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DEPARTMENT OF
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Mercury in Lake Whatcom Sediments

Spatial Distribution, Depositional History, and Tributary Inputs

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Mercury in Lake Whatcom Sediments

Spatial Distribution, Depositional History, and Tributary Inputs

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In Cooperation with
United States Geological Survey
Tacoma District Office
Tacoma, Washington
and
Whatcom County Health Department
Bellingham, Washington

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Abstract

Concerns over mercury levels in fish from Lake Whatcom prompted the Washington State Department of Ecology to conduct a joint study with the United States Geological Study (USGS) and the Whatcom County Health Department (WCHD) during 2002 and 2003.

The primary objective of this work was to evaluate the spatial distribution and historical deposition of mercury in Lake Whatcom. Mercury levels were evaluated by collecting and analyzing bottom sediments from the lake as well as surface water entering the lake from ten tributaries.

Data collection and analysis included:

1. During September 2002, 31 surface sediment samples and three deep sediment core samples were collected from Lake Whatcom and analyzed for total mercury. Methylmercury levels also were analyzed in 15 surface sediment samples.

2. Surface water was collected from ten tributaries to Lake Whatcom every other month between July 2002 and May 2003 to calculate mercury loadings.

3. USGS, in cooperation with WCHD, evaluated existing information on potential mercury sources to the lake. They also evaluated sediment core data collected from five nearby lakes in Whatcom County. This information is compiled and evaluated in a companion report prepared by USGS.

The data collected indicate that mercury levels in surface sediments from Lake Whatcom and surface water entering the lake do not appear to be elevated compared to other areas of Washington. Surface water concentrations fall at or below levels measured in rainfall at Seattle during 1998 - 2002. Core profiles suggest mercury concentrations began to increase from background levels in Lake Whatcom around 1900. Mercury levels steadily increased in the lake, reaching peak levels in 1987 to 1995. There is evidence to suggest that mercury concentrations in sediments have leveled off or are decreasing from peak concentrations.

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- Joan Vandersypen (Western Washington University) provided flow data on several tributaries and sediment data on Lake Whatcom.
- Randy Coots provided GIS technical assistance.
- Brandee Era-Miller input the project data into Ecology's Environmental Information Management System.
- Kristin Kinney compiled the field data logs and surface water results.
- Art Johnson and Dave Serdar provided valuable technical assistance.
- Dr. Anthony Paulson analyzed core data, especially with respect to age dating.
- Art Johnson, Steve Hood, Dr. Anthony Paulson, Don Vesper, and Peg Wendling reviewed the report and provided many valuable comments.
- Joan LeTourneau formatted and edited the final report.

Introduction

Lake Whatcom is a large, natural lake located in Whatcom County, in the northwestern corner of Washington State. The surface area of the lake covers about 5,000 acres, and the total watershed area is about 32,000 acres. The lake can be divided morphologically into three distinct basins formed by glacial sills. Basins 1 and 2 are relatively small and shallow (generally <24 meters). Basin 3, which has a maximum depth of about 100 meters, contains 96% of the lake volume. Morphometric data on Lake Whatcom are presented in Table 1.

Table 1. Morphometric Data on Lake Whatcom.

Characteristic	Basin 1	Basin 2	Basin 3	Entire Lake
Volume ($m^3 \times 10^6$)	19.4	18.0	883.5	921.0
% of Lake Volume	2.1	2.0	95.9	100.0
Maximum Depth (m)	29.0	21.0	103.0	103.0
Mean Depth (m)	9.2	11.2	54.0	46.0
Surface Area (km^2)	2.1	1.6	16.6	20.3
Length (km)	2.2	2.5	13.3	19.2
Maximum Width (km)	1.1	1.0	1.7	1.7

Land use in the Lake Whatcom watershed is a mix of urban/suburban and forestry. Basin 1, lying largely within the city limits of Bellingham, is in the most urbanized part of the watershed. Basins 2 and 3 are mainly within the jurisdiction of Whatcom County. Basin 2 is less developed than Basin 1 but also has a mix of urban and residential uses. Basin 3, the least developed portion of the watershed, is dominated by commercial forestry uses with the exception of Sudden Valley, a suburban residential development (Serdar et al., 1999).

Several streams drain to the lake. However, to maintain optimal lake levels, water is diverted into the lake from the middle fork of the Nooksack River. This diversion enters the lake at the southeastern end of Basin 3 via Anderson Creek. Outflow from the lake discharges to Whatcom Creek, which is located at the western end of Basin 1. An overview of the Lake Whatcom watershed is shown in Figure 1.

All of the major tributaries and many of the intermittent tributaries discharging to Lake Whatcom flow into Basin 3, which receives 87% of the drainage to the lake. The remaining watershed areas are drained by intermittently flowing streams, surface runoff directly into the lake, or man-made drainage systems (Delahunt, 1990). Seven perennial tributaries flow into Lake Whatcom: Anderson, Smith, Olsen, Carpenter, Austin, Brannian, and Fir creeks. Among them, Anderson, Austin, and Smith are the largest.

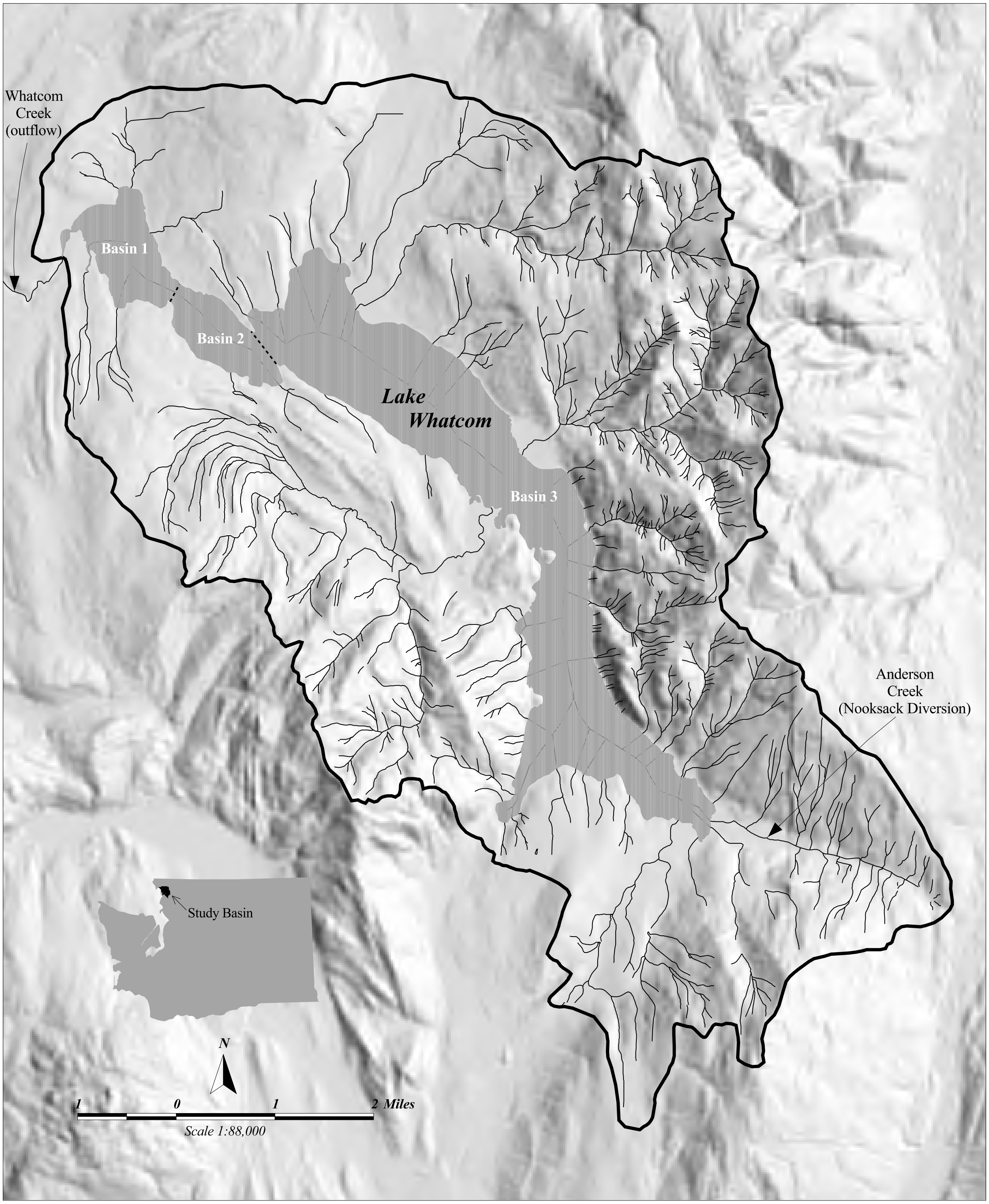

Figure 1. Lake Whatcom Study Area and Drainage Basin.

Protection of the lake is important because it serves as the primary drinking water source for about 86,000 Whatcom County residents. The lake is also used extensively for sport fishing, swimming, and other types of recreation (USGS, 2002; Serdar et al., 1999).

Concerns over mercury contamination in Lake Whatcom fish were raised after a study conducted by the Washington State Department of Ecology (Ecology) in 1998 reported a concentration of 0.50 mg/kg (wet weight) in a composite sample of smallmouth bass fillets (Serdar et al., 1999). For comparison, the average fish tissue concentration for other freshwater areas of Washington, calculated from Ecology's Environmental Information Management database, is 0.096 mg/kg. The national average for mercury in sport fish fillets is reported to be 0.36 mg/kg (EPA, 1992).

To determine if consumers of Lake Whatcom fish were at risk from mercury exposure, the Washington State Departments of Ecology, Fish and Wildlife, and Health, in conjunction with the Whatcom County Health Department (WCHD), conducted a fish tissue study during 2000, specifically targeting mercury. During this study, approximately 273 samples of finfish were collected and analyzed for mercury (Serdar et al., 2001). The average mercury level in smallmouth bass was 0.49 mg/kg with a maximum concentration of 1.84 mg/kg. Twelve samples (13%) collected during this study exceeded the EPA National Toxics Rule human health criterion of 0.825 mg/kg (Serdar et al., 2001). In 2001 EPA issued a revised methylmercury criteria of 0.3 mg/kg (EPA, 2001). Sixty-one (64%) of the smallmouth bass samples analyzed exceeded the revised methylmercury criteria.

There was also evidence in this 2000 study suggesting mercury concentrations were different among the three basins, with some fish samples from Basin 3 being elevated relative to Basins 1 and 2. This result was somewhat unexpected because Basin 3 is large and the contributing drainage area has a smaller percentage of urban land use than Basins 1 or 2. The reasons for the higher concentrations in Basin 3 were not determined, but Serdar suggested that transport of mercury to the lake from tributaries, atmospheric sources, or processes that convert mercury to methylmercury in the lake or connecting wetlands might all be contributing factors.

Some of the possible sources of mercury in Lake Whatcom include atmospheric deposition from global and local sources, discharges from tributaries (including the diversion from the Nooksack River), landfills, dumpsites, and local mining operations. Of these possible sources, local interest has focused on a chloralkali plant that operated in the city of Bellingham and emitted mercury into the atmosphere from the early 1960s until the late 1990s (USGS, 2002).

Study Description

In light of the concerns about mercury in Lake Whatcom, Ecology conducted this cooperative study with USGS and WCHD during July 2002 through May 2003. The primary objectives of the study were as follows:

- Determine the spatial distribution of mercury in surface sediments from Lake Whatcom.
- Evaluate historical trends in mercury levels and sedimentation rates.
- Estimate mercury loadings in ten tributaries to Lake Whatcom.

During the late summer of 2002, Ecology's Environmental Assessment Program collected approximately 30 surface sediments samples and three deep core samples from Lake Whatcom. All sediment samples were analyzed for total mercury. In addition, methylmercury levels were determined in 15 of the surface sediment samples distributed throughout the lake. Radio-dating, using ^{210}Pb and ^{137}Cs, was conducted on the sediment cores to determine net sedimentation rates and the time line of mercury accumulation.

