be anticipated in the Similkameen River, regardless of the number of dredges operating. A series of dilution calculations were done to estimate what effect multiple dredges would have on metals concentrations in the river. As a point of reference, the maximum number of dredges Ecology personnel have observed on the Similkameen is approximately 20.

The calculations were done for both the average September flow and the 7-day, 10-year low flow, 616 cfs and 182 cfs, respectively (USGS Nighthawk gage). The August ambient data (Table 5) were used for the upstream metals concentrations. At that time the river was at 581 cfs. The detection limit was used for zinc and lead.

Average metal concentrations were used for the dredge effluents (Table 6), adjusted for the fraction that would be expected to be in the dissolved phase (based on the dissolved/total recoverable ratios in Table 5). Effluent flow rates ranged from 0.4 - 1.2 cfs, averaging 0.7 cfs (Appendix C); 1.0 cfs was used in the calculations. It was assumed the dredges operated continuously.

The results of the dilution calculations are in Table 11. During average September flows, it is estimated that somewhere between 17 and 57 dredges operating continuously would be required to increase dissolved zinc, lead, and copper concentrations in the Similkameen River by 10%. It would take between approximately 200 and 520 dredges to have the same effect on total recoverable and dissolved arsenic, respectively. In order for zinc, lead, or copper concentrations to be doubled in the river, anywhere from 170 to 570 dredges would need to be operating. Arsenic concentrations in the dredge effluents are too low to cause an increase of that magnitude, regardless of river flow.

At the 7-day, 10-year low flow in the Similkameen, relatively few dredges could effect a 10% change in copper, lead, and zinc concentrations. It would take 50 or more continuously operating dredges to double concentrations of these metals.

As demonstrated elsewhere in this report, a 100% increase in the ambient arsenic, copper, lead, or zinc concentrations in the Similkameen River would not result in exceedances of aquatic life criteria.

Table 11. Estimated Number of Dredges Required to Increase Metals Concentrations in the Similkameen River by 1%, 10%, and 100% [see text for assumptions and data used]

	@ Average September Flow - 616 cfs		
	1%	10%	100%
Tot. Rec. Arsenic	20	200	**
Dissolved Arsenic	52	520	**
Dissolved Copper	6	57	570
Dissolved Lead	3	31	310
Dissolved Zinc	2	17	170
	@ 7-Day, 10-Year Low Flow - 182 cfs		
	1%	10%	100%
Tot. Rec. Arsenic	6	59	**
Dissolved Arsenic	15	150	**
Dissolved Copper	2	17	170
Dissolved Lead	1	9	92
Dissolved Zinc	1	5	51

**effluent concentration too low to result in 100% increase

Conclusions

Results of this study show that the concentrations of arsenic, copper, lead, and zinc discharged from small-scale gold dredges operating in the Similkameen River are not a significant toxicity concern for aquatic life. Although this activity will exacerbate the exceedances of the arsenic human health criteria that already occur, it would take very large numbers of dredges to effect a 10% change in the river's arsenic levels, even at low-flow conditions.

These conclusions may not apply to the sediment deposits behind Enloe Dam. This material could have different physical/chemical properties that the sediments evaluated in the present study.

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Appendices

A. Results from Analyzing Metals and Organic Compounds in Similkameen River Sediment Samples

B. Metals Data for Ecology Routine Monitoring Station 49B070, Similkameen River at Oroville

C. Site Locations and Other Information on the Similkameen River Gold Dredge Samples

D. Results on Laboratory Duplicates for the Similkameen River Gold Dredge Study

E. Results on Field Blanks for the Similkameen River Gold Dredge Study

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Appendix A-1. Results of Metals and Cyanide Analyses on Similkameen River Sediment Samples (mg/Kg, dry weight)

