Results and Recommendations from Monitoring Arsenic Levels in 303(d) Listed Rivers in Washington

Abstract

Recently collected data on arsenic levels in Washington State rivers and streams are analyzed in light of the 1998 303(d) listings for the Stillaguamish, Puyallup, Cowlitz, Yakima, Similkameen, Spokane, and Columbia rivers. The listings were based on historical data showing total recoverable arsenic concentrations exceeded very low EPA National Toxics Rule (NTR) human health criteria of 0.018 and 0.14 ug/L. The NTR criteria are for total inorganic arsenic, which is often the major form of arsenic in surface waters.

The recent data suggest that total recoverable arsenic concentrations in local rivers and streams are typically in the range of 0.2 - 1.0 ug/L, while concentrations greater than 2 to 5 ug/L may indicate contamination from anthropogenic sources. Arsenic levels in most 303(d) listed waterbodies are not clearly different from waterbodies that have no apparent sources, and some are comparable to rainwater.

It is recommended that 303(d) listings for arsenic be removed for the Puyallup, Cowlitz, Spokane, and Columbia rivers. The listings for the Similkameen and Stillaguamish rivers are currently being addressed through Total Maximum Daily Load (TMDL) studies. A TMDL should be conducted for arsenic in the lower Yakima River, where human activity has been shown to be the source of contamination. Water quality data considered for future 303(d) arsenic listings should clearly demonstrate that exceedances of standards are due to anthropogenic, rather than natural, sources and should include some measurement of total inorganic arsenic.

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Waterbody Numbers

WA-05-1010
WA-10-1020
WA-26-1040
WA-37-1010
WA-49-1030
WA-57-1010
WA-CR-1010
WA-CR-1020
WA-CR-1060

Introduction

To comply with requirements of the federal Clean Water Act, Section 303(d), every four years the Washington State Department of Ecology (Ecology) Water Quality Program (WQP) identifies polluted waterbodies that are not meeting state surface water quality standards and are not expected to improve within the next four years. The 303(d) list of water quality limited estuaries, lakes, rivers, and streams is then submitted to the U.S. Environmental Protection Agency (EPA). EPA requires the states to set priorities for cleaning up threatened waters and to establish a Total Maximum Daily Load (TMDL) for each. A TMDL entails an analysis of how much pollution a waterbody can assimilate and still remain healthy for its intended uses.

Eight waterbodies were placed on the 1998 303(d) list for exceeding human health water quality criteria for arsenic (Table 1). Washington State follows the EPA National Toxics Rule (40 CFR Part 131) when determining if a waterbody should be listed for human health concerns. The listing criteria for arsenic are 0.018 ug/L (parts per billion) for consumption of water and organisms, and 0.14 ug/L for consumption of organisms only. Although these criteria are for total inorganic arsenic, the 1998 listings were based on total recoverable arsenic data. Inorganic arsenic is often the major form of arsenic in surface waters.

No waterbodies are on the 303(d) list for exceeding state aquatic life standards for arsenic (WAC 173-201A-040). The arsenic standards for freshwater are 360 ug/L for acute exposure and 190 ug/L for chronic exposure. The standards apply to dissolved arsenic.

Arsenic is naturally occurring in rocks and soils, and routinely detectable in surface water. The approach of listing waterbodies based on total recoverable arsenic data resulted in every river which had data being listed. While many of these rivers appeared to have similar levels of arsenic, the comparability of the data is confounded by differences in the year and season of collection, sampling procedures, analytical methods, and detection limits.

The NTR arsenic criteria are at or below the detection limits of routinely available analytical methods. The 1998 303(d) list includes the following cautionary statement about these listings: "There is significant uncertainty regarding the accuracy of the current arsenic criteria for human health. Even EPA is reluctant to impose the criteria (62 FR 42179, August 5, 1997) that they promulgated on Washington State through the National Toxic Rule. Ecology is currently considering revising the arsenic standard."

In light of questions about the 1998 arsenic listings, the Ecology Environmental Assessment Program conducted routine monitoring of arsenic levels in selected 303(d) listed rivers and in several other rivers judged to be relatively free of significant anthropogenic sources of arsenic. The monitoring began in July 2001 and continued through June 2002. The objective was to provide WQP with a consistent set of low-level arsenic data that would aide them in determining if these listings are appropriate. Results and recommendations from the monitoring are the subject of the present report.

Table 1. 1998 303(d) Listings for Arsenic in the Water Column

Waterbody WRIA, Segment ID	Basis for Listing
Stillaguamish River WRIA 5, WA-05-1010	3 excursions beyond the National Toxics Rule criterion out of 3 samples (100%) at Ecology ambient monitoring station 05A070 (RM 11.1) between 9/91 and 9/96.
Puyallup River WRIA 10, WA-10-1020	3 excursions beyond the National Toxics Rule criterion out of 3 samples (100%) at Ecology ambient monitoring station 10A070 (RM 8.3) between 9/91 and 9/96.
Cowlitz River WRIA 26, WA-26-1040	3 excursions beyond the National Toxics Rule criterion out of 3 samples (100%) at Ecology ambient monitoring station 26B070 (RM 4.9) between 9/91 and 9/96.
Columbia River WRIA 27, WA-CR-1010	Fuhrer et al., 1996. 4 excursions beyond the National Toxics Rule criterion near Columbia City.
Columbia River WRIA 28, WA-CR-1010	Fuhrer et al., 1996. 4 excursions beyond the National Toxics Rule criterion at Hayden Island.
Columbia River WRIA 28, WA-CR-1010	Fuhrer et al., 1996. 4 excursions beyond the National Toxics Rule criterion at Warrendale.
Columbia River WRIA 31, WA-CR-1020	3 excursions beyond the National Toxics Rule criterion out of 3 samples (100%) at Ecology ambient monitoring station 31A070 (RM 290.5) between 9/91 and 9/96.
Yakima River WRIA 37, WA-37-1010	Fuhrer et al., 1996. 15 samples collected at station 50 (Kiona) exceeded the National Toxics Rule criterion between 1987 and 1990.
Yakima River WRIA 37, WA-37-1010	Fuhrer et al., 1996. 15 samples collected at station 52 (at Yakima RM 72 above Status Creek near Sunnyside) exceeded the National Toxics Rule criterion between 1987 and 1990.
Yakima River WRIA 37, WA-37-1010	Fuhrer et al., 1996. 6 samples collected at station 56 (RM 55) exceeded the National Toxics Rule criterion between 1987 and 1990.
Similkameen River WRIA 49, WA-49-1030	Dept. of Ecology, unpublished data (Johnson 1996 draft - submitted 10/31/97), show 2 excursions beyond the National Toxics Rule criterion on 8/29/95 and 4/26/96 at Nighthawk.
Similkameen River WRIA 49, WA-49-1030	Dept. of Ecology, unpublished data (Johnson 1996 draft - submitted 10/31/97), show 2 excursions beyond the National Toxics Rule criterion on 8/29/95 and 4/26/96 at Oroville.
Spokane River WRIA 57, WA-57-1010	3 excursions beyond the National Toxics Rule criterion out of 3 samples (100%) at Ecology ambient monitoring station 57A150 (RM 96.0) between 9/91 and 9/96.
Franklin D. Roosevelt Lake WRIA 61, WA-CR-1060	4 excursions beyond the National Toxics Rule criterion out of 4 samples (100%) at Ecology ambient monitoring station 61A070 (RM 735.1) between 9/91 and 9/96.

Among the waterbodies listed for arsenic in 1998, a draft TMDL assessment has been completed for the Similkameen River (Johnson, 2002) and a TMDL study is currently underway in the lower Stillaguamish River (Joy, 2001).