USGS, in cooperation with WCHD, collected and evaluated all existing information on potential mercury sources to the lake. The WCHD also provided supplemental funding for collection and analysis of five additional sediment cores from nearby lakes in Whatcom County. The purpose of these additional cores was to determine if mercury accumulation rates differed from Lake Whatcom.

Finally, to estimate mercury loadings from tributaries, surface water samples were collected every other month between July 2002 and May 2003 from ten tributaries to Lake Whatcom and analyzed for total mercury as part of the Lake Whatcom Dissolved Oxygen Total Maximum Daily Load (TMDL) (Cusimano et al., 2002).

The information collected through this cooperative effort provides a better understanding of current and historical mercury inputs to Lake Whatcom.

Sampling Design

Current and historical inputs of mercury to Lake Whatcom were evaluated by collecting and analyzing (1) surface sediments in Lake Whatcom, (2) sediment cores in Lake Whatcom and five nearby lakes, and (3) surface water from ten tributaries to Lake Whatcom.

Surface Sediments

Surface sediments were used to evaluate mercury concentrations near major tributaries and to assess spatial patterns in the basin. Surface sediment stations were selected using two techniques: focused tributary sites and random sites.

- Focused tributary stations were placed in the lake near the mouths of the ten tributaries selected for surface water sampling (see Figure 2).
- The remaining surface sediment stations (21) were distributed throughout the lake using a stratified random sampling design. Three strata, which corresponded to the three basins in the lake, were defined. The number of random stations in each basin was allocated based on the relative size of the basin compared to the total lake area. To provide adequate spatial coverage of each basin, a minimum of five stations were assigned to both Basins 1 and 2.

The number of focused and random stations in each basin is summarized in Table 2.

Table 2. Focused and Random Surface Sediment Stations in Lake Whatcom.

Basin	Focused	Random	Total
1	3	5	8
2	0	5	5
3	7	11	18
			31

Station positions in each basin were randomly selected by defining each stratum as a polygon using ARCVIEW® GIS software and then using the random point extension to generate the target number of station locations within each stratum. Coordinates of all sediment stations are listed in Appendix A, Table A1. The locations of these sites are also shown by basin in Figures 3a-c.

This design allowed for calculation of an estimate of the average mercury concentration in surface sediments from each basin. This design has been used successfully in other sediment studies to evaluate the areal extent of contamination (Long et al., 1996; NOAA/Ecology, 1999, and Norton et al., 2000).

All surface sediments were analyzed for total organic carbon (TOC), grain size, and total mercury. Five of the random stations in each basin were also analyzed for methylmercury. In Basins 1 and 2, this included all random stations. In Basin 3, all even-numbered stations (2, 4, 6, 8, and 10) were analyzed for methylmercury.

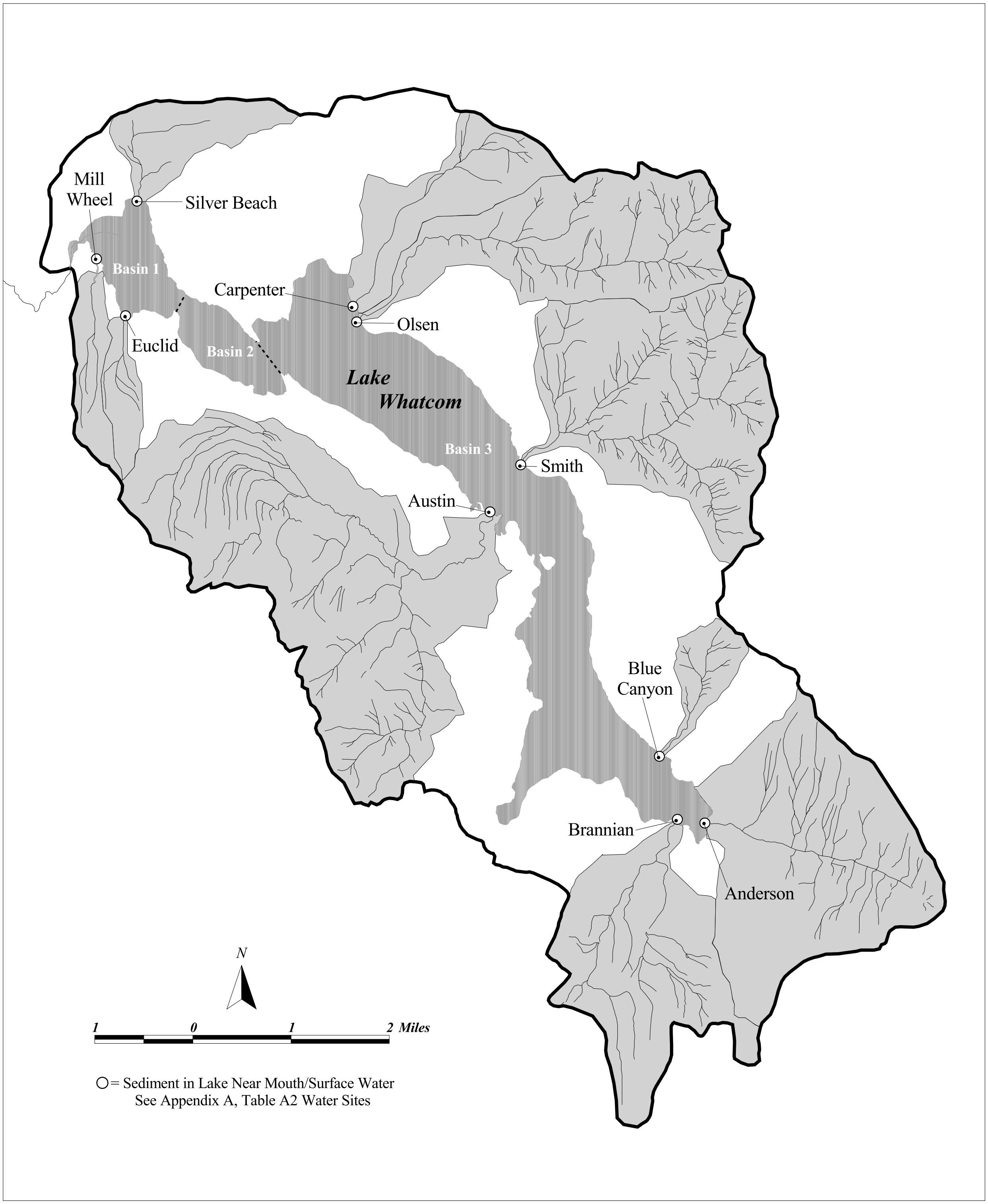

Figure 2. Tributaries Sampled for the Lake Whatcom Mercury Study.

Sediment Cores

Three sediment cores were collected in Lake Whatcom: one station at the deepest location in each of the three basins. These locations are shown in Figures 3a-c. Deep locations were selected for coring since it was anticipated that these areas would contain the finest sediments and most undisturbed vertical sediment profile. Similarly, one location in each of five surrounding lakes in Whatcom County was selected for coring. The five additional lakes selected by USGS and WCHD for sampling are listed in Table 3.

Table 3. Additional Lakes Selected for Sediment Coring in the Vicinity of Lake Whatcom.

Lake	Surface Area (acres)	Maximum Depth (m)	Selection Criteria
Baker Lake	3616	86	Global background
Lake Terrell	438	3	Local atmospheric background
Wiser Lake	123	-	>10 km north of Bellingham
Fazon Lake	32	-	>10 km downwind of Bellingham
Lake Samish	814	44	Upwind of Lake Whatcom

In each core, ten horizons were analyzed for TOC, total mercury, total lead, and ^{210}Pb. Five horizons in each core were also analyzed for ^{137}Cs as a check on the ^{210}Pb dating. ^{137}Cs dating was generally restricted to the upper 20 cm of each core since detectable fallout of ^{137}Cs began in the early 1950s with the beginning of atmospheric testing of nuclear weapons.

Tributary Surface Water

Surface water from ten tributaries to the lake was collected for determination of total recoverable mercury. The ten tributaries were: Anderson, Austin, Smith, Euclid, Silver Beach, Olsen, Brannian, Mill Wheel, Carpenter, and Blue Canyon Creeks.

These tributaries were selected for sampling based on a review of the following factors: access, impact on the lake (based on size of the discharge), drainage characteristics and land use patterns in the Lake Whatcom watershed, and availability of flow and conventional data from the Lake Whatcom Dissolved Oxygen TMDL and previous monitoring studies. The ten surface water sampling locations are shown in Figure 2 and described in Appendix A, Table A2.

Surface water samples were collected every other month between July 2002 and May 2003 as part of the Lake Whatcom Dissolved Oxygen TMDL. This resulted in a total of six sampling events during the study.

Sample Collection

Surface Sediments

Where applicable, sampling and analysis methods described in the Puget Sound Estuary Protocols (PSEP, 1996) were used. All surface sediment samples were collected from Ecology's 26' research vessel, *R.V. Skookum*, using a 0.1 m^2 stainless steel van Veen grab. At each surface sediment site, a composite sample was prepared from three individual grabs. The top 2-cm layer was sampled at each location to reflect recently deposited material. Stations were located and positions recorded using a differentially corrected global positioning system (GPS). A grab was considered acceptable if it was not over-filled with sediment, overlying water was present and not excessively turbid, the sediment surface was relatively flat, and desired depth penetration had been achieved. A field log was maintained during sampling.

Upon retrieving a successful grab, overlying water was siphoned off and the top 2-cm layer of sediment was removed with stainless steel spoons, placed in a stainless steel bowls, and homogenized by stirring. Aliquots for methylmercury analysis were removed from each grab prior to homogenizing and placed directly into sample containers. This procedure minimized the loss of methylmercury which could occur during homogenizing. For all samples, material in contact with the side walls of the grab was not retained for analysis. At the discretion of the project lead, larger debris (e.g., rocks, shells, and pieces of wood) that could not be homogenized was removed. Notes were made in the sample log of all debris originally present in the samples. Field logs for all surface sediment samples are included in Appendix A, Table A3.

Sub-samples of the homogenized sediment were placed in glass jars (Teflon lid liners) and cleaned to EPA QA/QC specifications (EPA, 1990). Separate 4-oz jars were used for total mercury and methylmercury, 2-oz jars were used for TOC, and 8-oz glass jars were used for grain size samples.

Stainless steel spoons and buckets used to manipulate the sediments were pre-cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute (10%) nitric acid, deionized water, and methanol. The equipment was then air-dried and wrapped in aluminum foil until used in the field. The same procedure was used to pre-clean the grab before going into the field. Between stations, cleaning of the grab consisted of thoroughly brushing with on-site water. If oil or visible contamination was encountered, the grab was cleaned between samples with a detergent wash followed by a rinse with on-site water.

All samples were stored in coolers on ice at 4°C and transported to the Ecology Manchester Environmental Laboratory (MEL) within 72 hours of collection. Samples for methylmercury analysis were frozen the same day as sampling occurred and transported directly to the contract laboratory within 24 hours. Containers, storage temperatures, and holding times used during this study are listed in Appendix B, Table B1. Chain-of-custody was maintained throughout the study.

Sediment Cores

Sediment cores were also collected from Ecology’s 26’ research vessel using a Wildco stainless steel box corer fitted with a 13 cm x 13 cm x 50 cm acrylic liner. Sediment recoveries ranged from a maximum of 50 cm in Lake Whatcom (Basin 1), Wiser Lake, and Fazon Lake to a minimum of 27.5 cm in Lake Terrell. Field logs for each of the cores are included in Appendix A, Table A4.