Site No.	Date	Sample No.	Depth Interval	Iron	Aluminum	Manganese	Zinc	Copper	Arsenic	Chromium	Nickel	Lead	Cadmium
						UPPER RIVER							
1	29-Aug-95	358246	0-2 cm	**12900**	**7030**	**236**	**35**	**22**	**12**	**12**	**12**	**2.4**	0.3 U
2	23-Aug-98	398060	0-10 cm	**14000**	**6980**	NA	**32**	**25**	**11**	**13**	**11**	**3.3**	0.5 U
						PALMER LAKE - NIGHTHAWK							
3	24-Aug-98	398061	0-10 cm	**15700**	**7790**	NA	**35**	**28**	**17**	**15**	**15**	**3.9**	0.5 U
4	30-Aug-95	358244	0-2 cm	**19500**	**10700**	**389**	**56**	**60**	**30**	**21**	**19**	**5.4**	0.3 U
4	24-Aug-98	398062	0-10 cm	**19900**	**10100**	NA	**48**	**51**	**43**	**22**	**19**	**5.4**	0.5 U
5	30-Aug-95	358243	0-2 cm	**17000**	**8490**	**300**	**46**	**43**	**46**	**18**	**17**	**4.5**	0.3 U
5	24-Aug-98	398063	0-10 cm	**13400**	**7040**	NA	**29**	**17**	**9.5**	**11**	**9.1**	**2.4**	0.5 U
						EAGLE ROCK							
6	24-Aug-98	398064	0-10 cm	**14700**	**7230**	NA	**33**	**24**	**19**	**13**	**12**	**3.0**	0.5 U
						ENLOE DAM							
7	23-Aug-98	398065	0-10 cm	**14200**	**7080**	NA	**31**	**18**	**12**	**13**	**12**	**2.4**	0.5 UJ
7	30-Sep-99	408020	0-1 ft	NA	NA	NA	**36**	**21**	**15**	**15**	**11**	**3.2**	**1.1**
7	30-Sep-99	408021	1-2 ft	NA	NA	NA	**31**	**13**	**7**	**11**	**7.8**	**2.0**	**0.86**
8	30-Sep-99	408022	0-1 ft	NA	NA	NA	**32**	**13**	**7.8**	**12**	**8.6**	**2.2**	**0.81**
8	30-Sep-99	408023	1-2 ft	NA	NA	NA	**30**	**12**	**7.2**	**11**	**7.9**	**2.0**	**0.79**
9	30-Aug-95	358242	0-2 cm	**16200**	**8940**	**305**	**50**	**45**	**21**	**18**	**16**	**4.1**	0.3 U
9	23-Aug-98	398066	0-10 cm	**14600**	**7275**	NA	**32**	**21**	**14**	**14**	**12**	**2.8**	0.5 U
9	30-Sep-99	408024	0-1 ft	NA	NA	NA	**33**	**17**	**10**	**13**	**9.2**	**2.3**	**0.94**

Note: Detections highlighted in **BOLD**
NA = not analyzed
U = not detected at or above reported value
J = estimated value
UJ = not detected at or above reported estimated value

Appendix A-1. (continued)

Site No.	Date	Sample No.	Depth Interval	Silver	Beryllium	Thallium	Mercury	Antimony	Selenium	Cyanide
				UPPER RIVER						
1	29-Aug-95	358246	0-2 cm	0.3 U	NA	NA	0.01 U	NA	0.4 U	NA
2	23-Aug-98	398060	0-10 cm	**0.66**	**0.24**	**0.38** J	**0.012**	4 UJ	0.3 U	0.10 U
				PALMER LAKE - NIGHTHAWK						
3	24-Aug-98	398061	0-10 cm	**0.78**	**0.28**	**0.50** J	**0.018** J	4 UJ	0.3 U	0.10 U
4	30-Aug-95	358244	0-2 cm	**0.30** J	NA	NA	**0.012**	NA	0.4 U	NA
4	24-Aug-98	398062	0-10 cm	**0.83**	**0.38**	0.3 U	**0.029**	4 UJ	0.3 U	0.10 U
5	30-Aug-95	358243	0-2 cm	**0.30** J	NA	NA	0.01 U	NA	0.4 U	NA
5	24-Aug-98	398063	0-10 cm	**0.59**	**0.24**	0.3 U	**0.031**	4 UJ	0.3 U	0.10 U
				EAGLE ROCK						
6	24-Aug-98	398064	0-10 cm	**0.74**	**0.23**	0.3 U	**0.0085**	4 UJ	0.3 U	0.10 U
				ENLOE DAM RESERVOIR						
7	23-Aug-98	398065	0-10 cm	**0.58**	**0.21**	0.3 U	**0.0072**	4 UJ	0.3 U	0.10 U
7	30-Sep-99	408020	0-1 ft	2 U	**1.3**	0.3 U	**0.013**	5 UJ	0.3 U	NA
7	30-Sep-99	408021	1-2 ft	2 U	**0.97**	0.3 U	0.01 U	5 UJ	0.3 U	NA
8	30-Sep-99	408022	0-1 ft	2 U	**1.2**	0.3 U	0.01 U	5 UJ	0.3 U	NA
8	30-Sep-99	408023	1-2 ft	2 U	**1.0**	0.3 U	0.01 U	5 UJ	0.3 U	NA
9	30-Aug-95	358242	0-2 cm	0.3 U	NA	NA	**0.012**	NA	0.4 U	NA
9	23-Aug-98	398066	0-10 cm	**0.73**	**0.23**	0.3 U	**0.014** J	4 UJ	0.3 U	0.10 U
9	30-Sep-99	408024	0-1 ft	2 U	**1.1**	0.3 U	0.01 U	5 UJ	0.3 U	NA