Selection of Monitoring Stations

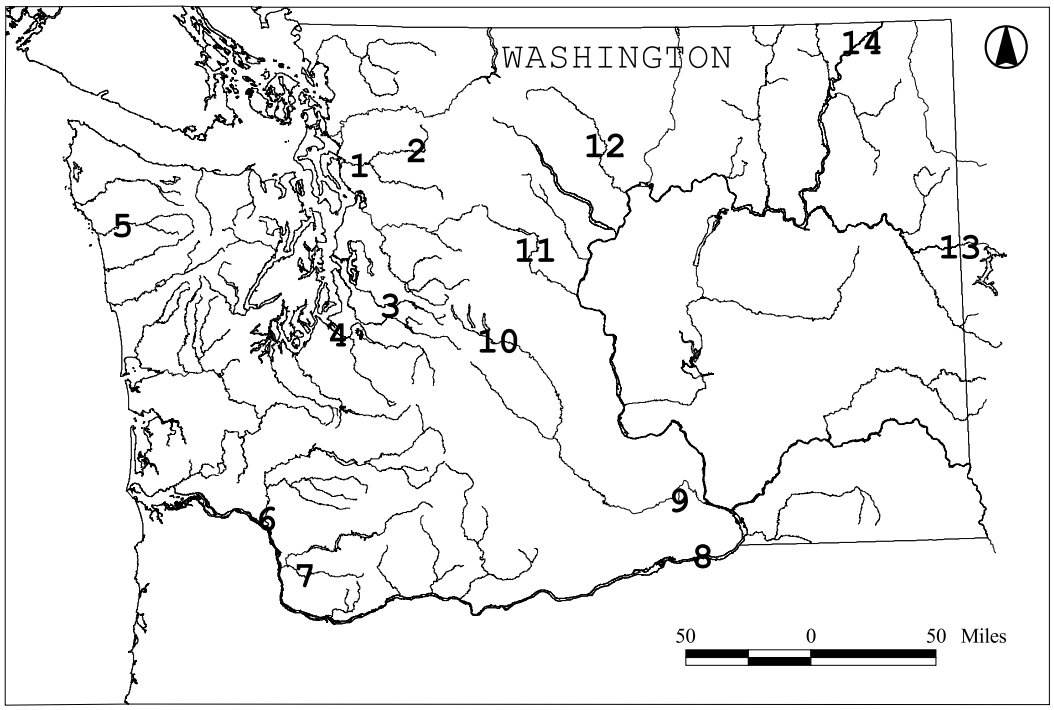
Monthly arsenic sampling was conducted at 14 stations in the Ecology 2001 - 2002 ambient monitoring network (Figure 1, Table 2).

Seven of these stations were selected because arsenic data from that site had been used for 303(d) listing of the river. Seven additional sites were selected as reference stations. Reference stations were either in the upper drainage of the listed waterbody or in a nearby river that had no obvious sources of arsenic, based on professional judgment. No appropriate ambient monitoring stations were available that might serve as a reference for the Spokane or Columbia rivers. There were no ambient stations in the vicinity of the Columbia River listings at Columbia City, Hayden Island, or Warrendale.

A series of upstream-to-downstream samples was also collected in the Puyallup, Cowlitz, and lower Columbia rivers (Figure 2). These transects were made in the fall of 2001 and spring of 2002 and included several major tributaries. The objective here was to obtain screening-level data that might point to sources of arsenic. Detailed information on sampling locations is provided in Appendix A.

The water samples were analyzed for total recoverable arsenic. Inorganic arsenic was determined in a subset of the April 2002 ambient samples. The cost of analyzing inorganic arsenic precluded analyzing a large number of samples.

Temperature, conductivity, and total suspended solids were measured for all sampling sites. Other routine parameters at Ecology ambient monitoring stations include but are not limited to dissolved oxygen, pH, turbidity, fecal coliform bacteria, soluble reactive phosphorus total phosphorus, ammonia, nitrate+nitrite, and total nitrogen.

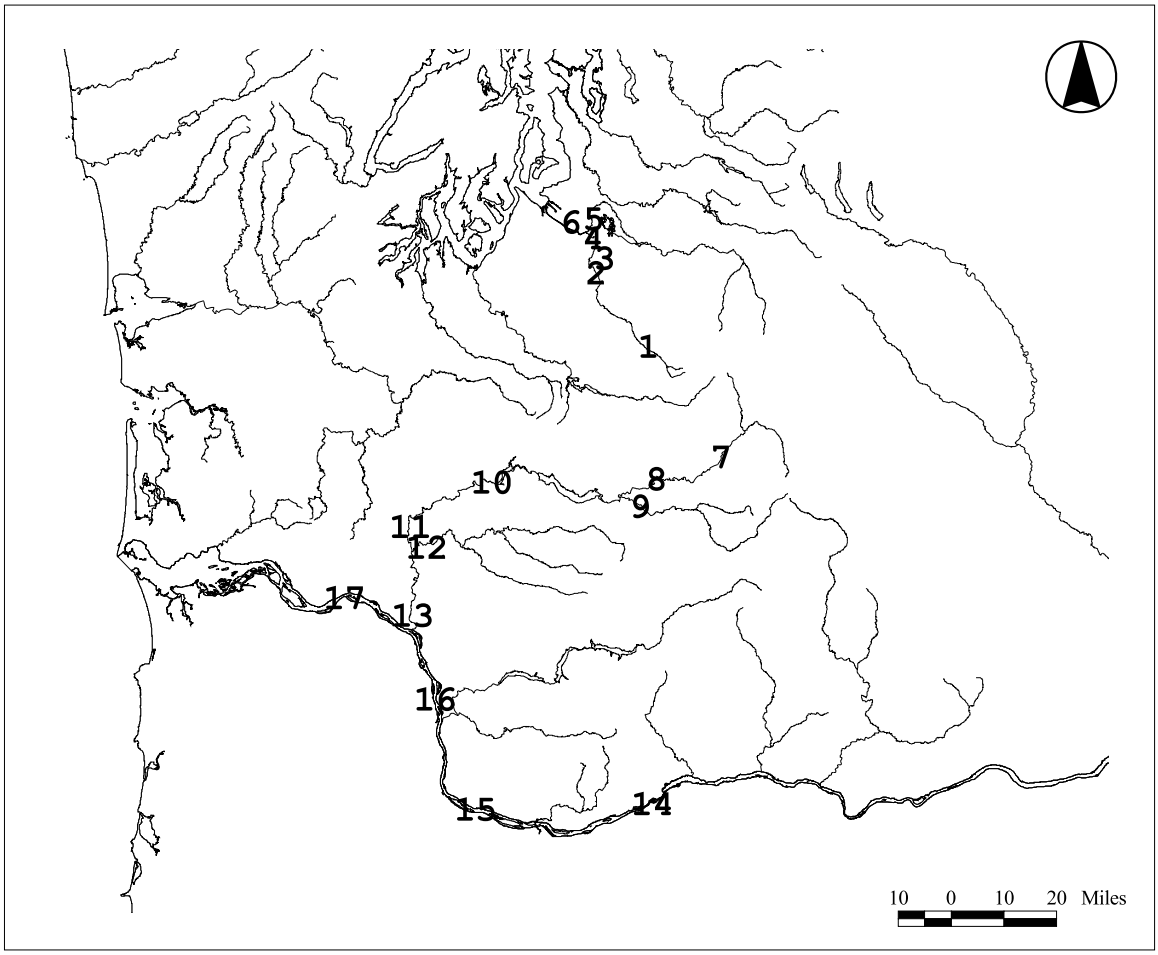


1. Stillaguamish River nr Silvana
2. NF Stillaguamish River nr Darrington
3. Cedar River nr Landsburg
4. Puyallup River @ Meridian Street
5. Hoh River @ DNR Campground
6. Cowlitz River @ Kelso
7. EF Lewis River nr Dollar Corner
8. Columbia River @ Umatilla
9. Yakima River @ Kiona
10. Yakima River nr Cle Elum
11. Wenatchee River nr Leavenworth
12. Methow River @ Twisp
13. Spokane River @ Stateline Bridge
14. Columbia River @ Northport

Figure 1. Ecology Ambient Monitoring Stations Where Monthly Arsenic Samples Were Collected, July 2001 - June 2002.

Table 2. Ecology Ambient Monitoring Stations Where Monthly Arsenic Samples Were Collected, July 2001 - June 2002.

Station No.	Station Name	303(d) Listed	Reference Station
05A070	Stillaguamish River nr Silvana	x	
05B110	NF Stillaguamish River nr Darrington		x
08C110	Cedar River nr Landsburg		x
10A070	Puyallup River @ Meridian Street	x	
20B070	Hoh River @ DNR Campground		x
26B070	Cowlitz River @ Kelso	x	
27D090	EF Lewis River nr Dollar's Corner		x
31A070	Columbia River @ Umatilla	x	
37A090	Yakima River @ Kiona	x	
39A090	Yakima River nr Cle Elum		x
45A110	Wenatchee River nr Leavenworth		x
48A140	Methow River @ Twisp		x
57A150	Spokane River @ Stateline Bridge	x	
61A070	Columbia River @ Northport	x	



Puyallup River

1. Puyallup R. ab. Electron
2. Puyallup R. ab. Carbon R.
3. Carbon River
4. Puyallup R. ab. White R.
5. White River
6. Puyalllup R. @ Meridian St.