Upon retrieving a successful core, overlying water was siphoned off, the liner removed from the corer, and the sediment core was extruded and sectioned into 1-cm thick layers using aluminum plates. The core was extruded using a gear-driven piston that pushes the sediment column up and out of the liner. This process resulted in a maximum of 42 sub-sections per core. The bottom portion of the core (typically 4-6cm) was sectioned into 2-cm intervals. Material in contact with the sidewall of the core liner and extruding piston was removed prior to sub-sampling the core. Each section retained was placed in a separate 8-oz glass jar, sealed in plastic bags, and stored in coolers on ice pending processing in the laboratory.

Sections for analysis were chosen to be representative of intervals along the core length which reflect sediments deposited over several decades reaching native material. Horizons not selected for initial analysis were archived frozen to allow for future analysis if needed. Sections selected for analysis were homogenized in the laboratory, and sub-samples were split into various containers for analysis: 2-oz jars for TOC, 4-oz jars for total mercury, lead, and radio-dating samples.

All utensils used to manipulate samples and the core liners were pre-cleaned using the same procedure employed for the sediment manipulation items. A different pre-cleaned acrylic core liner was used for each station.

Tributary Surface Water

Surface water samples for total recoverable mercury determinations were collected as grab samples at each of the ten tributary sites. Sampling personnel wore non-talc nitrile gloves when collecting samples. Sample containers for mercury determinations were Teflon bottles specifically cleaned at MEL for low-level metals analysis (Kammin et al., 1995). After collection, the samples were preserved in the field using ultra-pure acid supplied in pre-washed Teflon vials by MEL and placed in plastic bags for storage at 4°C. Sampling and field measurement protocols for conventional parameters (pH, temperature, conductivity, dissolved oxygen, and flow) followed those specified in the Lake Whatcom Dissolved Oxyen TMDL Project Plan (Cusimano et al., 2002). All surface water samples were wrapped in plastic bags and stored in coolers on ice at 4°C and delivered to MEL within 48 hours of collection.

Sample Analysis

Table 4 summarizes the analytical methods and laboratories used in this study. Samples for this study were analyzed by MEL and accredited contract laboratories selected by MEL.

Table 4. Analytical Methods and Laboratories Used.

Parameter	Method	Reference	Laboratory
Sediment/Cores			
TOC	Combustion/CO2 Measurement, Report @ 70°C/104°C (9060)	PSEP, 1996/ EPA, 1986	MEL
Percent Solids	Gravimetric Dry @ 104°C (EPA 160.3)	PSEP, 1996	MEL
Grain Size	Sieve and Pipette	PSEP, 1996	Rosa
Total-Hg	CVAA (Modified EPA 245.5)	EPA, 1991	MEL
Methyl-Hg	CV/GC/AFS (Modified EPA 1630)	EPA, 1998	Brooks-Rand
Total-Pb	ICP (EPA 200.8)	EPA, 1994	MEL
Pb-210	Gamma Spectroscopy/LEPD (EPA 901.1)	EPA, 1980	STL
Cs-137	Gamma Spectroscopy/HPGD (EPA 901.1)	EPA, 1980	STL
Water			
Total-Hg	CVAA (EPA 245.7)	EPA, 1991	MEL

Methods

CVAA=	Cold Vapor Atomic Emission
CV/GC/AFS=	Cold Vapor/Gas Chromatography/Atomic Fluorescence Spectroscopy
ICP=	Inductively Coupled Plasma
LEPD=	Low Energy Photo Detector
HPGD=	Hyperpure Germanium Detector

Laboratories

MEL=	Manchester Environmental Laboratory, Manchester, WA.
Rosa=	Rosa Environmental & Geotechnical Laboratory, Seattle, WA.
Brooks Rand=	Brooks Rand, Seattle, WA.
STL=	Severn Trent Services, Richland, WA.

TOC concentrations were determined at both 70°C to minimize the loss of organic compounds and 104°C to report on a true dry-weight basis and improve detection limits for samples that could have TOC levels <2% (Cook, K., 1993).

Quality Assurance

For sediments, one blind field replicate (a single sample homogenized and split in the field) was prepared at a frequency of 1 per set of 20 samples. Additionally, at one random station selected by USGS, in each of the three basins, a split sample was prepared and provided to USGS for determination of total mercury at an independent laboratory. Two of the three splits were analyzed for methylmercury. USGS also submitted six blind reference materials for total mercury and two blind samples for methylmercury in sediments.

Field logs were maintained describing all procedures used to collect and process the samples in the field. Only pre-cleaned sampling equipment and containers, as previously described, were used. To minimize risk of cross-contamination, the sampling sequence began with the lowest expected concentration samples and finished with the areas of highest expected contamination. Care was taken while operating the vessel in shallow water so as not to disturb the sediments being sampled. Sample containers were placed in polyethylene bags to further reduce the possibility of cross-contamination.

For surface water samples, one blind field replicate was prepared per collection. As a check for container contamination, a bottle blank (blank water in a sample container) was also analyzed during every other collection.

Laboratory quality control (QC) samples included analysis of method blanks, duplicate matrix spikes, analytical replicates, and laboratory control samples.

In general, data quality for the project was very good with no major problems encountered with analysis of samples. Data quality goals identified in the Lake Whatcom Sediment Mercury Study Project Plan were met in almost all instances (Norton, 2002). Consequently, the data are considered useable as reported and qualified. Increased uncertainty due to failure to meet a data quality objective has been considered when reporting results and conclusions. Quality assurance data generated for the project and case narratives for the individual analyses are included in Appendix B. A summary of data quality is presented below.

Field and laboratory replicate results for sediments were good. Relative percent differences were as follows: percent solids= <1%, total organic carbon= <14%, total mercury= <5%, and total lead= <1%. Several percent solids, total organic carbon, and total mercury results were qualified as estimates due to minor exceedance of holding times. One methylmercury result was qualified as an estimate due to the sample being received in a broken jar. The sample was intact and successfully transferred to another container. Due to the low density and volume of several core sections, minimum reporting limits for ^{210}Pb activity were higher than the required reporting limit of 1.5 pCi/g in several sections. This complicated dating of several cores and required re-analysis of additional core sections. To provide a consistency check between analytical runs, several samples analyzed in the first sample run were reanalyzed during a supplemental analytical run.

The frequency of analysis of laboratory control samples and standard reference materials specified in the project plan was not met for total mercury in water (planned= 3; actual= 2) and total organic carbon (planned= 2; actual= 0). Results of analysis of standard reference materials for total mercury and methylmercury in sediment were within the 95% confidence interval for 3 of 5 determinations for total mercury and 1 of 2 for methylmercury. All results were within 20% of the certified values for both parameters.

Split samples were submitted to MEL and an independent laboratory for analysis of total mercury and methylmercury. Two of the 3 splits for total mercury agreed within 12%. Relative percent difference for the remaining split was 27%. For methylmercury, relative percent differences between the two sets of splits were 3% and 74%, respectively. The higher degree of variation between one of the methylmercury intercomparison samples is probably related to the lack of homogeneity or the samples. These samples were collected directly into sample containers from the surface of the grab prior to compositing and homogenizing the samples.

Mercury was not detected in any of the field blanks for the water collections. Even though the frequency of analysis of reference materials for mercury in water was less than the target, results indicated good accuracy, being within 3% of the certified value. Replicate results agreed within 14% for mercury in water.

Results and Discussion

Surface Sediments

Surfaces sediments were collected adjacent to the mouths of ten tributaries entering the lake to screen these areas as potential mercury sources. Twenty additional sites were distributed randomly to evaluate typical mercury levels in the lake. A complete list of results for surface sediments from Lake Whatcom is included in Appendix C, Table C1.

Total organic carbon (TOC) levels ranged from 1.7% to 16.3%, with a mean of 5.3%. The highest values were typically present at the random stations in Basin 1, while the lowest levels were measured near the tributaries in Basin 3. The higher levels measured in Basin 1 are consistent with the field logs that indicated the presence of plant and wood material in many of the samples.

Grain size analysis indicated that almost all of the random sites in the lake were composed of >60% fines (<0.62um). In contrast, eight of the ten sites sampled near the tributary mouths were primarily sand. Grain size results are consistent with field observations and bathymetry which indicates fine grain material is being transported away from the mouths of the tributaries and is being deposited in the deeper portions of the lake.

Summary statistics for total mercury levels in Lake Whatcom surface sediments are shown in Table 5. Individual results for both total mercury and methylmercury are displayed by basin in Figures 3a-c.

Table 5. Total Mercury Levels in Surface Sediments from Lake Whatcom in 2002 (mg/kg, dw).

Location	N=	Minimum	Maximum	Mean
Basin 1				
Tributaries	3	0.041	0.18	0.12
Random	5	0.15	0.22	0.20
Basin 2				
Random	5	0.15	0.20	0.17
Basin 3				
Tributaries	7	0.038	0.11	0.072
Random	11	0.014	0.21	0.14
Overall	31	0.014	0.22	0.14

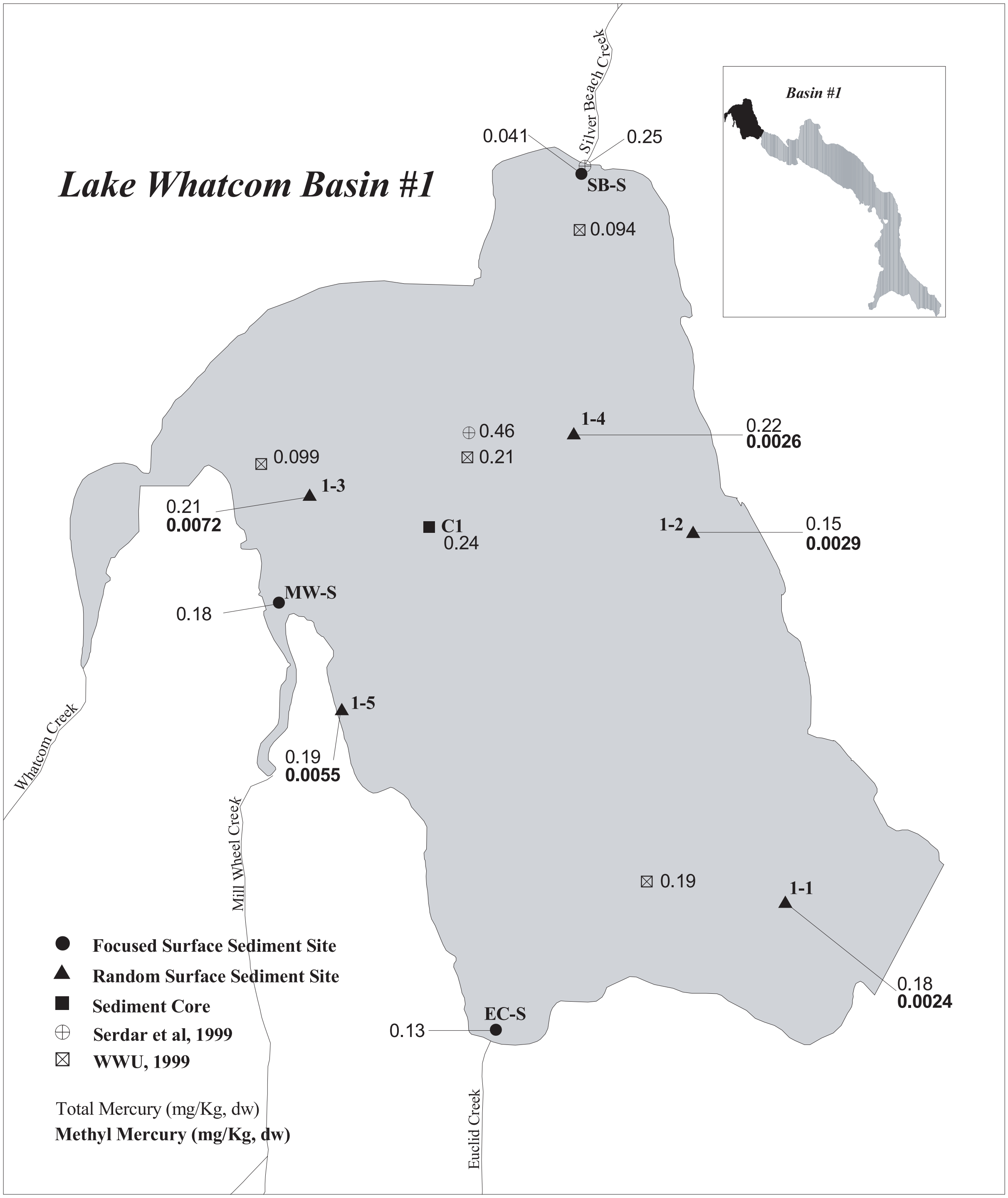

Figure 3a. Total Mercury and Methylmercury in Surface Sediments (0-2 cm) from Basin 1, Lake Whatcom. (0-2 cm sections of core were used for comparison with surface sediments).