Note: Detections highlighted in **BOLD**
NA = not analyzed
U = not detected at or above reported value
J = estimated value
UJ = not detected at or above reported estimated value

Appendix A-2. Results from Analyzing Semivolatiles, PCBs, and Pesticides in Core Samples Collected behind Enloe Dam in September 1999 (ug/Kg, dry weight; only detected compounds shown)

Site No:	7		8		9
Location:	Upper Reservoir		Middle Reservoir		Lower Res.
Depth Interval (cm):	0-30	30-60	0-30	30-60	0-30
Sample No:	408020	408021	408022	408023	408024
Semivolatiles					
Polyaromatic Hydrocarbons					
Naphthalene	**13**	6.7 U	**7.8** J	12 U	**7.9** J
1-Methylnaphthalene	**14**	6.7 U	**5.8** J	**5.6** J	**7.6** J
2-Methylnaphthalene	**17**	6.7 U	**9.2** J	**8.2** J	**10** J
Fluorene	**8.9** J	6.7 U	12 U	12 U	12 U
Phenanthrene	**55**	**4.2** J	**8.9** J	**8.0** J	**12** J
Anthracene	**23**	6.7 U	12 U	12 U	12 U
Fluoranthene	13 U	**4.2** J	**8.7** J	12 U	**9.7** J
Pyrene	**8.4** J	6.7 U	**6.6** J	**6.3** J	**7.7** J
Benzo(a)anthracene	13 U	**5.2** J	12 U	**9.4** NJ	12 U
Chrysene	13 U	6.7 U	12 U	12 U	**9.6** J
Total PAH	**139**	**14**	**47**	**38**	**64**
Miscellaneous Compounds					
2-Methylphenol	**8.5**	6.7 U	12 U	12 U	**5.9** J
4-Chloro-3-Methylphenol	13 U	6.7 U	12 U	12 U	**17**
2-Nitroaniline	13 U	6.7 U	12 U	12 U	**36**
3-Nitroaniline	**49**	6.7 U	12 U	12 U	12 U
Dibenzofuran	**12** J	6.7 U	**6.4** J	**6.3** J	**7.0** J
Retene	**522**	**7.9**	**83**	**48**	**203**
Carbazole	**1.2** J	6.7 U	12 U	12 U	12 U
Di-N-butylphthalate	**3490** E	54 U	386 U	711 U	243 U
Butylbenzylphthalate	26 U	**10**	19 U	23 U	22 U
PCBs	ND	ND	ND	ND	ND
Chlorinated Pesticides	ND	ND	ND	ND	ND
Organophosphorus Pesticides	ND	ND	ND	ND	ND
Nitrogen Pesticides	ND	ND	ND	ND	ND

Note: Detections highlighted in **BOLD**
U = not detected at or above reported value
J = estimated value
NJ = evidence analyte is present; value is an estimate
E = estimated value that exceeds the calibration
ND = not detected

Appendix B. Metals Data for Ecology Routine Monitoring Station 49B070, Similkameen River @ Oroville (ug/L)