Cowlitz River

7 Cowlitz R. @ Packwood
8. Cowlitz R. ab. Cispus R.
9. Cispus River
10. Cowlitz R. bw Mayfield Dam
11. Cowlitz R. ab. Toutle R.
12. Toutle River
13. Cowlitz R. @ Kelso

Columbia River

14. Columbia R. @ Beacon Rock
15. Columbia R. @ Ryan Pt.
16. Columbia R. @ Columbia City
17. Columbia R. @ Abernathy Pt.

Figure 2. Sampling Sites for Arsenic Transects, Fall 2001 and Spring 2002

Methods

Field

Sampling methods for the ambient monitoring program are described in Hallock (2001). Sample containers for this project were obtained from the Ecology Manchester Environmental Laboratory or Frontier Geosciences Inc., Seattle, WA.

Arsenic sampling methods followed EPA Method 1669 guidance on clean sampling procedures for metals (EPA, 1995). The ambient monitoring samples were collected with a stainless steel bridge sampler developed by the Ecology Freshwater Monitoring Unit. This sampler and the field procedures used for metals at ambient stations are described in Hopkins (1996). The samples for the transects down the Puyallup, Cowlitz and Columbia rivers were collected from the bank by wading into the river or with the sample bottle attached to the end of a polyethylene pole.

Total recoverable arsenics samples were collected directly into pre-cleaned 500 mL Teflon bottles. The samples were preserved to pH <2 with sub-boiled 1:1 nitric acid, carried in small Teflon vials, one per sample. Teflon sample bottles, Nalgene filters (see below), and Teflon acid vials were cleaned at Manchester Laboratory, as described in Kammin et al. (1995), and sealed in plastic bags. Bottle blanks from this procedure have had no arsenic detectable at or above 0.2 ug/L.

Samples for inorganic arsenic were filtered in the field through a pre-cleaned 0.45 um Nalgene filter unit (#450-0045, type S). The filtrate was transferred to 60 mL glass vials and acidified with ultra-clean HCl to 1%.

The arsenic samples were placed in polyethylene bags and, along with other samples, held on ice for transport to Ecology headquarters. The samples were kept in a secure cooler and transported to Manchester Laboratory within one-to-two days of collection. The inorganic arsenic samples were collected over a period of approximately three weeks, held at Ecology headquarters, and then transported to Frontier Geosciences at the end of this period.

Laboratory

All samples were analyzed at Manchester Laboratory, except inorganic arsenic was analyzed at Frontier Geosciences. Total recoverable arsenic was analyzed by inductively coupled plasma - mass spectrometry using EPA Method 200.8. Total inorganic arsenic was analyzed by hydride generation-cryogenic trapping-gas chromatography-atomic absorption spectrometry. Analytical methods for arsenic are further described in Johnson (2002). Methods for other parameters are given in Hallock (2001).

Data Quality

Manchester Laboratory prepared written quality assurance reviews that establish the quality of the total recoverable arsenic 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, standard reference material (SRM), matrix spike and matrix spike duplicate recoveries, and duplicate sample analyses. No problems were encountered that compromise the accuracy, validity, or usefulness of the data. The case narratives and complete chemical data are available from the author.

The SRM for this project was SLRS-4, River Water Reference Material for Trace Metals. SLRS-4 was prepared by the National Research Council of Canada using St. Lawrence River water. It has a certified arsenic value of 0.68+/-0.06 ug/L, which is in the range of concentrations normally encountered in uncontaminated rivers and streams. SLRS-4 was analyzed with each sample set. Arsenic recoveries ranged from 92 -128%.

The variability in the total recoverable data reported here can be estimated from results on replicate field samples and laboratory split samples (Table 3). The replicate and split sample pairs generally agreed within 20% or better. These results have been averaged for use in the remainder of this report, using the detection limit for non-detected values.

Table 3. Precision Data for Arsenic (ug/L, total recoverable)

		Field Replicates			Lab Duplicates		
Station	Date	Sample #1	Sample #2	RPD	Sample #1	Sample #2	RPD
Puyallup R. @ Meridian St.	24-Apr-02	0.51	0.53	8%	0.50	0.52	8%
"	26-Sep-01	1.0	0.98	4%	1.0	1.0	0%
Cowlitz R. @ Kelso	25-Apr-02	0.28	0.25	21%	0.24	0.31	58%
"	5-Oct-01	0.46	0.47	4%	0.46	0.46	0%
Yakima R. @ Kiona	3-Apr-02	NA	NA	- -	1.0	1.0	0%
"	4-Sep-01	NA	NA	- -	2.2	2.3	9%
"	5-Dec-01	NA	NA	- -	1.2	1.2	0%
Hoh R. @ DNR Campground	15-Apr-02	NA	NA	- -	0.50	0.46	16%
"	24-Sep-01	NA	NA	- -	0.25	0.25	0%
"	10-Dec-01	NA	NA	- -	0.24	0.22	17%
Columbia R. @ County Line Pk.	25-Sep-01	1.2	1.2	0%	1.2	1.2	0%

RPD = relative percent difference; range of results as percent of mean concentration

Quality control data reported by Frontier Geosciences for the inorganic arsenic analysis included results for procedural blanks, SRM NIST 1640, laboratory duplicates, and a MS/MSD. All results were within QC limits. The case narrative and complete chemical data are available from the author.

Results

Ambient Data

Table 4 summarizes the monthly monitoring data on total recoverable arsenic in terms of detection frequency and minimum, maximum, mean, and median concentrations. A box plot of the data is provided in Figure 3. Appendix B has the results for individual samples, including data on flow, temperature, pH, conductivity, total suspended solids, and turbidity.

Table 4. Summary Statistics on Arsenic Concentrations at Ecology Ambient Monitoring Stations, July 2001 - June 2002 (ug/L, total recoverable)

Station Name	Detection Frequency	Minimum	Maximum	Mean	Median
Wenatchee R nr Leavenworth	0/12	<0.10	<0.20	<0.20	<0.20
Yakima R nr Cle Elum	4/12	<0.10	0.28	0.19	0.20
Hoh R @ DNR Campground	7/12	<0.10	0.50	0.24	0.22
EF Lewis R nr Dollar's Corner	7/12	0.13	0.63	0.30	0.20
Cowlitz R @ Kelso	12/12	0.22	0.74	0.39	0.36
Methow R @ Twisp	12/12	0.31	0.51	0.40	0.39
Cedar R nr Landsburg	12/12	0.12	0.71	0.42	0.39
Columbia R @ Northport	12/12	0.26	0.86	0.44	0.41
Spokane R @ Stateline Br	12/12	0.43	0.67	0.52	0.51
NF Stillaguamish nr Darrington	12/12	0.19	2.0	0.67	0.49
Puyallup R @ Meridian St	12/12	0.47	1.1	0.71	0.65
Columbia R @ Umatilla	12/12	0.42	1.4	1.0	1.0
Stillaguamish R nr Silvana	12/12	0.37	2.6	1.1	0.83
Yakima R @ Kiona	12/12	0.82	2.7	1.5	1.2

Arsenic was detectable at all stations except for the upper Wenatchee River, a reference station near Leavenworth. There were no detections in the upper Wenatchee at or above 0.10 to 0.20 ug/L. The detection frequency at three other reference stations – Yakima River near Cle Elum, Hoh River, and East Fork Lewis River – was approximately 30 to 60% of the