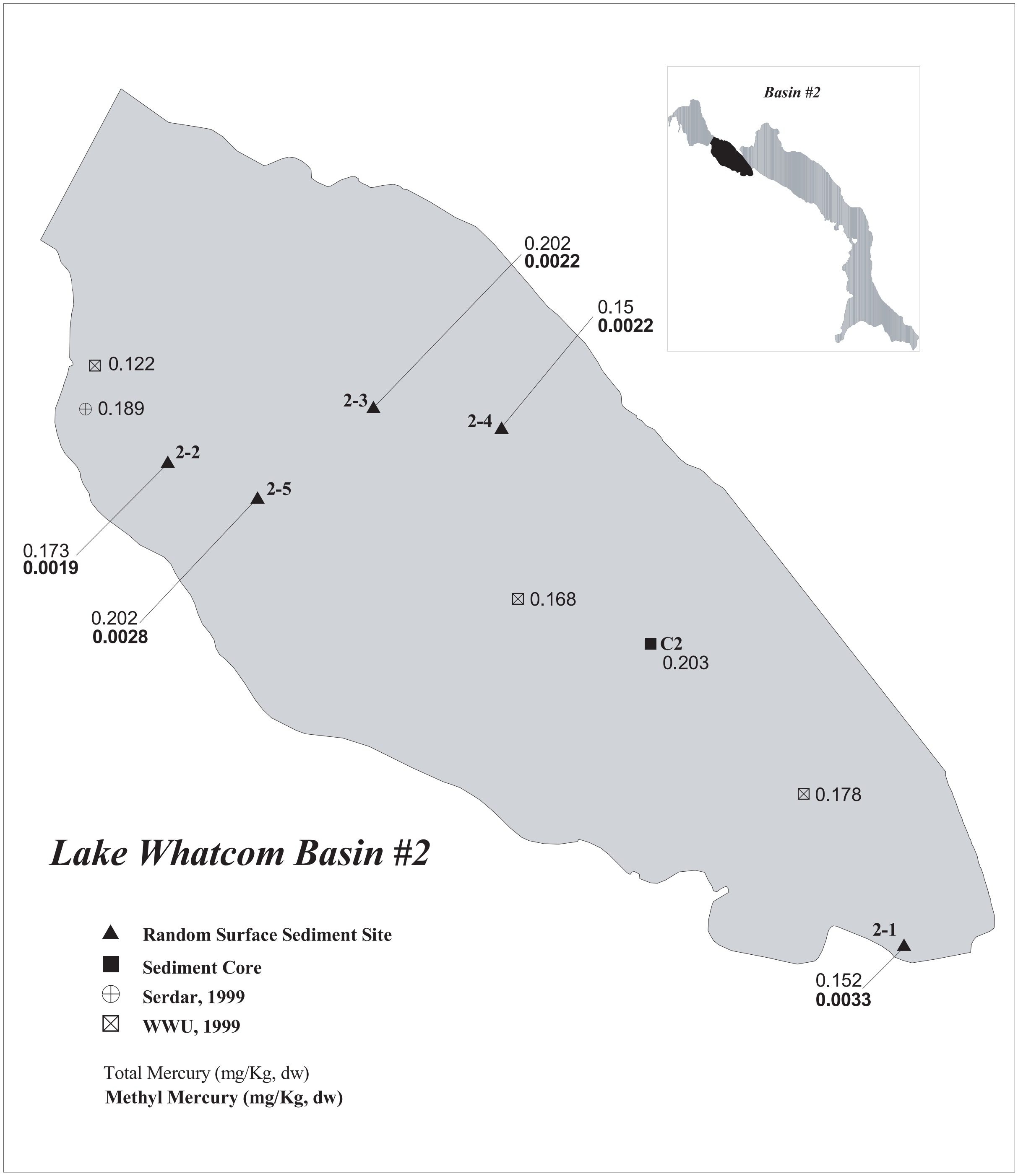

Figure 3b. Total Mercury and Methylmercury in Surface Sediments (0-2 cm) from Basin 2, Lake Whatcom (0-2 cm sections of core were used for comparison with surface sediment).

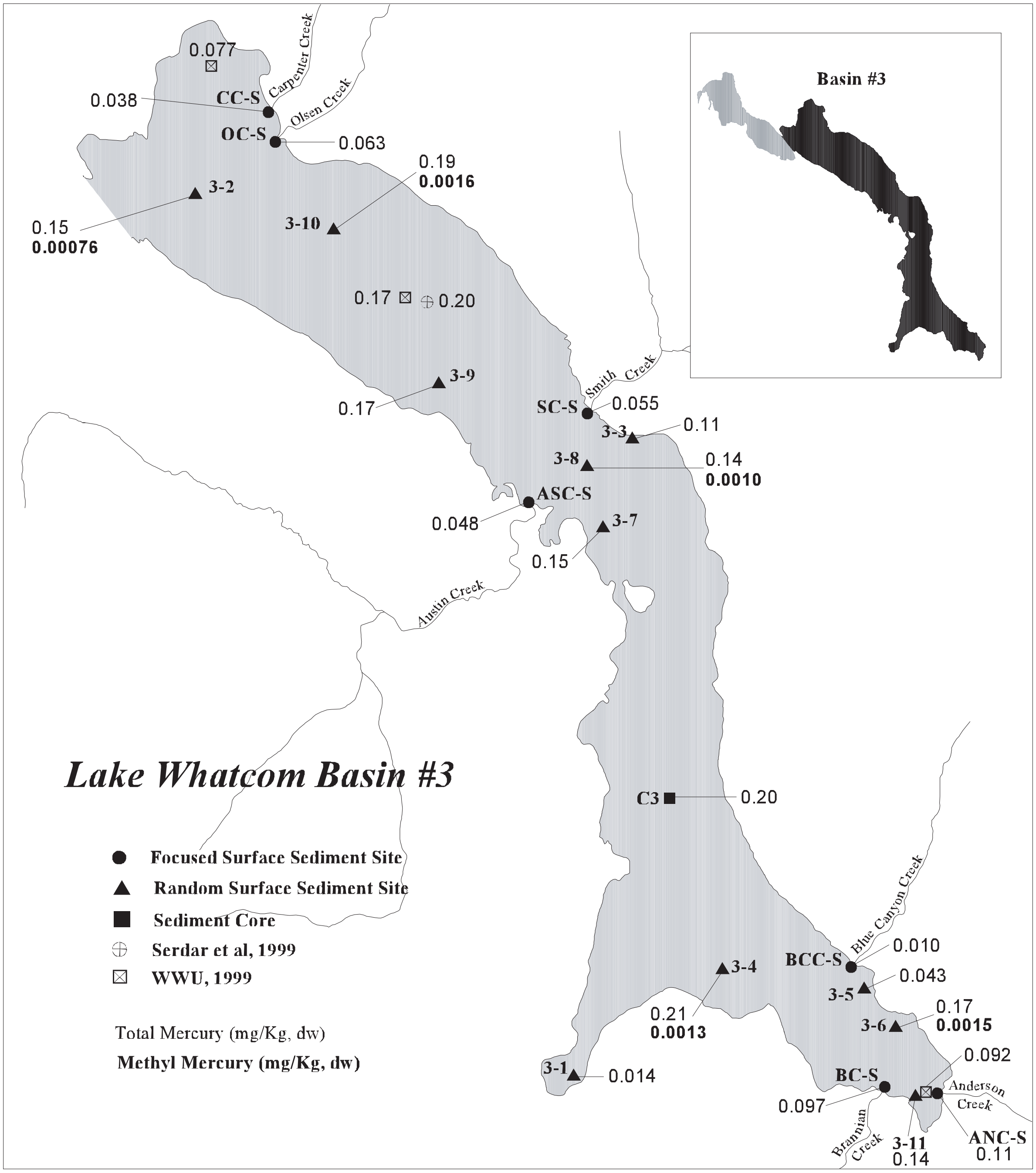

Figure 3c. Total Mercury and Methylmercury in Surface Sediments (0-2 cm) from Basin 3, Lake Whatcom (Note: 0-2 cm sections of core were used for comparison with surface sediments).

Concentrations of total mercury were fairly consistent throughout Lake Whatcom ranging from 0.014 to 0.22 mg/kg (dry weight). The overall mean value for the Lake calculated using all stations was 0.14 mg/kg. Slightly higher concentrations were measured at the random sites in all three basins compared to the tributary sites. The highest concentration (0.22 mg/kg) measured was present at station 1-4 in the central portion of Basin 1 (Figure 3a). This location is near the area where the maximum concentrations of total mercury have been measured in two previous surface sediment collections in the lake (WWU, 1999; Serdar et al., 1999).

A regression analysis was used to see if percent fines and TOC were correlated with mercury levels in surface sediments. Results of this analysis indicated that while both factors had significant correlations with total mercury concentrations, percent fines (r^2= 0.54, p= <0.001) explained more of the variability in the data set than did TOC (r^2= 0.23, p= 0.005).

Total mercury concentrations in surface sediments are plotted against percent fines in Figure 4a. Basin 3 tributary sites tended to have the lowest mercury levels. Compared to the other areas sampled, these sites also had the lowest percent fines content. When total mercury concentrations are normalized to percent fines, little difference was seen between mean mercury levels in the three basins (Figure 4b). Percent fines normalized mercury concentrations were calculated by dividing total mercury concentrations by percent fines (>62 um) and then multiplying the result by 100.

To place total mercury levels in Lake Whatcom surface sediments into perspective, data from Lake Whatcom are compared to other data on mercury levels in Washington lakes and remote lakes in the Fraser River drainage of British Columbia (Table 6).

Table 6. Comparison of Mercury Concentrations in Lake Whatcom Surface Sediments to Other Data on Lakes in Washington and British Columbia (mg/kg, dw).