Date	Arsenic				Cadmium				Chromium				Copper			
	Diss.		Tot. Rec.		Diss.		Tot. Rec.		Diss.		Tot. Rec.		Diss.		Tot. Rec.	
09-Oct-95					0.04	U	0.1	U			1	U	0.609		0.7	
11-Dec-95			21.6		0.04	U	0.1	U			4		2.51		10.1	
12-Feb-96			1.94		0.02	U	0.1	U			5	U	0.972		1.5	B
15-Apr-96			3.6		0.077	J	0.1	U			1.5		5.21	J	5.2	
11-Jun-96			6.27		0.022		0.1	U			1.4		1.39		6.3	
13-Aug-96			3.78		0.04		0.1	U			0.4	U	0.846		1.3	
15-Oct-96			2.77		0.019		0.1	U			0.4	U	0.759		1.1	J
10-Dec-96			1.9		0.019		0.1	U			0.4	U	0.48		0.7	
15-Apr-97			2.04		0.02	U	0.1	U			0.27		1.21		2.3	
10-Jun-97			8.28		0.02	U	0.1	U			1.4		1.44		8.7	
12-Aug-97			4.18		0.02	U	0.1	U			0.2	U	0.881		1.1	
15-Dec-98					0.02	U							0.554			
11-May-99					0.02	U							1.22			
02-May-00			3.4													
06-Jun-00			4.6													
11-Jul-00			2.1													
15-Aug-00	5.4		4.4													
05-Sep-00			3.3													
04-Oct-00			2.6													
08-Nov-00																
06-Dec-00																
17-Jan-01																
07-Feb-01																
07-Mar-01																
04-Apr-01	2.36		2.25													
09-May-01	1.6		2.35													
06-Jun-01																
08-Oct-02	3.09		3.07		0.1	U	0.1	U	0.42		0.5	U	0.81		0.99	
03-Dec-02	2.06		1.93		0.02	U	0.1	U	0.75		0.5	U	0.51		0.75	
04-Feb-03	1.73		1.61		0.02	U	0.1	U	0.3		0.5	U	0.74		1.01	
08-Apr-03	1.64		1.7		0.1	U	0.1	U	0.5	U	0.5	U	0.5	U	1.39	J
03-Jun-03	1.5		4.33		0.02	U	0.1	U	0.25	U	1.3		1.18		4.57	
05-Aug-03	6.37		5.61		0.02	U	0.1	U	0.4		0.5	U	0.77		0.98	

B = The analyte was detected in the method blank.
U = The analyte was not detected at or above the reported result.
J = The analyte was positively identified. The associated numerical result is an estimate.

Appendix B. (continued)

Date	Lead				Mercury		Nickel				Zinc				Hardness
	Diss.		Tot. Rec.		Total		Diss.		Tot. Rec.		Diss.		Tot. Rec.		
09-Oct-95	0.03	U	0.1	U	0.001	U	1	U			1.1		5.9	B	86
11-Dec-95	0.362		1.5		0.001		1	U			5	U	14.1	B	82
12-Feb-96	0.025		0.1		0.001	U	0.586				1.2	B	5	U	76
15-Apr-96	0.72	J	0.8		0.002		1.62	J			4.2	B	4.8		63
11-Jun-96	0.032		0.8		0.004		0.508				1.1		10.8	B	43
13-Aug-96	0.02	U	1		0.001	U	0.615				1		3.4	B	78
15-Oct-96	0.087		0.1	U	0.002	U	0.6				1.4	J	3.5	J	98
10-Dec-96	0.03	U	0.2		0.001	U	0.5				0.76		4	J	95
15-Apr-97	0.02	U	0.2		0.002	U	0.73				0.49		14.6		95
10-Jun-97	0.03		0.9		0.002	U	0.562				3.37		13	J	45
12-Aug-97	0.039		0.2		0.002	U	0.602				1.81		2.2		87
15-Dec-98	0.02	U			0.002	U	0.898				0.77				112
11-May-99	0.027				0.003		0.665				1.4	J			66
02-May-00															
06-Jun-00															
11-Jul-00															
15-Aug-00															95.4
05-Sep-00															88.6
04-Oct-00															90.1
08-Nov-00															86.8
06-Dec-00															104
17-Jan-01															103
07-Feb-01															103
07-Mar-01															73.2
04-Apr-01															103
09-May-01															
06-Jun-01															46.7
08-Oct-02	0.02	U	0.14		0.002	U	0.49		0.81		1	U	5	U	94.6
03-Dec-02	0.036		0.1	U	0.0033		0.73		0.71		1	U	5	U	97.8
04-Feb-03	0.02	U	0.1	U	0.002	U	0.39		0.46		1	U	5	U	81.4
08-Apr-03	0.02	U	0.11		0.004	U	0.62		0.91		1.1		5	U	79.4
03-Jun-03	0.041		0.44		0.0066		0.39		1.33		1.3		5.7		38.3
05-Aug-03	0.02	U	0.1	U	0.002	U	0.54		0.66		1	U	5	U	94.7
															38.3