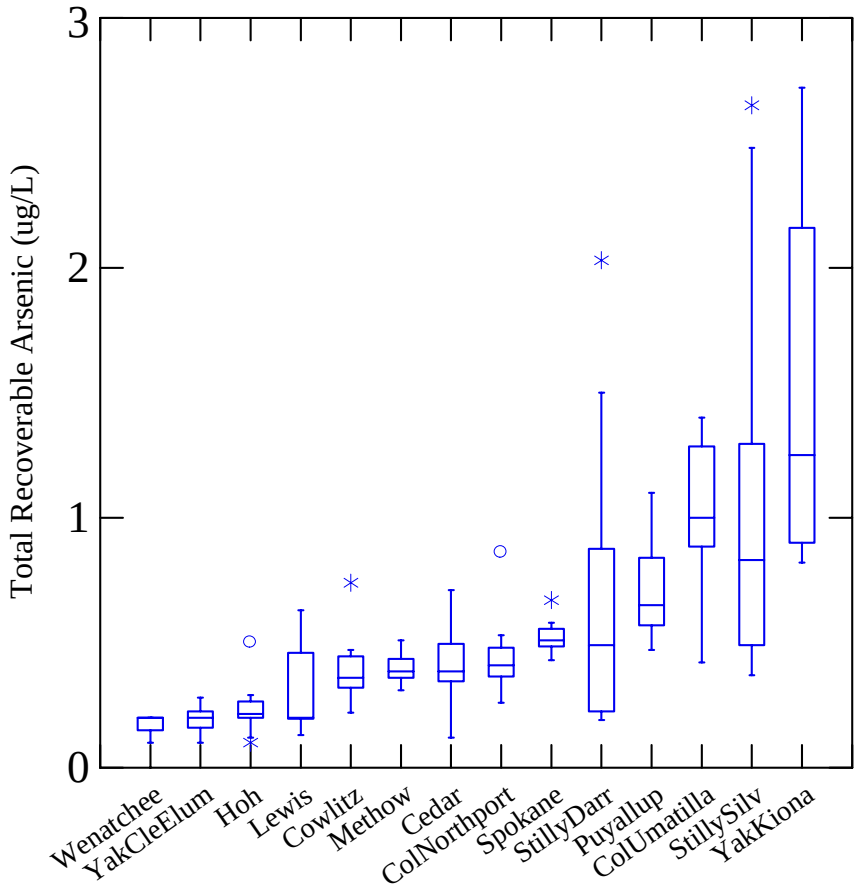


Figure 3. Box Plot of Arsenic Concentrations at Ecology Ambient Monitoring Stations, July 2001 through June 2002. (Detection limit used for non-detected values.)

samples. Arsenic was detected in 100% of the samples from the remaining ten stations, including the Methow, Cedar, and North Fork Stillaguamish reference stations.

Arsenic concentrations at these 14 ambient stations ranged from less than 0.10 to 2.7 ug/L. The overall median concentration was 0.58 ug/L.

The highest levels were recorded for the lower Yakima River @ Kiona and lower Stillaguamish River @ Silvana. Studies by the U.S. Geological Survey (USGS) have shown that the elevated arsenic in the Yakima is due to historical use of lead-arsenate pesticides (Fuhrer et al., 1996). Natural sources of arsenic are known to occur in the Stillaguamish basin, specifically, geologic formations in the south fork watershed (Davies et al., 1991; Ficklin et al., 1989; Goldstein, 1988).

Omitting the data from the lower Yakima, median arsenic concentrations among the remaining ambient stations are confined to a relatively narrow range of <0.2 to 1.0 ug/L, with an overall median of 0.40 ug/L. Reference stations were sometimes lower than and sometimes higher than 303(d) listed stations.

Except for the upper Wenatchee River, arsenic concentrations at all stations exceeded the NTR human health arsenic criteria of 0.018 and 0.14 ug/L The 0.10 - 0.20 ug/L detection limit achieved for total recoverable arsenic was not low enough for comparing the upper Wenatchee results to the NTR (but see inorganic data below).

Inorganic Arsenic Data

The inorganic arsenic data are in Table 5. These samples were filtered in the field, and the results are for the dissolved fraction.

Table 5. Inorganic Arsenic Data (ug/L)

Station	Date	Dissolved Inorganic Arsenic	Total Recoverable Arsenic	Percent Dissolved Inorganic
Puyallup R @ Meridian St.	16-Apr-02	0.40	0.96	42%
Cowlitz R @ Kelso	17-Apr-02	0.16	0.74	22%
Hoh R @ DNR Campground	15-Apr-02	0.092	0.50	18%
Methow R @ Twisp	02-Apr-02	0.26	0.38	68%
Wenatchee R nr Leavenworth	03-Apr-02	0.050	<0.10	<50%
Cedar R nr Landsburg	24-Apr-02	0.31	0.33	94%
Yakima R @ Kiona	03-Apr-02	0.66	1.0	66%
Spokane R @ Stateline Br.	09-Apr-02	0.37	0.51	73%

Dissolved inorganic arsenic concentrations ranged from 0.050 to 0.66 ug/L. The Wenatchee River near Leavenworth had the lowest concentration and the Yakima River @ Kiona had the highest concentration, in keeping with results for total recoverable. All samples exceeded NTR criteria, with the Wenatchee only exceeding the lower 0.018 ug/L criterion.

Dissolved inorganic arsenic was 18 to 94% of total recoverable. These dissolved data may underestimate total inorganic arsenic by a substantial amount. Most of the arsenic in rivers and streams is in inorganic form (Callahan et al., 1979; Anderson and Bruland, 1991). Other Ecology data on total inorganic arsenic in Washington rivers and streams is currently limited to the Similkameen River. In the Similkameen, total inorganic arsenic is typically $\geq$ 75% of total recoverable (Johnson, 2002).

Downstream Transects

The results from the downstream transects conducted in the Puyallup, Cowlitz, and lower Columbia rivers are shown in Table 6. The arsenic levels measured in these samples were in the same range as the ambient data discussed above.

Examination of the data for the Cowlitz shows that, under both low and high flow conditions, arsenic levels were greater in the upper river than the lower river. The 303(d) listing is based on Ecology ambient data collected near the river mouth (Cowlitz River @ Kelso). The highest concentrations were found in the Toutle River. These results suggest that the arsenic levels in the Cowlitz are primarily due to natural sources such as glacier melt water and/or volcanic activity (Toutle River).

A different pattern is seen in the Puyallup River, where arsenic concentrations were either similar or increased from upstream to downstream. During low flow, mainstem concentrations were 0.76 to 1.0 ug/L. Concentrations more than doubled from upstream to downstream during high flow – from 0.21 to 0.52 ug/L – with the Carbon and White rivers appearing to be important sources. The 303(d) listing is based on Ecology ambient data for the lower river (Puyallup River @ Meridian Street).

Only a few arsenic data were obtained for the lower Columbia River. Results suggest a slight decrease in arsenic concentrations moving downstream from Beacon Rock to County Line Park. The 303(d) listings are based on USGS data collected at Columbia City, Hayden Island, and Warrendale, all in Oregon. In Table 6, Ryan Point is on the Oregon side off the upstream end of Hayden Island, and County Line Park is on the Washington side opposite Warrendale.

Other Data

Contaminated Rivers and Streams

The highest arsenic concentrations Ecology has recorded in a major Washington river have been in the Similkameen. The second highest arsenic concentrations for a major river have been observed in the lower Yakima.

Table 6. Results from Arsenic Transects (total recoverable)

Location	Date	Temp. (°C)	Conduct. (umhos/cm)	TSS (mg/L)	Arsenic (ug/L)
Fall 2001					
Cowlitz R. @ Packwood	05-Oct-01	11.0	65	28	0.79
Cowlitz R. above Cispus River	05-Oct-01	NA	NA	NA	NA
Cispus River	05-Oct-01	NA	NA	NA	NA
Cowlitz R. below Mayfield Dam	05-Oct-01	13.6	61	1	0.27
Cowlitz R. above Toutle River	05-Oct-01	11.7	73	2	0.33
Toutle River	05-Oct-01	13.3	413	5	1.2
Cowlitz R. @ Kelso	05-Oct-01	13.1	114	8	0.46
Puyallup R. above Electron	26-Sep-01	7.7	62	371	0.76
Puyallup R. above Carbon River	26-Sep-01	9.3	56	558	1.2
Carbon River	26-Sep-01	10.8	66	717	1.0
Puyallup R. above White River	26-Sep-01	10.2	65	1000	1.5
White River	26-Sep-01	13.0	112	92	1.3
Puyallup R. @ Meridian St.	26-Sep-01	11.5	79	313	1.0
Columbia R. @ Beacon Rock	25-Sep-01	19.5	149	2	1.5
Columbia R. @ Ryan Point	25-Sep-01	18.8	152	2	1.2
Columbia R. @ Columbia City	25-Sep-01	19.4	141	4	1.1
Columbia R. @ County Line Park	25-Sep-01	19.3	155	4	1.1
Spring 2002					
Cowlitz R. @ Packwood	25-Apr-01	6.6	49	1U	0.22
Cowlitz R. above Cispus River	25-Apr-01	6.9	56	24	0.35
Cispus River	25-Apr-01	6.0	54	7	0.19
Cowlitz R. below Mayfield Dam	25-Apr-01	7.9	54	2	0.19
Cowlitz R. above Toutle River	25-Apr-01	7.3	56	9	0.13
Toutle River	25-Apr-01	9.8	148	481	0.95
Cowlitz R. @ Kelso	25-Apr-01	9.0	70	50	0.26
Puyallup R. above Electron	24-Apr-01	7.9	66	2	0.21
Puyallup R. above Carbon River	24-Apr-01	8.4	68	7	0.22
Carbon River	24-Apr-01	7.8	72	3	0.36
Puyallup R. above White River	24-Apr-01	7.0	75	12	0.35
White River	24-Apr-01	8.1	79	11	0.68
Puyallup R. @ Meridian St.	24-Apr-01	7.5	72	7	0.52

Webber (2001) assessed the state of water quality in the Canadian portion of the Similkameen River based on data collected up to 1997. He demonstrated that a seasonal peak in total recoverable arsenic concentrations occurs near the U.S. border during the spring. Tailings piles and waste rock deposited along the stream banks in British Columbia have been the major source.