Location	N=	Number of Lakes	Mean	Maximum
Lake Whatcom				
Present Study	31	-	0.14	0.23
WWU, 1999	10	-	0.14	0.21
Serdar et al., 1999	3	-	0.28	0.46
Other Areas				
Washington State[1,2]	64	23	0.086	0.48
Fraser River Drainage, B.C.[3]	4	4	-	0.069

[1] Fischnaller et al., 2003
[2] Serdar, 1994
[3] Gray and Tuominen, 1998

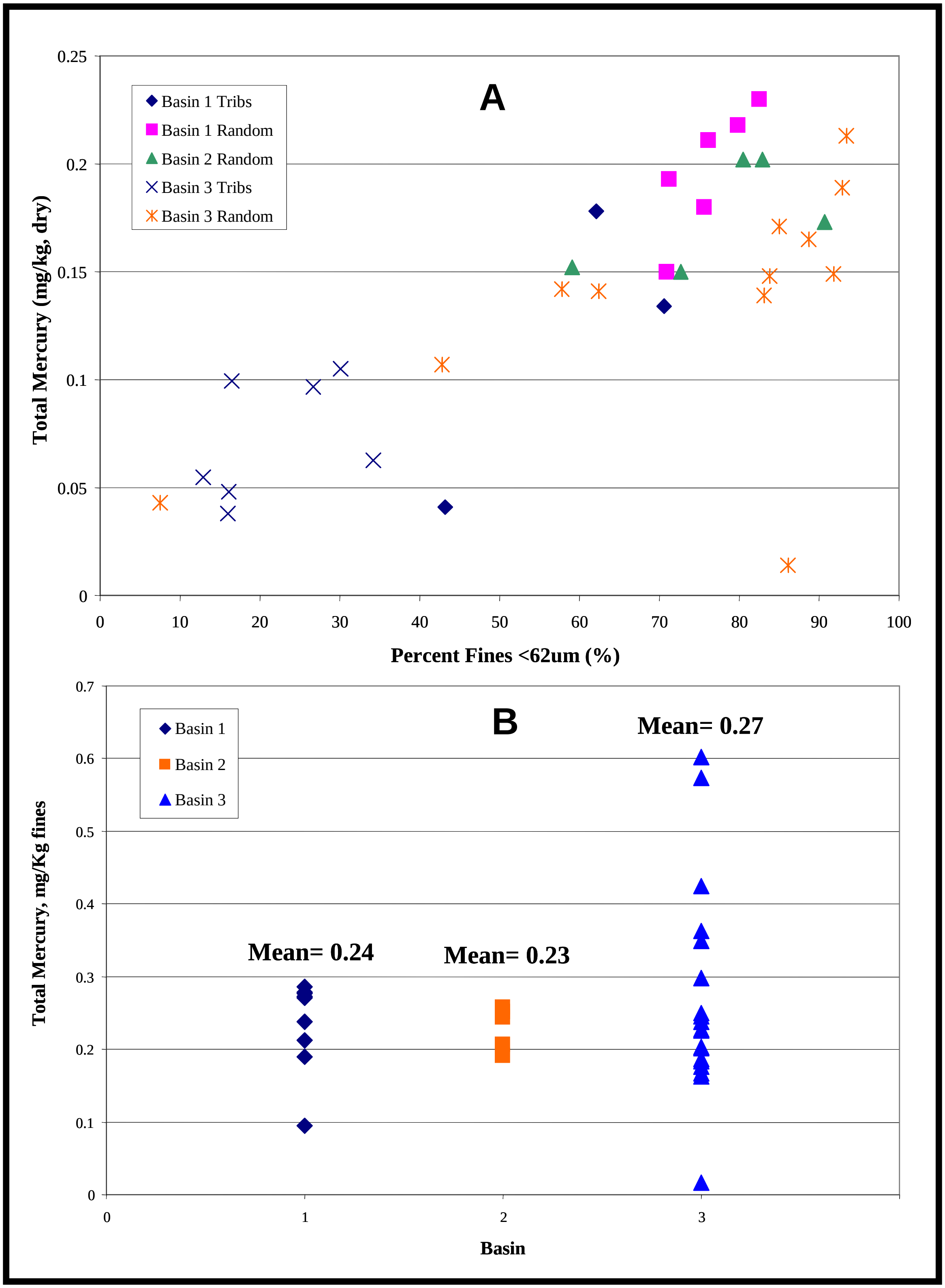

Figure 4a. Total Mercury Concentrations in Lake Whatcom Surface Sediments on a Dry Weight Basis vs Percent Fines.

Figure 4b. Fines Normalized Mercury Concentrations by Basin.
(Percent fines normalized mercury concentrations in Figure 4b were calculated by dividing total mercury by percent fines (<62um) and then multiplying by 100.)

In 1999, Western Washington University (WWU) measured mercury concentrations in surface sediments from Lake Whatcom (WWU, 1999). Concentrations reported for ten sites in the lake ranged from 0.077 to 0.21 mg/kg, with a mean of 0.14 mg/kg (see Figures 3a-c). The highest concentration was measured in the central portion of Basin 1. Ecology's 1998 study also sampled sediments from the lake and several tributaries. Total mercury concentrations ranged from 0.04 to 0.46 mg/kg, with a mean of 0.28 mg/kg. Again the highest concentration was reported near the central portion of Basin 1.

Regionally, the average freshwater sediment concentration for 22 Washington lakes sampled by Ecology between 1993 and 2002 was 0.086, mg/kg. The maximum value reported in four remote lakes in the Fraser River drainage of British Columbia was 0.069 mg/kg. Additionally, the median concentrations of mercury in sediments from streams in the Puget Sound Basin sampled as part of the USGS National Water Quality Assessment Program (NWQA) was 0.1 mg/kg (McCoy and Black, 1998). Based on comparison with these data, sediment concentrations of total mercury in Lake Whatcom do not appear to be high compared to other basins in Puget Sound or elsewhere in the region, with the exception of one anomalously high value from the 1998 Ecology study (Serdar et al., 1999).

Ecology is currently updating recommended numerical Freshwater Sediment Quality Values (FSQVs) for use in Washington State. These guidelines are intended to evaluate the potential for toxic effects on sediment dwelling organisms. Until these guidelines are formally adopted as standards, Ecology uses best professional judgment on a case-by-case basis to evaluate freshwater sediment quality through the use of biological testing (bioassay or benthic communities) or comparison with available FSQVs.

Various FSQVs have been used in North America to evaluate total mercury concentrations in sediments. They range from levels where biological effects are known to always occur down to levels below which biological effects rarely occur. Five effects levels are summarized in Table 7. (Avocet Consulting, 2002; 2003).

Table 7. Selected Freshwater Sediment Quality Values for Total Mercury.

Freshwater Sediment Quality Value	Mercury Concentration (mg/kg, dw)	Effects Level
Apparent Effects Threshold (AET)	0.56	Level above which biological effects have always been observed.
Floating Percentile Method (FPM)	0.50	Proposed level which optimizes reliability and sensitivity in predicting adverse biological effects.
Probable Effects Level (PEL)	0.49	Level at which adverse biological effects are frequently seen.
Lowest Effects Level (LEL)	0.20	Level at which adverse biological effects are seen in 5% of benthic species.
Threshold Effects Level (TEL)	0.17	Level below which adverse biological effects rarely occur.

Apparent Effects Threshold (AETs) values were recommended for use in Washington on an interim basis in 1997 after evaluating synoptic (bioassay + chemical) freshwater sediment data from the state (Cubbage and Batts, 1997). Environment Canada has adopted the Probable Effects Level (PEL) and Threshold Effects Level (TEL) sediment quality guidelines for use as freshwater sediment criteria in Canadian provinces that do not have their own criteria. Ontario additionally considers sediments to be degraded when contaminant levels exceed the Lowest Effects Level (LEL). For sediment contaminant levels falling between the LEL and TEL, biological assessment tools are recommended to establish what action, if any, is needed for a particular waterbody. As an alternative to AETs, the Floating Percentile Method (FPM) has recently been recommended for adoption in Washington State because it is more reliable and provides FSQVs that better predict toxicity in the Washington State data set (Avocet Consulting, 2003).

None of the total mercury concentrations measured in surface sediments during the present study exceeded the three highest levels listing in Table 7 (AET, FPM, or PEL). Eighteen percent of the sites exceeded the LEL, while 36% of the sites were above the TEL. The majority of values exceeding these levels were from Basin 1. Based on comparison with the FSQVs listed above in Table 7, there appears to be a low potential for adverse biological effects in Lake Whatcom sediments due to total mercury concentrations.

Methylation of mercury is a key step in the entrance of mercury into the food chain. Methylation is a complex process that can occur in both sediments and the water column (EPA, 2001). Methylmercury was analyzed in a subset of the Lake Whatcom surface sediment samples since nearly 100% of the mercury that bioaccumulates in upper trophic level fish tissue is methylmercury. Methylmercury concentrations represented <2% of the total mercury level in all sediments tested. The mean methylmercury contribution to the total mercury concentration by basin was as follows: Basin 1= 2.0%, Basin 2= 1.4%, and Basin 3= 0.71%.

A regression analysis was again used to see if a correlation was present between methylmercury and TOC levels in Lake Whatcom surface sediments. Figure 5 shows the results of this analysis.

A good correlation (r^2= 0.79, p=,0.001) between methylmercury and TOC levels is present. This relationship suggests that the TOC content of the sediments is one of the major factors controlling the methylmercury content of surface sediments in the lake.

The slightly higher percentage of methylmercury in Basin 1 could be influenced by the higher TOC levels measured in Basin 1 sediments compared to the other basins. In addition, methylation of mercury primarily occurs under anaerobic conditions. Basins 1 and 2 (especially Basin 1) have historically exhibited oxygen depletion in bottom waters during the late summer and early fall (Cusimano et al., 2002). The combination of these two factors could be contributing to the higher methylmercury levels observed in Basin 1 compared to the other two basins. Lake Whatcom is currently the subject of a TMDL to address low oxygen levels. If successful in reducing oxygen depletion in bottom waters, the higher oxygen levels could also reduce the rate of mercury methylation.

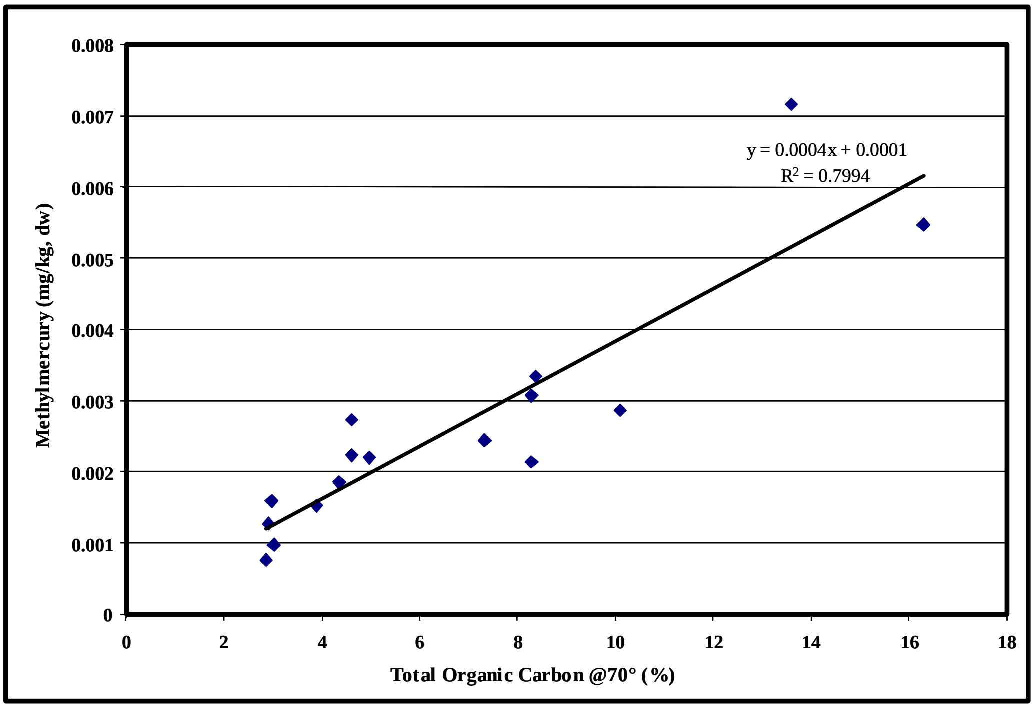

Figure 5. Methylmercury Concentrations in Lake Whatcom Surface Sediments vs. Total Organic Carbon

Sediment Cores

Sediment cores were collected and dated from each of the three basins in Lake Whatcom and five other lakes in Whatcom County to evaluate historical trends in mercury concentrations. A complete list of analytical results for each core is included in Appendix C, Table C2.

Three methods, which use ^{210}Pb, ^{137}Cs, and stable Pb (lead) as markers, were used to generate a weight of evidence sedimentation rate for each of the cores (Paulson, 2003). A general description of each method is provided below.