B = The analyte was detected in the method blank.
U = The analyte was not detected at or above the reported result.
J = The analyte was positively identified. The associated numerical result is an estimate.

Appendix C. Site Locations and Other Information on Similkameen River Gold Dredge Samples

Site No. Date Owner	Site Description	River Mile Latitude Longitude*	Dredge Description and Operation	Effluent Flow Stream Depth/Velocity[†] Substrate	Ecology Personnel
#1 1-Jul-04 Creegan	Approx. 500 ft. below BNRR bridge, left bank	6.5 48 56 54 119 27 40	"Precision" dredge, 5" intake reduced to 4", 250 gpm pump, 6-8 feet off bank	1.2 cfs 2.5 ft. / 2.3 fps cobble w/ gravel & sand	Peterschmidt Johnson
#2 1-Jul-04 Lease	Approx. 100 yards below Eagle Rock, left bank	10.8 48 58 58 119 32 05	Custom, 6" intake reduced to 4", 1,200-1,500 gpm pump, 6 feet off bank	1.2 cfs 3 ft. / 0.9 fps cobble w/ sand	Peterschmidt Johnson
#3 18-Aug-04 Ching	S-turn @ irrigation canal crossing, left bank	13.7 48 59 15 119 32 25	Stilt mounted, 2.5"intake, 6.5 hp, working in streamside hole	no data 1.5 ft. / 1.4 fps cobble and boulders	Coffin Latham
#4 18-Aug-04 Sweeney	Approx. 1/2 mile upstream of S-turn, left bank	14.1 48 59 20 119 34 36	Floating dredge, 3" intake, 5 hp pump, 3 feet off bank	no data 1 ft. / 0.9 fps boulders	Coffin Latham
#5 18-Aug-04 Hard	Approx. 1 mile above Eagle Rock, left bank	11.1 48 58 51 119 32 24	Floating dredge, 4" intake, 5 hp pump	no data 3 ft. / 2.2 fps bedrock w/ fines	Coffin Latham
#6 19-Aug-04 Franklin	Above Eagle Rock, left bank	10.9 48 58 53 119 32 17	"Keene" dredge, 4" intake, 5 hp pump	no data 1.3 ft. / 2.5 fps cobble and bedrock	Coffin Latham
#7 18-Aug-04 Estes	Approx. 2 miles below Nighthawk left bank	15.8 48 29 12 119 33 58	"Keene" triple sluice, 4" intake, 300-450 gpm, 20 feet off bank	no data 1.4 ft. / 0.35 fps large cobble w/ fines	Coffin Latham
#8 18-Aug-04 Wade	River Oaks RV Resort, left bank	5.2 48 56 13 119 26 35	"Dahlke Polydredge", 4" intake, 300 gpm, 5 hp pump, 20 feet off bank	1.0 cfs 1.5 ft / 0.5 fps cobble	Johnson Wittmeier

Appendix C. (continued)