Between 1984 and 1997, the British Columbia aquatic life guideline of 5 ug/L was exceeded on 19 occasions (5% of values), and almost all of these occurred during spring freshet when turbidity was elevated. The B.C. drinking water guideline of 25 ug/L was exceeded three times, all prior to 1992. A maximum concentration of 56 ug/L has been recorded historically. In recent years, arsenic concentrations have generally been less than 10 ug/L (Johnson, 2002).

Elevated arsenic concentrations have been observed in smaller streams, also in association with mining activity. Raforth et al. (2000, 2002) surveyed water quality in creeks draining Washington mining districts. Elevated arsenic concentrations in the range of 5 to 16 ug/L (total recoverable) were found in 5 of the 20 creeks sampled.

Background

It is not possible to state with certainty what the natural background is for arsenic in Washington rivers and streams. Ecology has obtained data on several waterbodies that have or have had only limited human activity (Table 7). The range in total recoverable arsenic concentrations at these sites is similar to the ambient data previously discussed.

Table 7. Arsenic Concentrations in River and Stream Locations Without Known Sources of Contamination (ug/L)

Waterbody	County	Sample Location	Date	N =	Tot. Rec. Arsenic	Reference
Stehekin R.	Chelan	Lake Chelan	12/86-11/87	5	0.41 +/- 0.18	Patmont et al. (1989)
Railroad Cr.	Chelan	Glacier Peak Wilderness	6/96, 9/96	2	0.69, 0.88	Johnson & White (1997)
Douglas Cr.	Douglas	Badger Mountain	4/97	1	0.95	Johnson (1998)
Swauk Cr.	Kittitas	Blewett Pass	6/97, 10/97	2	0.38, <1.5	Raforth et al. (2000)
Toroda Cr.	Okanogan	Okanogan Nat. Forest	6/97, 10/97	2	1.2, <1.5	"
Goat Cr.	Okanogan	Near Mazama	6/00, 5/01	2	<0.20, 0.62	Raforth et al. (2002)
Clugston Cr.	Stevens	Near Colville	6/00, 5/01	2	<0.50, 0.37	"

Arsenic levels have been measured in samples of Pacific Northwest rainwater, although not recently. Crecelius et al. (1975) measured arsenic concentrations in several dozen unfiltered rain samples collected from the Seattle area and west of the Olympic Mountains in 1974. Total recoverable arsenic concentrations in Seattle precipitation averaged 17+/-8 ug/L. Crecelius attributed the high concentrations in Seattle rain to the ASARCO smelter in Tacoma, now closed.

Rainwater samples taken west of the Olympics contained only 0.4+/-0.2 ug/L arsenic. Precipitation at this location would be expected to have background levels of arsenic. These concentrations are in the same range as most rivers and streams in Washington.

Conclusions and Recommendations

The data presented in this report suggest that arsenic concentrations in local rivers and streams are typically in the range of 0.2 - 1.0 ug/L. Concentrations greater than 2 to 5 ug/L may indicate contamination from anthropogenic sources. The arsenic levels in most 303(d) listed waterbodies are not clearly different from waterbodies that have no apparent sources and are comparable to rainwater. Exceedances of the NTR arsenic criteria are to be expected in Washington rivers and streams.

Therefore, it is recommended that the 1998 303(d) listings for arsenic be removed for the Puyallup, Cowlitz, Spokane, and Columbia rivers (both the lower river and Franklin D. Roosevelt Lake). These actions would be consistent with Ecology's new 303(d) listing policy for toxic pollutants, which states that "Data submitted for toxic pollutants must be for the specific isomer or chemical fraction that the criteria relate to." (WQP Policy 1-11)

The listings for the Similkameen and Stillaguamish rivers are currently being addressed through TMDLs. The draft TMDL report for the Similkameen recommends a numeric water quality target for arsenic of 0.4 - 0.6 ug/L (Johnson, 2002). It is anticipated that the results of the Stillaguamish TMDL will point to natural sources of arsenic (Joe Joy, personal communication).

Although there is no total inorganic arsenic data for the Yakima River, USGS has conducted a detailed analysis of arsenic sources to the river. Their studies show the contamination is due to human activity (Fuhrer et al., 1996). It is therefore recommended that a TMDL be conducted for arsenic in the lower Yakima River.

Table 8 summarizes this report's recommendations for the arsenic listings. Of the 14 listings evaluated, eight are recommended for delisting, three are recommended for TMDLs, and three have TMDLs currently underway.

Water quality data considered for future 303(d) arsenic listings should clearly demonstrate that any exceedances of standards are due to anthropogenic sources, and should include some measurement of total inorganic arsenic. Arsenic levels in Washington rivers and streams should be attributed to natural sources, unless shown to be otherwise.

Table 8. Summary of Recommendations on 1998 303(d) Listings for Arsenic in the Water Column

Waterbody WRIA, Segment ID	Remove from 303(d) List	Conduct TMDL Study	TMDL Study Currently Underway
Puyallup River WRIA 10, WA-10-1020	X		
Cowlitz River WRIA 26, WA-26-1040	X		
Columbia River WRIA 27, WA-CR-1010	X		
Columbia River WRIA 28, WA-CR-1010	X		
Columbia River WRIA 28, WA-CR-1010	X		
Columbia River WRIA 31,WA-CR-1020	X		
Spokane River WRIA 57, WA-57-1010	X		
Franklin D. Roosevelt Lake WRIA 61, WA-CR-1060	X		
Yakima River WRIA 37, WA-37-1010		X	
Yakima River WRIA 37, WA-37-1010		X	
Yakima River WRIA 37, WA-37-1010		X	
Stillaguamish River WRIA 5, WA-05-1010			X
Similkameen River WRIA 49, WA-49-1030			X
Similkameen River WRIA 49, WA-49-1030			X

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References

Anderson, L.C.D. and K.W. Bruland. 1991. Biogeochemistry of Arsenic in Natural Waters: Importance of Methylated Species. Environ. Sci. Tech. 25:420-427.

Callahan, M.A. et al. 1979. Water-related Environmental Fate of 129 Priority Pollutants. EPA-440/4-79-029a.

Crecelius, E.A., M.H. Bothner, and R. Carpenter. 1975. Geochemistries of Arsenic, Antimony, Mercury, and Related Elements in Sediments of Puget Sound. Environ. Sci. Tech. 9(4):325-333.

Davies, J., R. Davis, D. Frank, F. Frost, D. Garland, S. Milham, R.S. Pierson, R.S. Raasina, S. Safioles, and L. Woodruff. 1991. Seasonal Study of Arsenic in Ground Water: Snohomish County, Washington. Snohomish Health District and Washington State Dept. of Health unpublished report. p.18.

EPA. 1995. Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Levels. EPA 821-R-95-034.

Ficklin, W.H., D.G. Frank, P.K. Briggs, and R.E. Tucker. 1989. Analytical Results for Water, Soil, and Rocks Collected Near the Vicinity of Granite Falls Washington as Part of an Arsenic-in-groundwater Study. U.S. Geological Survey, Open-File Report 89-148. p. 9.

Fuhrer, G.J., D.J. Cain, S.W. McKenzie, J.F. Rinella, J.K. Crawford, K.A. Sach, and M.I. Hornberger. 1996. Surface-Water-Quality Assessment of the Yakima River Basin in Washington: Spatial and Temporal Distribution of Trace Elements in Water, Sediment, and Aquatic Biota, 1987-91. U.S. Geological Survey, Open-File Report 95-440.