Primarily produced in the atmosphere, ^{210}Pb is a natural decay product of radon gas (^{222}Rn). After formation ^{210}Pb rapidly adsorbs to aerosol particles and is deposited on land and water surfaces. Once deposited on land and water ^{210}Pb rapidly absorbs to particulates. These particulates quickly settle from the water column and are incorporated into bottom sediments. Since the rates of both sediment and ^{210}Pb deposition are constant over time and the half-life of ^{210}Pb is known, by measuring ^{210}Pb activity at different depths in the core the rate of sediment accumulation and date of formation can be calculated. Since small amounts of ^{222}Rn are present in sediments, this supported amount must be subtracted from the total to obtain the excess amount of ^{210}Pb, which represents the amount added to the water column from atmospheric sources. By plotting the excess ^{210}Pb as a function of depth of dry mass of sediment accumulated, the slope of this line represents the sedimentation rate (Schell and Nevissi, 1980).

A porosity correction for each layer is also used to account for compaction of the sediments with depth.

Similar methods were used to assign dates using ^{137}Cs and stable Pb. ^{137}Cs was first produced by atmospheric testing of nuclear weapons in ~1953 (49 years before 2002), with concentrations peaking in 1964. The first appearance of elevated stable Pb values in sediments in western Washington lakes occurred between 1920 and 1940 (Van Metre et al., 2000 in Yake, 2001), with low level increases possibly due to emissions from the Asarco smelter in Tacoma and addition of tetraethyl-Pb to gasoline. The peak for stable Pb is typically around 1975. The sedimentation rate based ^{137}Cs and stable Pb was determined by dividing the accumulated mass sedimentation at the mid-point of the interval in which the peak was found by 38 years for ^{137}Cs (2002 -1964) and 27 years for stable Pb (2002 - 1975). The peak was defined as the mid-point of those sections in which values are within 10% of the highest value.

A summary of estimated net sedimentation rates determined in the present study is presented in Table 8.

Table 8. Estimated Net Sedimentation Rates Determined for Lake Whatcom and Surrounding Lakes from Dated Sediment Cores.

	Mass Accumulation (g/cm^2/yr)			Linear Accumulation (cm/yr)
Waterbody	Weight of Evidence	Minimum	Maximum	
Lake Whatcom				
Basin 1	0.045	0.018	0.074	0.3
Basin 2	0.040	0.016	0.105	0.24
Basin 3	0.040	0.034	0.08	0.2
Other Lakes				
Lake Terrell	0.031	0.029	0.095	0.36
Wiser Lake	0.048	0.04	0.079	0.041
Fazon Lake	0.039	0.022	0.051	0.52
Lake Samish	0.072	0.046	0.085	0.47
Baker Lake	0.37	-	-	0.99
Washington and Fraser Drainage, B.C[1,2,3]. (N=12)	-	0.03	0.33	0.13-0.49

Minimums and maximums from all methods of determining sedimentation rates.

[1] Van Metre et al., 2001

[2] Yake, 2001

[3] Gray and Tuominen, 1998

Sedimentation rates determined for Lake Whatcom were fairly consistent among the three basins, ranging from 0.040 g/cm^2/yr in Basins 2 and 3 to 0.045 g/cm^2/yr in Basin 1. The overall mean for the lake was 0.042 g/cm^2/yr. Rates determined for the other five lakes in Whatcom County ranged from 0.031 g/cm^2/yr in Lake Terrell to 0.37 g/cm^2/yr in Baker Lake. The rate determined for Baker Lake is highly speculative due to the difficulty in dating this core. The core did not reach native deposits due to the thickness of sediment layer which has accumulated after installation of a dam below the location of the natural Baker Lake basin.

Overall, sedimentation rates determined for Lake Whatcom fall within the low end of the range of rates reported for other lakes in Washington and the Fraser River drainage in British Columbia. Given the size of the lake and the relative lack of major sediment inputs, these rates seem reasonable.

Based on the calculated sedimentation rates and measured mercury concentrations, historical profiles of mercury accumulation in Lake Whatcom were constructed (Figure 6).

In general, a similar pattern of mercury accumulation was observed in all three cores from Lake Whatcom. Mercury concentrations began to increase in Lake Whatcom from background levels around approximately 1900. This finding is consistent with other studies that have documented increases in anthropogenic mercury inputs related to industrialization (Schuster et al., 2002).

Mercury levels continued to increase steadily in Lake Whatcom, peaking in the period from approximately 1987 to 1995. Peak mercury concentrations measured in the Lake Whatcom cores represent an approximately 2-3 fold increase over background levels.

Mercury concentrations appear to have leveled off or are decreasing from peak concentrations observed in the early to mid-1990s. Comparing peak levels in the cores to the average surface sediment (0-2 cm) concentrations measured in the lake in 2002 also suggests that concentrations are decreasing over time. Mean surface sediment concentrations in 2002 (Table 5) are approximately 25% less than historical peaks observed in the sediment cores, which occurred approximately ten years ago. The decline in mercury levels observed is consistent with declines reported in other studies which have evaluated trends in mercury accumulation using dated sediment and ice cores from North America (Schuster et al., 2002).

The declines in mercury levels observed in sediments would suggest that mercury sources to the lake have been reduced. It is anticipated that mercury levels in the lake will continue to decline on a time scale consistent with sediment mixing processes in the lake. A more comprehensive evaluation of the existing data, including an evaluation of atmospheric mercury loading to the lake, is being conducted by USGS as part of the regional Whatcom County mercury evaluation (Paulson, 2003). This evaluation will help determine whether source reductions have occurred and mercury levels will continue to decline in Lake Whatcom.

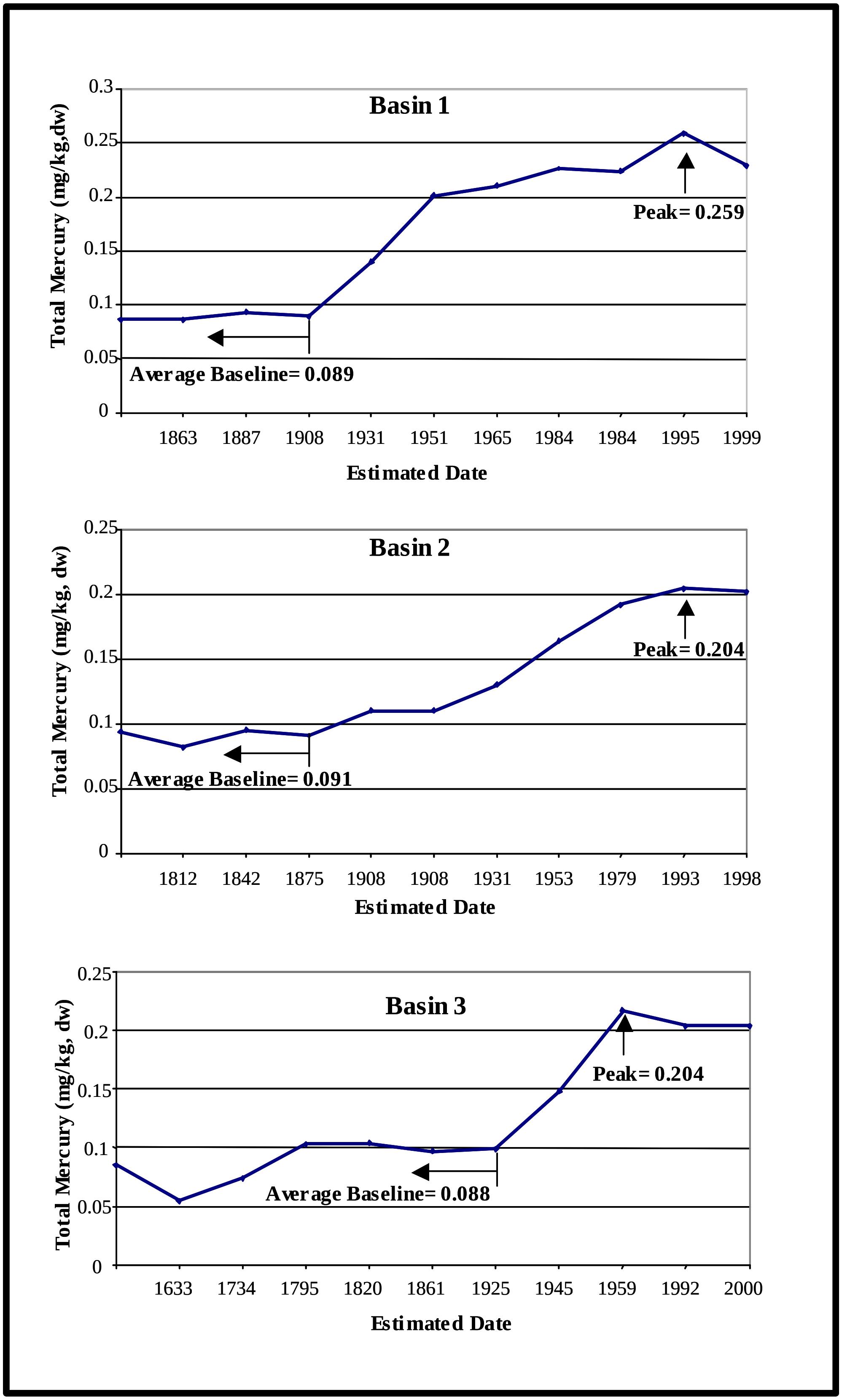

Figure 6. Historical Mercury Concentrations in Lake Whatcom Constructed from Dated Sediment Cores.

Tributary Surface Water

Ten tributaries to Lake Whatcom were selected for sampling based primarily on the size of the discharge, the desire to represent different drainage characteristics and land use patterns, and availability of flow and conventional data. The majority of tributary inputs to the lake occur in Basins 1 and 3, with the largest being Anderson Creek (Nooksack diversion). Each tributary was sampled every other month from July 2002 to May 2003. The timing of sampling in relation to daily precipitation received at the Bellingham Airport weather station is shown below in Figure 7.

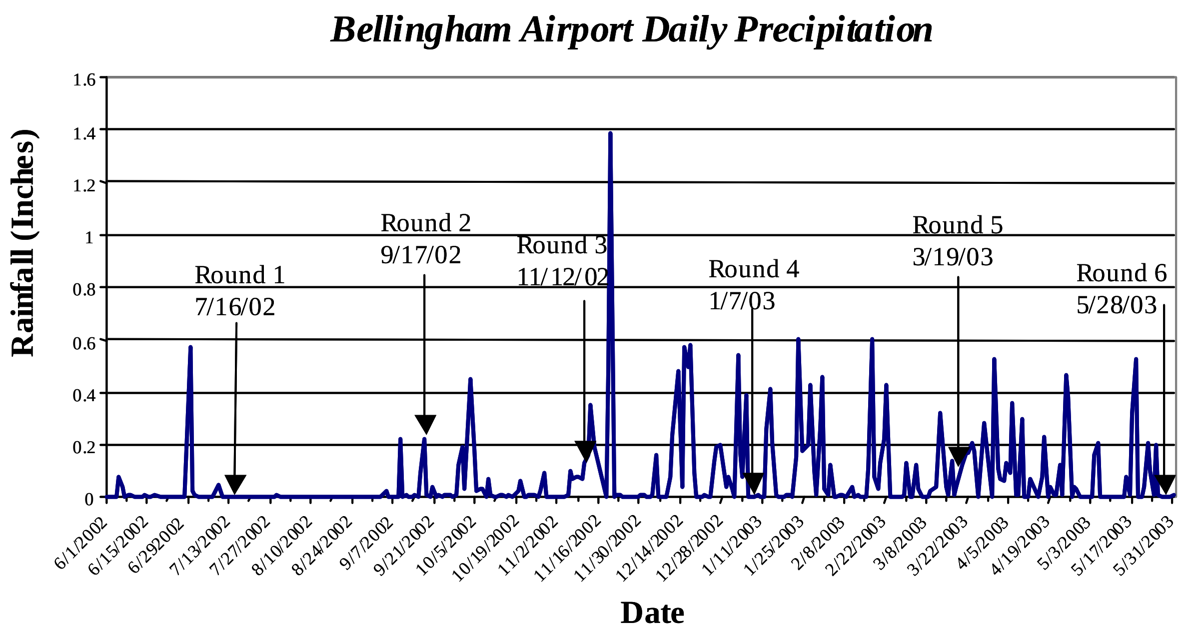

Figure 7. Daily Precipitation Record for Bellingham Airport from June 1, 2002 to May 31, 2003 Showing Tributary Sampling Days.