Site No. Date Owner	Site Description	River Mile Latitude Longitude*	Dredge Description and Operation	Effluent Flow Stream Depth/Velocity[†] Substrate	Ecology Personnel
#9 19-Aug-04 - -	Approx. 1.5 miles above Eagle Rock, left bank	13 48 59 08 119 33 39	3" intake, 5.5 hp pump, 20 feet off bank	0.2 cfs 1.3 ft. / 0.7 fps cobble and gravel	Peterschmidt Johnson
#10 18-Aug-04 Wade	River Oaks RV Resort, left bank	5.2 48 56 13 119 26 35	"Dahlke Polydredge", 4" intake, 300 gpm, 5 hp pump, 20 feet off bank	1.0 cfs 1.5 ft / 0.5 fps cobble	Johnson Wittmeier
#11 19-Aug-04 - -	Approx. 1/2 mile above S-turn, left bank	14.3 48 59 20 119 34 50	Custom dredge, 4" intake, 5.5 hp pump, 30 feet off bank	0.4 cfs 2 ft. / 0.3 fps cobble	Peterschmidt Johnson
#12 21-Sep-04 Chase	"Boat ramp", left bank	13.3 48 58 50 119 32 32	Floating dredge, 4" intake, 7 hp pump, 10 feet off bank	0.5 cfs 1.5 ft. / 0.85 fps cobble and gravel	Peterschmidt Johnson
#13 21-Sep-04 Miltner	Approx. 1 mile above Eagle Rock, left bank	12.8 48 58 54 119 33 24	Floating dredge, 4" intake, 5.5 hp pump, 10 feet off bank	0.4 cfs 0.9 ft. / 1.3 fps cobble w/ gravel & silt	Peterschmidt Johnson
#14 22-Sep-04 - -	Approx. 1 mile below Enloe Dam, left bank	8.5 48 57 41 119 29 46	Floating dredge, 2.4 inch intake, 6.5 hp pump, 15 feet off bank	- - - - boulders	Peterschmidt

*NAD 27

[†]immediately upstream of dredge intake hose

Appendix D. Results on Laboratory Duplicates for the Similkameen River Gold Dredge Study (laboratory splits)

Sample Type:	Ambient River Water						Dredge Effluent					
Sample No.:	274080	274080-dup.	RPD	344230	344230-dup.	RPD	274087	274087-dup.	RPD	344242	344242-dup.	RPD
Tot. Rec. Zinc (ug/L)	1.6	2.3	36	<1.0	<1.0	0	2.1	2.0	5	3.5	4.0	13
Tot. Rec. Copper (ug/L)	2.4	2.5	4	1.2	1.2	0	2.3	2.3	0	3.2	3.1	3
Tot. Rec. Lead (ug/L)	0.12	0.15	22	<0.10	<0.10	0	0.21	0.21	0	0.40	0.42	5
Tot. Rec. Arsenic (ug/L)	3.7	4.0	8	4.2	4.2	0	3.2	3.2	0	7.1	7.1	0
Dissolved Zinc (ug/L)	1.0	1.1	10	1.2	1.1	9	N/A	N/A	- -	N/A	N/A	- -
Dissolved Copper (ug/L)	0.82	0.83	1	0.87	0.83	5	N/A	N/A	- -	N/A	N/A	- -
Dissolved Lead (ug/L)	<0.02	<0.02	0	<0.10	<0.10	0	N/A	N/A	- -	N/A	N/A	- -
Dissolved Arsenic (ug/L)	2.8	2.8	0	4.2	4.2	0	N/A	N/A	- -	N/A	N/A	- -
TSS (mg/L)	10	10	0	2	3	40	N/A	N/A	- -	N/A	N/A	- -
Turbidity (NTU)	3.7	4.2	13	2.2	2.2	0	N/A	N/A	- -	N/A	N/A	- -
Hardness (mg/L)	52	52	0				N/A	N/A	- -	N/A	N/A	- -

RPD = relative percent difference (range of duplicates as percent of duplicate mean)
N/A = not analyzed

Appendix E. Results on Field Blanks for the Similkameen River Gold Dredge Study (ug/L)

Sample Type	Date	Zinc	Copper	Lead	Arsenic
Bottle Blank	30-Jun-04	<1.0	<0.10	<0.10	<0.10
Filter Blank	"	0.56	<0.10	<0.02	<0.10
Bottle Blank	18-Aug-04	<1.0	<0.10	<0.10	<0.10
Filter Blank	"	1.1	<0.10	<0.10	<0.10
Bottle Blank	21-Sep-04	<1.0	<0.10	<0.10	<0.10
Filter Blank	"	<0.50	<0.10	<0.02	<0.10