Goldstein, L. 1988. A Review of Arsenic in Ground Water with an Emphasis on Washington State. Unpublished M.S. thesis, The Evergreen State College, Olympia, WA. p. 102.

Hallock, D. 2001. River and Stream Ambient Monitoring Report for Water Year 2000. Washington State Dept. Ecology, Olympia, WA. Pub. No. 01-03-042.

Hopkins, B. 1995. Metals Concentrations in River and Streams Dropped from the 1994 Section 303(d) List. Washington State Dept. Ecology, Olympia, WA. Pub. No. 95-352.

Hopkins, B. 1996. Ambient Metals Project Proposal - Final Quality Assurance Project Plan. Washington State Dept. Ecology, Olympia, WA.

Johnson, A. 1994. Zinc, Copper, Lead, and Cadmium Concentrations in Four Washington Rivers. Washington State Dept. Ecology, Olympia, WA. Pub. No. 94-58.

Johnson, A. 1998. Rainbow Trout Abnormalities in Douglas Creek: Results from Chemical Analyses. Memorandum to T. Jackson. Washington State Dept. Ecology, Olympia, WA. Pub. No. 98-e02.

Johnson, A. 2002 (draft). A Total Maximum Daily Load Assessment for Arsenic in the Similkameen River. Washington State Dept. Ecology, Olympia, WA.

Johnson, A. and J. White. 1997. Effects of Holden Mine on the Water, Sediments, and Benthic Macroinvertebrates of Railroad Creek (Lake Chelan). Washington State Dept. Ecology, Olympia, WA. Pub. No. 97-330.

Joy, J. 2001. Stillaguamish River Basin and Port Susan Total Maximum Daily Load Evaluation Update - Quality Assurance Project Plan. Washington State Dept. Ecology, Olympia, WA.

Kammin, W.R., S. Cull, R. Knox, J. Ross, M. McIntosh, and D. Thomson. 1995. Labware Cleaning Protocols for the Determination of Low-level Metals by ICP-MS. American Environmental Laboratory 7(9).

Patmont, C.R., G. Pelletier, D. Banton, and C. Ebbesmeyer. 1989. Lake Chelan Water Quality Assessment. Prep. for Washington State Dept. Ecology by Harper Owes, Seattle, WA. Pub. No. 89-e36.

Raforth, R. L., 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 Dept. Ecology, Olympia, WA. Pub. No. 00-03-004

Raforth, R. L., D. Norman, and A. Johnson. 2002. Second Screening-Level Investigation of Water and Sediment Quality of Creeks in Ten Washington Mining Districts, with Emphasis on Metals. Washington State Dept. Ecology, Olympia, WA. Pub. No. 02-03-024.

Webber, T.N. 2001. State of Water Quality in the Similkameen River, 1979 - 1997. Ministry of Environment, Lands, and Parks; and Environment Canada.

Appendix A. Description of Sampling Sites for Arsenic Monitoring, July 2001 - June 2002

Station	Description	Lat	Long
Stillaguamish River near Silvana	On I-5 bridge just N. of Exit 208	48.19704	122.2107
N. Fork Stillaguamish near Darrington	On Swede Haven Rd. 0.9 miles N. of Hwy 530	48.27983	121.7024
Cedar River near Landsburg	At Trude Rd crossing 2.25 miles NE of Lands	47.39094	121.9201
Puyallup River at Meridian St	At bridge on Meridian just N. of Puyallup	47.2026	122.2937
Hoh River at DNR Campground	Just before bridge on 101 in DNR Campground	47.80675	124.251
Cowlitz River at Kelso	Allen Main Street bridge	46.14539	122.9143
E. Fork Lewis River near Dollar's Corner	At Lewis River Bottom Rd bridge	45.81456	122.5918
Columbia River at Umatilla	Under Umatilla Interstate bridge below	45.93124	119.3245
Yakima River at Kiona	.1 miles NW of Hwy 12 and Kiona	46.25347	119.4781
Yakima River at Cle Elum	Located at the bridge off Interstate 90	47.19181	120.9489
Wenatchee River at Leavenworth	Located at the bridge on Icicle Creek Rd	47.57722	120.6739
Methow River at Twisp	At Gage House .5 miles up Wagner Rd	48.34792	120.107
Spokane River at Stateline bridge	At the bridge on Stateline Village Rd	47.69851	117.0446
Columbia River at Northport	State Highway 25 bridge	48.92241	117.7766
Cowlitz River above Cispus River	SR 12 bridge south of Randle	46.53278	121.9567
Cowlitz River above Toutle River	Boat launch off Imboden Rd	46.36833	122.9344
Puyallup River above Carbon River	Highway 162 bridge	47.13	122.2361
Puyallup River above White River	Upstream of Traffic Ave bridge	47.19639	122.2514
Columbia River at County Line Park	Downstream end of Camping Area	46.1735	123.2116
Columbia River at Beacon Rock	Boat dock	45.61878	122.0194
Carbon River	Gravel Rd at end of McCutcheon Rd	47.12417	122.2286
Cispus River	Bridge 5 miles above Cowlitz Falls Dam	46.45778	122.0283
Columbia River at Columbia City	Pixie Park	45.88972	122.8036
Puyallup River above Electron	Bridge near Moose Junction, Rainier Timber	46.90472	122.0344
Cowlitz River at Kelso*	Boat launch at Gerhart Garden Park	46.10917	122.8931
Cowlitz River below Mayfield Dam	WDFW Salmon Hatchery	46.50972	122.63
Cowlitz River at Packwood	Skate Creek Rd bridge	46.61222	121.6792
Columbia River at Ryan Point	Near boat launch at Ryan Point County Park	45.61019	122.6253
Toutle River	Barnes Rd bridge	46.36833	122.9344
White River	Sumner Library	47.20528	122.245

*Transect samples (Table 6)

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Appendix B. Data for Ambient Stations

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
23-Jul-01	Hoh R @ DNR Campground	1210	14.3	7.84	77	6	6.6	0.20 U
27-Aug-01	Hoh R @ DNR Campground	1800	12.4	7.52	77	6	8.8	0.28
24-Sep-01	Hoh R @ DNR Campground	1019	11.9	7.66	79	4 J	7.4 J	0.25
29-Oct-01	Hoh R @ DNR Campground	2460	7.5	7.48	82	8	6.2	0.20 U
26-Nov-01	Hoh R @ DNR Campground	3449	6.6	7.14	72	21	16	0.29
10-Dec-01	Hoh R @ DNR Campground	4110	6.3	7.33	68	13	9.4	0.23
28-Jan-02	Hoh R @ DNR Campground	3090	4.1	7.37	65	19	10	0.25
18-Feb-02	Hoh R @ DNR Campground	2000	6.4	7.44	71	9	5.7	0.20 U
25-Mar-02	Hoh R @ DNR Campground	2180	7.7	7.43	71	5	4.2	0.20 U
15-Apr-02	Hoh R @ DNR Campground	6200	6.7	7.31	60	55	26	0.50
27-May-02	Hoh R @ DNR Campground	2250	9.1	7.62	69	14	7.5	0.12
24-Jun-02	Hoh R @ DNR Campground	2039	12.7	7.77	69	4	4.6	0.10
17-Jul-01	NF Stillaguamish nr Darrington	72	10.9	7.59	56	1 U	0.5 U	0.75
21-Aug-01	NF Stillaguamish nr Darrington	41	12.2	7.95	81	1 U	1.6	0.68
18-Sep-01	NF Stillaguamish nr Darrington	41	11.9	7.70	84	1	0.5	0.69
23-Oct-01	NF Stillaguamish nr Darrington	1549	6.8	7.34	31	201 J	80	1.0
14-Nov-01	NF Stillaguamish nr Darrington	6909	7.5	7.04	20	284 J	80	1.5
11-Dec-01	NF Stillaguamish nr Darrington	405	4.5	7.29	48	2	1.1	0.27
22-Jan-02	NF Stillaguamish nr Darrington	0?	2.6	7.43	46	2	1.2	0.23
27-Feb-02	NF Stillaguamish nr Darrington	706	3.6	7.21	41	16	16	2.0
19-Mar-02	NF Stillaguamish nr Darrington	366	3.2	7.38	46	2	1.3	0.30
23-Apr-02	NF Stillaguamish nr Darrington	597	4.7	7.31	36	4	2.3	0.22
22-May-02	NF Stillaguamish nr Darrington	706	6.1	7.32	30	3	2.5	0.21
19-Jun-02	NF Stillaguamish nr Darrington	NA	7.9	7.28	27	6	1.1	0.19