Measurable precipitation only occurred on three of the six sampling events during the course of the study, and peak rainfall events were severely missed. Consequently, the measured concentrations and flows probably under represent high-flow conditions in the tributaries when most of the loading of particulates and mercury would likely occur.

Total mercury concentrations measured in each of the tributaries are shown in Figure 8. A complete list of water results is included in Appendix C, Table C3.

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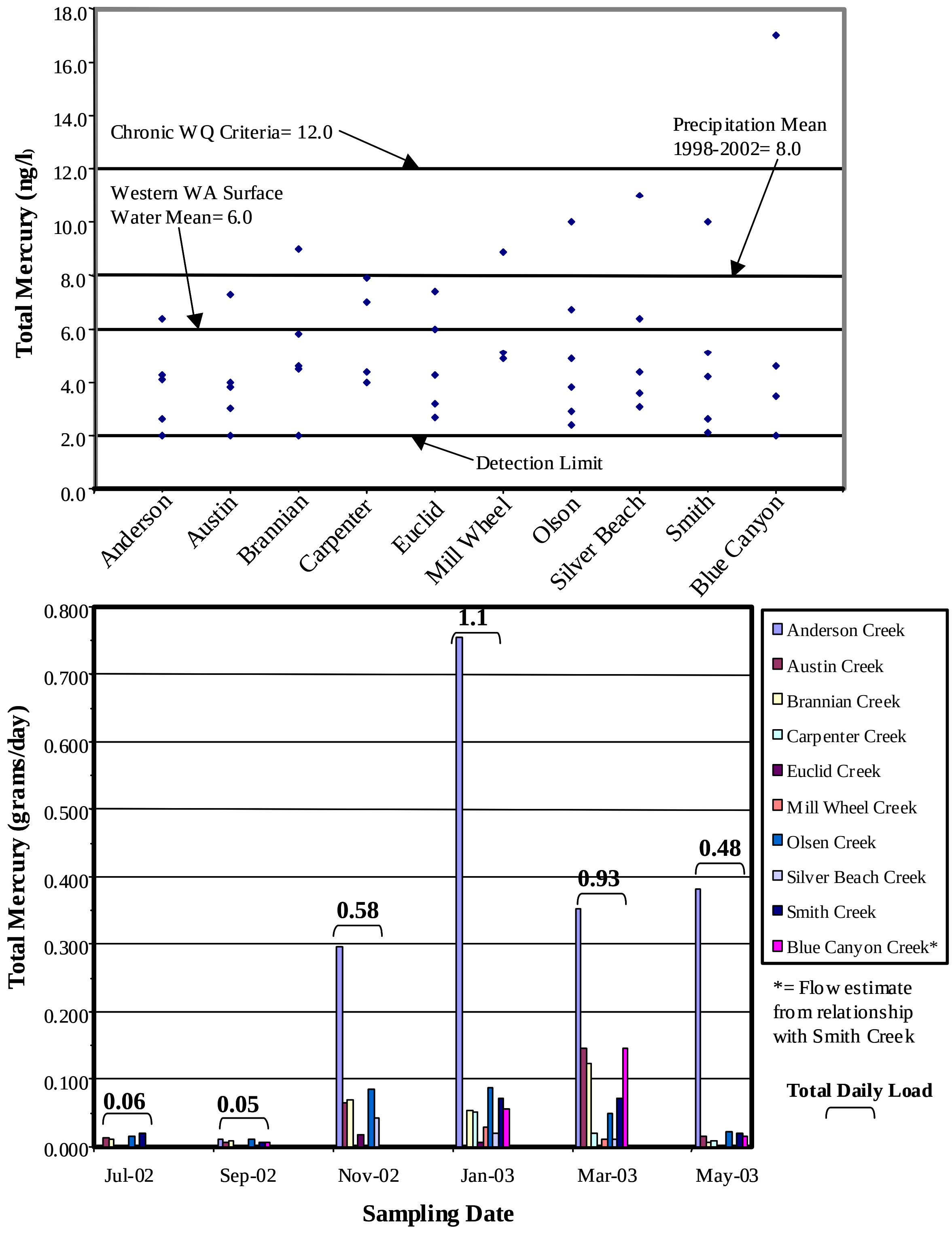

Figure 8. Summary of Concentrations and Loadings to Lake Whatcom from Ten Tributaries, July 2002 to May 2003.

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Mercury levels in all tributaries were generally low during the monitoring period. Concentrations ranged from the detection limit of 2 ng/l to 17 ng/l with a mean concentration of 5 ng/l. The majority of concentrations measured fall at or below those measured in rainfall from 1998 to 2002 at the Seattle (NOAA Sandpoint) air monitoring station operated by the National Atmospheric Deposition Program (NADP, 2003). In addition most of the concentrations are similar to the mean surface water concentration for western Washington calculated from data in Ecology's Environmental Information Management System. Only one value exceeded the chronic water quality standard (12 ng/l) during the monitoring period. This occurred during the November 2002 sampling in Blue Canyon Creek, which discharges to the upper portion of Basin 3.

Total mercury loadings to Lake Whatcom are also shown in Figure 8. Total mercury loadings for each tributary were calculated using the hourly average flow calculated from 15-minute readings on the day of sampling and the measured mercury concentration. The total loading shown for each tributary in Table 9 represents the sum of the total mercury load measured during all sampling events. Combined mercury loadings from all tributaries were low, ranging from 0.05 to 1.1 grams/day. The highest loading was measured during the January 2003 sampling. A relative ranking of the combined mercury loadings measured from each tributary during the monitoring period is shown in Table 9.

Table 9. Relative Ranking of Mercury Loadings from Ten Tributaries to Lake Whatcom, July 2002 to May 2003.

Tributary (Creek)	*Grams of Mercury	% of Total
Anderson	1.8	55.7
Brannian	0.28	8.5
Olsen	0.27	8.4
Austin	0.25	7.6
Blue Canyon	0.22	6.9
Smith	0.19	5.9
Carpenter	0.080	2.5
Silver Beach	0.078	2.4
Mill Wheel	0.041	1.3
Euclid	0.025	0.8
Total	3.2	100

*=Sum of measured load from tributaries during all sampling events, July 2002 to May 2003

Anderson Creek was the most important contributor of total mercury loading from surface water entering the lake during the six instances when samples were collected from July 2002 to May 2003. Anderson Creek accounted for 56% of the total mercury loading measured during these sampling events. Since mercury concentrations are similar in the tributaries, the higher loading from Anderson Creek is primarily a function of flow. The Nooksack diversion into Anderson Creek was operating during all sampling events. Note that the reported loads only represent a daily load from the measured sites at the time of collection and do not account for other terrestrial or atmospheric inputs. To more accurately represent mercury loadings on an annual basis, a harmonic mean flow should be calculated for each of the tributaries and used in conjunction with average mercury concentrations for each tributary to calculate annual loadings to the lake. Harmonic mean flows for each of the tributaries are being developed for use in water quality modeling for the Lake Whatcom Dissolved Oxygen TMDL. After a harmonic mean flow analysis has been performed, a more accurate estimate of mercury loadings to the lake on an annual basis can be calculated using the water quality model developed for the lake. In addition to the need for harmonic flow data, mercury concentrations under high-flow conditions are not well represented in the sampling conducted during the present study. Together, harmonic flows and additional high-flow mercury data should provide a more refined estimate of surface water loadings of mercury to the lake.

One additional sample was collected from Anderson Creek on January 28, 2004 to evaluate mercury concentrations and loadings under high-flow conditions. The mercury concentration in this sample was 6.2 ng/l compared to a mean of 3.5 ng/l measured between July 2002 and May 2003. Flow during this sampling event was 104.7 cfs. The calculated load of total mercury from this sampling was 1.6 grams. This value is similar to the total load measured during the six previous sampling events combined. This demonstrates that while total mercury concentrations are somewhat similar during different time periods in Anderson Creek, loadings can be much higher during high-flow events.

Conclusions

Surface sediments and sediment cores were collected in September 2002, and surface water was collected between July 2002 and May 2003, to evaluate the spatial and temporal distribution of mercury in Lake Whatcom.

Concentrations of total mercury in surface sediments were fairly consistent throughout Lake Whatcom, ranging from 0.014 to 0.22 mg/kg (dry weight). Surface sediment concentrations in Lake Whatcom do not appear to be high compared to levels measured in other areas of Washington. Sediment core profiles indicate that mercury concentrations began to increase from background levels in Lake Whatcom around approximately 1900. Mercury levels continued to steadily increase in the lake, peaking in the period from approximately 1987 to 1995. In most instances there is evidence that mercury concentrations have leveled off or are decreasing from peak concentrations. Mean surface sediment concentrations are approximately 25% less than historical peaks observed in the sediment cores.

The majority of mercury concentrations measured in surface water entering the lake from tributaries fall at or below those measured in rainfall from 1998 to 2002. In addition, concentrations are similar to the mean surface water concentration for western Washington Anderson Creek accounted for approximately 56% of the total mercury loading measured in surface runoff during the six instances that samples were collected between July 2002 and May 2003. Even though Anderson Creek had the largest surface water load of mercury to the lake measured during this study, no violations of the chronic water quality criteria were observed.

The data collected seem to indicate that mercury inputs to Lake Whatcom have decreased in recent years. It is anticipated that mercury levels in the lake will continue to decline consistent with the timeframe of sediment mixing processes. Factors affecting bioaccumulation of mercury in fish tissue are complex and are the subject of considerable research nationwide. However, it is anticipated that fish tissue concentrations would also decline in response to declining mercury levels in sediments.

The major findings of the present study are summarized below:

- Concentrations of total mercury in surface sediments in Lake Whatcom ranging from 0.014 to 0.22 mg/kg, dw. The overall mean value for the Lake calculated using all stations was 0.14 mg/kg. The highest concentration (0.22 mg/kg) was measured in the central portion of Basin 1. This finding is consistent with two previous surface sediment collections in the lake.

- The data collected suggest that total mercury concentrations in Lake Whatcom surface sediments are primarily controlled by grain size. TOC content is one of the major factors controlling methylmercury levels in surface sediments.

- Lake Whatcom sediment concentrations of total mercury do not appear to be high compared to data from other basins in Puget Sound or elsewhere in the region.

- Based on comparison with available Freshwater Sediment Quality Values, there appears to be a low potential for adverse biological effects in sediments due to total mercury concentrations.

- Sedimentation rates determined for Lake Whatcom were as follows:
  Basin 1= 0.045 g/cm^2/yr, Basin 2= 0.040 g/cm^2/yr, and Basin 3= 0.040 g/cm^2/yr.
  The overall mean sedimentation rate for the lake was 0.042 g/cm^2/yr.

- Sediment cores indicate that mercury concentrations began to increase from background levels in Lake Whatcom around approximately 1900. Mercury levels continued to steadily increase in Lake Whatcom, peaking in the period from approximately 1987 to 1995. Mercury concentrations in Lake Whatcom have increased by approximately 2-3 fold over background levels. In most instances, there is evidence that mercury concentrations have leveled off or are decreasing from peak concentrations. Mean surface sediment concentrations are approximately 25% less than historical peaks observed in the sediment cores.

- Concentrations in tributaries ranged from the detection limit of 2 ng/l to 17 ng/l, with a mean concentration of 5 ng/l. The majority of concentrations measured fall at or below those measured in rainfall from 1998 to 2002 at Seattle. In addition, most of the concentrations are similar to the mean surface water concentration for western Washington. Only one value exceeded the chronic water quality standard (12 ng/l) during the monitoring period. This occurred during the November 2002 sampling in Blue Canyon Creek, which discharges to the upper portion of Basin 3.