Appendix B. Ambient Data (continued)

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
17-Jul-01	Stillaguamish R nr Silvana	1090	15.0	7.78	75	9	11	0.41
22-Aug-01	Stillaguamish R nr Silvana	4278	14.8	7.72	76	279	100	2.7
19-Sep-01	Stillaguamish R nr Silvana	488	14.1	7.50	99	2	1.1	0.93
23-Oct-01	Stillaguamish R nr Silvana	17215	7.6	7.22	38	588 J	320 J	1.6
14-Nov-01	Stillaguamish R nr Silvana	26322	8.3	7.08	26	1290	800 J	2.5
11-Dec-01	Stillaguamish R nr Silvana	3893	4.8	7.47	58	56	60	0.99
22-Jan-02	Stillaguamish R nr Silvana	3808	3.3	7.47	58	47	45	0.88
27-Feb-02	Stillaguamish R nr Silvana	5281	3.8	7.21	52	27	20	0.70
19-Mar-02	Stillaguamish R nr Silvana	3551	3.6	7.37	60	15	11	0.57
23-Apr-02	Stillaguamish R nr Silvana	3422	5.7	7.27	42	59	40	0.78
22-May-02	Stillaguamish R nr Silvana	7674	8.4	7.14	37	11	8.7	0.41
19-Jun-02	Stillaguamish R nr Silvana	NA	9.4	7.17	32	11	7.8	0.37
16-Jul-01	Cedar R nr Landsburg	439	10.6	7.75	64	4	1.3	0.54
20-Aug-01	Cedar R nr Landsburg	279	10.1	8.05	83	1	0.5 U	0.71
17-Sep-01	Cedar R nr Landsburg	293	10.7	7.51	72	1 U	0.8	0.70
24-Oct-01	Cedar R nr Landsburg	492	8.5	7.62	55	1	0.9	0.45
12-Nov-01	Cedar R nr Landsburg	647	8.2	7.38	46	4 J	1.1	0.36
12-Dec-01	Cedar R nr Landsburg	627	6.6	7.69	52	1	0.6	0.40
23-Jan-02	Cedar R nr Landsburg	1130	4.8	7.80	39	1	0.8	0.26
25-Feb-02	Cedar R nr Landsburg	785	5.9	7.53	48	2	0.8	0.41
20-Mar-02	Cedar R nr Landsburg	820	5.8	7.51	48	6	1.8	0.37
24-Apr-02	Cedar R nr Landsburg	1080	6.6	7.35	43	5	1.3	0.33
20-May-02	Cedar R nr Landsburg	555	10.2	7.41	53	1 U	0.6	0.36
17-Jun-02	Cedar R nr Landsburg	1130	11.4	7.42	39	2	0.7	0.12

Appendix B. Ambient Data (continued)

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
18-Jul-01	Puyallup R @ Meridian St	2110	14.0	7.57	65	69	45	0.83
22-Aug-01	Puyallup R @ Meridian St	1940	12.4	7.52	69	446	240	1.1
19-Sep-01	Puyallup R @ Meridian St	1180	12.2	7.57	85	146	110	0.85
30-Oct-01	Puyallup R @ Meridian St	2550	9.0	7.36	75	52 J	17	0.63
27-Nov-01	Puyallup R @ Meridian St	3740	6.2	7.46	69	63 J	16	0.56
11-Dec-01	Puyallup R @ Meridian St	3580	5.4	7.62	72	75	11	0.67
29-Jan-02	Puyallup R @ Meridian St	3670	3.3	7.21	78	19	6.4	0.47
19-Feb-02	Puyallup R @ Meridian St	2800	6.0	7.56	74	38 J	7.5 J	0.62
26-Mar-02	Puyallup R @ Meridian St	3489	6.6	7.68	65	11	2.8	0.47
16-Apr-02	Puyallup R @ Meridian St	8320	6.7	7.36	49	314	40	0.96
28-May-02	Puyallup R @ Meridian St	3630	11.2	7.45	41	215 J	22	0.77
25-Jun-02	Puyallup R @ Meridian St	4450	14.3	7.48	46	38	23	0.58
25-Jul-01	Cowlitz R @ Kelso	3250	17.3	7.60	104	7	2.7	0.34
29-Aug-01	Cowlitz R @ Kelso	3170	17.1	7.66	104	16	8.6	0.43
26-Sep-01	Cowlitz R @ Kelso	3040	14.3	7.52	110	7	3.0	0.47
31-Oct-01	Cowlitz R @ Kelso	5050	10.3	7.52	121	76	20	0.46
28-Nov-01	Cowlitz R @ Kelso	18000	8.4	7.75	59	309 J	20	0.37
12-Dec-01	Cowlitz R @ Kelso	14499	7.1	7.41	65	63 J	13	0.30
29-Jan-02	Cowlitz R @ Kelso	18100	4.8	7.16	63	75	23	0.30
20-Feb-02	Cowlitz R @ Kelso	8820	6	7.34	75	217	37	0.35
26-Mar-02	Cowlitz R @ Kelso	12300	7.4	7.54	66	85	19	0.34
17-Apr-02	Cowlitz R @ Kelso	15100	7	7.37	57	421 J	130	0.74
29-May-02	Cowlitz R @ Kelso	13100	10.4	7.57	70	377	29	0.39
26-Jun-02	Cowlitz R @ Kelso	12700	11.5	7.49	68	36	5.3	0.22

Appendix B. Ambient Data (continued)

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
25-Jul-01	EF Lewis R nr Dollar's Corner	no data	21.8	7.9	51	2	1.3	0.42
29-Aug-01	EF Lewis R nr Dollar's Corner	"	21.5	8.04	54	2	1.1	0.54
26-Sep-01	EF Lewis R nr Dollar's Corner	"	15.1	7.47	65	3	2.4	0.63
31-Oct-01	EF Lewis R nr Dollar's Corner	"	9.3	7.50	39	49	14	0.50
28-Nov-01	EF Lewis R nr Dollar's Corner	"	6.9	7.57	35	3	2.9	0.20 U
12-Dec-01	EF Lewis R nr Dollar's Corner	"	6.4	7.24	32	2	2.4	0.20 U
30-Jan-02	EF Lewis R nr Dollar's Corner	"	4.1	7.28	31	2	2.0	0.20 U
20-Feb-02	EF Lewis R nr Dollar's Corner	"	5.5	7.30	25	2	1.6	0.20 U
27-Mar-02	EF Lewis R nr Dollar's Corner	"	7.0	7.45	28	1	1.3	0.20 U
17-Apr-02	EF Lewis R nr Dollar's Corner	"	6.1	7.28	27	3	3.2	0.13
29-May-02	EF Lewis R nr Dollar's Corner	"	10.8	7.46	24	11	4.8	0.19
26-Jun-02	EF Lewis R nr Dollar's Corner	"	17.6	7.45	41	1	0.6	0.19
09-Jul-01	Columbia R @ Northport	73100	17.5	8.40	136	2 J	1.1 J	0.44
06-Aug-01	Columbia R @ Northport	61200	18.5	8.46	129	2	1.2	0.35
10-Sep-01	Columbia R @ Northport	80200	17.2	8.41	130	1 J	1.1 J	0.32
15-Oct-01	Columbia R @ Northport	67400	12.2	8.04	144	2	0.9	0.53
05-Nov-01	Columbia R @ Northport	63400	9.4	7.92	141	1	0.7	0.40
03-Dec-01	Columbia R @ Northport	96500	6.7	7.78	126	2	1.0	0.26
14-Jan-02	Columbia R @ Northport	80300	3.6	8.17	131	1	0.8	0.39
11-Feb-02	Columbia R @ Northport	64300	3.2	7.46	91.4 J	1	1.5	0.86
11-Mar-02	Columbia R @ Northport	62800	2.7	8.26	NA	1	1.1	0.42
08-Apr-02	Columbia R @ Northport	51500	5.6	8.12	142	3	1.4	0.52
12-May-02	Columbia R @ Northport	90400	7.9	7.84	143	2	1.7	0.44
03-Jun-02	Columbia R @ Northport	199000	11.1	8.27	111	11	3.1	0.38

Appendix B. Ambient Data (continued)

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
11-Jul-01	Columbia R @ Umatilla	94800	20.1	8.33	137	4	1.9	0.89
08-Aug-01	Columbia R @ Umatilla	96600	21.4	8.21	150	3	2.1	1.4
12-Sep-01	Columbia R @ Umatilla	73480	19.4	8.42	151 J	4	2.1	1.2
17-Oct-01	Columbia R @ Umatilla	67500	14.6	8.11	160	4	2.3	1.1
07-Nov-01	Columbia R @ Umatilla	116030	12.6	7.96	191	3	1.7	1.4
05-Dec-01	Columbia R @ Umatilla	125500	8.6	7.92	161	2	1.5	0.99
16-Jan-02	Columbia R @ Umatilla	170800	5.8	8.09	171	3	2.5	1.0
13-Feb-02	Columbia R @ Umatilla	148900	3.9	8.05	108 J	2	1.7	0.42
13-Mar-02	Columbia R @ Umatilla	15400	4.6	8.28	154	5	3.4	0.88
10-Apr-02	Columbia R @ Umatilla	152600	8.6	8.23	200	7	5.3	1.4
15-May-02	Columbia R @ Umatilla	211600	11.7	8.14	127	5	2.6	0.69
05-Jun-02	Columbia R @ Umatilla	376900	14.3	7.91	108	7	3.9	NA
09-Jul-01	Yakima R nr Cle Elum	3048	15.9	7.84	49	5	1.9	0.20 U
13-Aug-01	Yakima R nr Cle Elum	2894	21.2	7.35	43	5 J	2.2 J	0.28
03-Sep-01	Yakima R nr Cle Elum	1880	15.6	7.38	53	2 J	1.1 J	0.26
08-Oct-01	Yakima R nr Cle Elum	517	10.8	7.72	57	2	1.2	0.25
12-Nov-01	Yakima R nr Cle Elum	497	6.0	7.49	63	1 U	0.6	0.20 U
03-Dec-01	Yakima R nr Cle Elum	520	4.5	7.64	66	2	0.7	0.20 U
07-Jan-02	Yakima R nr Cle Elum	616	3.5	7.14 J	65 J	5	1.4	0.20 U
04-Feb-02	Yakima R nr Cle Elum	564	3.2	7.83	70	1	0.6	0.20 U
04-Mar-02	Yakima R nr Cle Elum	689	4.6	8.23	71	1	0.7	0.20 U
01-Apr-02	Yakima R nr Cle Elum	1132	6.3	7.95	70	3	1.2	0.12
06-May-02	Yakima R nr Cle Elum	1047	6.7	6.95	61	3	1.8	0.10
10-Jun-02	Yakima R nr Cle Elum	2639	12.2	7.67	51	3	1.7	0.10 U

Appendix B. Ambient Data (continued)

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
10-Jul-01	Yakima R @ Kiona	957	25.3	8.02	252	8	4.9	2.4
14-Aug-01	Yakima R @ Kiona	1030	26.2	7.94	277	8 J	3.8 J	2.7
04-Sep-01	Yakima R @ Kiona	1502	19.4	7.95	288	10 J	4.8 J	2.3
10-Oct-01	Yakima R @ Kiona	1028	12.2	8.40	303	6	2.9	2.0
14-Nov-01	Yakima R @ Kiona	1583	8.8	8.37	256	NA	4.6	1.3
05-Dec-01	Yakima R @ Kiona	2067	5.0	8.34	221	8	4.4	1.2
09-Jan-02	Yakima R @ Kiona	8328	5.6	7.67	117 J	379	170	1.5
06-Feb-02	Yakima R @ Kiona	2038	3.7	8.06	207	7	3.8	0.93
06-Mar-02	Yakima R @ Kiona	2941	5.7	7.96	171	18	7.4	0.82
03-Apr-02	Yakima R @ Kiona	3132	12	8.45	159	35	13	1.0
08-May-02	Yakima R @ Kiona	2846	12.9	8.56	155	11	6.8	0.82
12-Jun-02	Yakima R @ Kiona	5700	17.6	7.74	121	57	18	0.87
10-Jul-01	Wenatchee R nr Leavenworth	1680	17.3	8.18	29	5	0.7	0.20 U
14-Aug-01	Wenatchee R nr Leavenworth	588	21.7	8.02	38	3 J	0.7 J	0.20 U
04-Sep-01	Wenatchee R nr Leavenworth	Mar-01	17.4	8.17	40	8 J	0.8 J	0.20 U
10-Oct-01	Wenatchee R nr Leavenworth	217	7.8	7.66	46	1	0.8	0.20 U
14-Nov-01	Wenatchee R nr Leavenworth	1050	6.7	7.43	36	NA	1.5	0.20 U
05-Dec-01	Wenatchee R nr Leavenworth	928	3.2	6.79	35	2	0.5	0.20 U
09-Jan-02	Wenatchee R nr Leavenworth	4580	2.9	7.28 J	28 J	9	2.0	0.20 U
06-Feb-02	Wenatchee R nr Leavenworth	827	1.5	7.14	37	1 U	0.5 U	0.20 U
06-Mar-02	Wenatchee R nr Leavenworth	1310	2.6	8.39	37	1 U	0.6	0.20 U
03-Apr-02	Wenatchee R nr Leavenworth	1300	3.3	6.98	45	2	1.3	0.10 U
08-May-02	Wenatchee R nr Leavenworth	3370	4.9	7.07	35	2	0.9	0.10 U
04-Jun-02	Wenatchee R nr Leavenworth	8860	7.0	6.98	26	14	2.7	0.10 U

Appendix B. Ambient Data (continued)

Date	Station Name	Flow (cfs)	Temp. (°C)	pH (S.U.)	Conduct. (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	TR Arsenic (ug/L)
11-Jul-01	Methow R @ Twisp	518	15.7	8.31	118	2	0.5	0.44
15-Aug-01	Methow R @ Twisp	193	16.5	8.09	170	1 U	0.5 U	0.51
05-Sep-01	Methow R @ Twisp	154	12.3	8.24	182	1 U	0.5 U	0.50
09-Oct-01	Methow R @ Twisp	189	9.3	8.26	161	1 U	0.5 U	0.43
13-Nov-01	Methow R @ Twisp	185	6.8	8.00	155	1 U	0.5 U	0.36
04-Dec-01	Methow R @ Twisp	196	2.7	7.96	152	1 U	0.5 U	0.37
08-Jan-02	Methow R @ Twisp	205	4.8	7.89	146 J	2	1.0	0.31
05-Feb-02	Methow R @ Twisp	186	3.0	8.13	150	2	0.7	0.31
05-Mar-02	Methow R @ Twisp	254	4.5	8.22	139	2	0.5	0.39
02-Apr-02	Methow R @ Twisp	477	7.7	8.27	133	5	1.1 J	0.38
07-May-02	Methow R @ Twisp	1840	5.5	8.04	99	2	1.1	0.36
11-Jun-02	Methow R @ Twisp	4380	8.4	7.92	61	14	3.8	0.41
10-Jul-01	Spokane R @ Stateline Br	1060	23	7.92	55	2 J	1.1 J	0.43
07-Aug-01	Spokane R @ Stateline Br	511	22	8.20	62	10 J	1.3 J	0.58
11-Sep-01	Spokane R @ Stateline Br	1040	19	8.11	65 J	3	1.2	0.67
15-Oct-01	Spokane R @ Stateline Br	1800	13.1	8.09	58	1 U	0.7	0.53
05-Nov-01	Spokane R @ Stateline Br	2350	10.5	7.93	59	1 U	0.6	0.49
03-Dec-01	Spokane R @ Stateline Br	3460	6.4	7.30	56	1 U	0.7	0.51
14-Jan-02	Spokane R @ Stateline Br	7540	4.5	7.86	54	2	1.3	0.47
12-Feb-02	Spokane R @ Stateline Br	4620	2.8	7.24	31.5 J	2	1.1	0.49
12-Mar-02	Spokane R @ Stateline Br	6760	3.0	7.54	57	2	1.8	0.56
09-Apr-02	Spokane R @ Stateline Br	12000	3.7	8.01	58	2 J	1.3	0.51
13-May-02	Spokane R @ Stateline Br	16000	8.7	7.66	44	3	4.0	0.55
04-Jun-02	Spokane R @ Stateline Br	28100		8.15	38	4	2.8	0.48

U = not detected at or above reported value J = estimated value