- Combined mercury loadings from all tributaries during the six sampling events were low, ranging from 0.05 to 1.1 grams/day. The highest loading was measured during the January 2003 sampling. Anderson Creek accounted for 56% of the total mercury loading measured from surface water during the six sampling events. Again, additional flow and concentration data (especially during high-flow conditions) are needed to provide better annual estimates of mercury loading to the lake from surface water.

Recommendations

Based on results of the present study, the following recommendations are made:

- The data collected suggest that mercury levels are declining, and will continue to decline in Lake Whatcom. Given the low levels detected in tributaries, it seems unlikely that conducting a Total Maximum Daily Load study for mercury in Lake Whatcom would succeed in accelerating mercury reductions in the lake. A more comprehensive evaluation of the existing data, including an evaluation of atmospheric mercury loading to the lake, is being conducted by USGS as part of the regional Whatcom County mercury evaluation. This evaluation will help determine whether source reductions have occurred and whether mercury levels will continue to decline in Lake Whatcom.

- Additional total mercury concentrations in selected tributaries to the lake could be determined under high-flow conditions to increase the accuracy of the surface water loading estimate. This sampling should focus on Anderson Creek. In addition, no data are available from Anderson Creek for periods when the Nooksack diversion is not operating.

- A mercury loading simulation should be included as part of the water quality model being developed for Lake Whatcom. The loading estimate should use mercury concentrations measured for each of the tributaries, along with the supplemental high-flow data and the harmonic mean flow developed for the model simulation.

- Total recoverable and methylmercury concentrations should be measured in Lake Whatcom near-bottom waters. These data would be useful in evaluating compliance with a calculated water quality target for the lake that would prevent mercury bioaccumulation in fish tissue above the recommended EPA human health criteria for mercury in fish tissue.

- Periodic monitoring of mercury levels in recreationally targeted fish from the lake should continue in order to determine if mercury levels are declining over time.

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Appendices

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Appendix A

Field Data

Table A1 – Locations of Surface Sediment and Sediment Core Sampling Sites

Table A2 – Locations of Tributary Surface Water Sampling Sites

Surface Sediment Field Logs

Sediment Core Field Logs

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Table A1. Locations of Surface Sediment and Sediment Core Sampling Sites

Basin 1- Tributary Surface Sediment Sites (deg/min)

Station ID	Latitude		Longitude	
MW-S	48	45.552	122	24.978
SB-S	48	46.047	122	24.365
EC-S	48	45.039	122	24.509

Basin 1- Random Surface Sediment Sites (deg/min)

Station ID	Latitude		Longitude	
1-1	48	45.196	122	23.933
1-2	48	45.654	122	24.125
1-3	48	45.691	122	24.855
1-4	48	45.771	122	24.353
1-5	48	45.423	122	24.778

Basin 1- Core Site (deg/min)

Station ID	Latitude		Longitude	
C-1	48	45.674	122	24.629

Basin 2- Random Surface Sediment Sites (deg/min)

Station ID	Latitude		Longitude	
2-1	48	44.343	122	22.323
2-2	48	44.845	122	23.544
2-3	48	44.907	122	23.208
2-4	48	44.894	122	22.999
2-5	48	44.806	122	23.392

Basin 2- Core Site (deg/min)

Station ID	Latitude		Longitude	
C-2	48	44.632	122	22.788

Table A1 (cont.). Locations of Surface Sediment and Sediment Core Sampling Sites

Basin 3- Tributary Surface Sediment Sites (deg/min)

Station ID	Latitude		Longitude	
CC-S	48	45.176	122	21.356
OC-S	48	45.079	122	21.303
SC-S	48	43.735	122	18.953
BCC-S	48	41.012	122	16.876
ANC-S	48	40.420	122	16.251
BC-S	48	40.447	122	16.581
ASC-S	48	43.246	122	19.265

Basin 3- Random Surface Sediment Sites (deg/min)

Station ID	Latitude		Longitude	
3-1	48	40.486	122	18.849
3-2	48	44.765	122	21.803
3-3	48	43.586	122	18.494
3-4	48	41.009	122	17.749
3-5	48	40.888	122	16.721
3-6	48	40.745	122	16.457
3-7	48	43.169	122	18.716
3-8	48	43.464	122	18.842
3-9	48	43.857	122	19.958
3-10	48	44.598	122	20.765
3-11	48	40.407	122	16.291

Basin 3- Core Site (deg/min)

Station ID	Latitude		Longitude	
C-3	48	41.829	122	18.214

Positions report in NAD 83

Table A2. Locations of Tributary Surface Water Sampling Sites

Station ID	Station Name	Description
ANC-W	Anderson Creek (Nooksack Diversion)	The site is located at the bridge where South Bay Drive crosses the creek. The Anderson Creek gage is mounted in the existing stilling well on the east side of Anderson Creek, approximately 0.5 km from the mouth of the creek.
ASC-W	Austin Creek	Approximately 1800 ft upstream from where the creek flows into Lake Whatcom. The Austin Creek gage is mounted on the north west support pillar under the bridge over Austin Creek (Lake Whatcom Blvd.), approximately 1 km from the mouth.
BC-W	Brannian Creek	Downstream of South Bay Drive, approximately 600 m from mouth.
CC-W	Carpenter Creek	Near mouth.
EC-W	Euclid Creek	East of Euclid Ave. 120 m from mouth. Upstream of public trail.
MW-W	Mill Wheel Creek	Upstream side of the culvert the passes under Flynn street.
OC-W	Olsen Creek	The site is located at the bridge where North Shore Road crosses the creek. The gage is at the left bank upstream side of the bridge
SB-W	Silver Beach Creek	Adjacent to Hayward Ct. Approx 130 m from mouth.
SC-W	Smith Creek	Samples are collected approximately 100 yards upstream from Lake Whatcom.
BCC-W	Blue Canyon Creek	Samples are collected upstream from the culvert crossing at Blue Canyon road.

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Surface Sediment Field Logs

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Surface Sediment Sample Field Log

Site: Lake Whatcom Sediment Hg - Tribs

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
MW-5	1	7.5	9/18/2002	1255	12	Gray silty w/rooted plants fine 48.45.552 122.24.978
(embayment)	2	9.2	9/18/2002	1110	12	"
	3	9.0	9/18/2002	1115	14	"
SB-S	1	4.5	9/18/2002	1340	15	Light brown sandy with some silt small gravel and rooted plants
(small flow)	2	4.5	9/18/2002	1350	11	" Worm and freshwater mussel in sample
	3	3.9	9/18/2002	1355	15	Clay with some shell, gravel and sand. Snails present
EC-S	1	5.5	9/18/2002	1425	17	organic, more silt and clay, some sand
(small flow)	2	6.7	9/18/2002	1430	16	Silt with some clay and organic material, rooted plants
	3	7.0	9/18/2002	1440	17	"
CC-S	1	32	9/18/2002	1510	8	Sandy with some grey/brown silt, small gravel
(no flow)	2	40	9/18/2002	1520	8	Woody debris, some sand and silt
	3	46	9/18/2002	1530	8	Some wood mainly sandy material, some organics
OC-S	1	55	9/18/2002	1610	7	Primarily gray sand with some gravel
(flowing on beach)	2	50	9/18/2002	1615	7	"
	3	55	9/18/2002	1625	7	" Brown to gray sand, some silt

Recorder: ***DN***

Surface Sediment Sample Field Log

Site: Lake Whatcom Sediment Hg - Tribs

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
SC-S	1	45	9/18/2002	1650	6	Sandy steep bottom
(Creek flowing on beach)	2	43	9/18/2002	1655	10	debris on surface, freshwater clams
	3	45	9/18/2002	1700	12	Leaf litter, wood debris, organic debris, some sand
ASC-S	1	30	9/18/2002	1720	6	Brown coarse sand with some wood debris on surface
(Larger creek flowing)	2	25	9/18/2002	1725	7	Brown fine sand with some organics on surface
	3	20	9/18/2002	1730	15	Silt with some clay
BCC-S	1	57	9/18/2002	1805	4	Gray sand with wood debris on surface
(Not flowing)	2	90	9/18/2002	1815	11	Brown sand with some silt, wood debris on surface
	3	DNC	DNC	DNC	DNC	4 attempts @ 3rd Grab
ANC-S	1	50	9/18/2002	1830	14	Organic debris on surface, leaf and wood, sandy with some silt
(Good flow in Creek)	2	52	9/18/2002	1840	14	" less leaves than #1
	3	55	9/18/2002	1845	16	"
BC-S	1	95	9/18/2002	1900	12	Leaf litter on surface, silty with some sand
(Good flow in Creek)	2	95	9/18/2002	1905	13	"
	3	96	9/18/2002	1910	14	"

Recorder: ***DN***

Surface Sediment Sample Field Log

Site: Lake Whatcom Sediments Hg - Basin 1

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
1-4	1	40	9/19/2002	0835	13	Silty sand, brown to gray
	2	40	9/19/2002	0845	18	Brown to gray silty sand
	3	40	9/19/2002	0855	17	"
1-3	1	30	9/19/2002	0910	15	Brown to gray silty, watery
	2	30	9/19/2002	0920	11	Wood debris, brown to gray silt
	3	30	9/19/2002	0925	15	Brown to gray silt, some organics
1-5	1	23	9/19/2002	0935	13	Brown to black silt, wood debris
	2	23	9/19/2002	0946	16	Brown silt with some wood debris
	3	23.0	9/19/2002	0950	16.0	" Some sheen on water
1-1	1	22	9/19/2002	1005	17	Brown silt with some plants rooted, some sand
	2	22	9/19/2002	1015	17	Brown silt with some sand, coontail rooted
	3	22	9/19/2002	1020	17	"
1-2 (1st alternate station used)	1	9	9/19/2002	1040	17	Brown silt with vegetation, wood at depth
	2	9	9/19/2002	1045	16	"
	3	9	9/19/2002	1055	16	" Rooted vegetation

Recorder: ***DN***

Surface Sediment Sample Field Log

Site: Lake Whatcom Sediment Hg - Basin 2

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
2-2	1	40	9/19/2002	1115	17	Brown to gray silty with some sand, thin aerobic layer
	2	39	9/19/2002	1120	17	" thin oxidized layer on surface
	3	40	9/19/2002	1125	17	"
2-5	1	45	9/19/2002	1135	16	Brown to gray silt, thin oxidized layer < 1cm
	2	45	9/19/2002	1140	18	Brown to gray silt, thicker oxidized layer than grab #1
	3	45	9/19/2002	1145	17	"
2-4	1	35	9/19/2002	1210	15	Brown oxidized layer on surface gray below purple oxidation
	2	35	9/19/2002	1220	14	" Some clay clumps
	3	33.0	9/19/2002	1230	15	"
2-3 (1st alternate station used)	1	43	9/19/2002	1315	17	"
	2	43	9/19/2002	1320	17	"
	3	43	9/19/2002	1325	15	"
2-1	1	26	9/19/2002	1250	15	Brown to gray silty with wood chunks
	2	33	9/19/2002	1255	17	Brown to gray fine silt, less wood than #1
	3	31	9/19/2002	1300	18	"

Recorder: ***DN***

Surface Sediment Sample Field Log

Site: Lake Whatcom Sediments Hg - Basin 3

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
3-2	1	213	9/19/2002	1345	14	Brown silt, sawdust at depth
	2	214	9/19/2002	1355	14	Brown silt, wood debris (fibers)
	3	213	9/19/2002	1410	13	"
3-10	1	250	9/19/2002	1430	14	Brown silt with sand at depth, small amount of wood
	2	251	9/19/2002	1440	14	Thin brown layer over gray silt below smaller layer of wood @ depth over sand
	3	251	9/19/2002	1445	15	Thin brown layer over gray silt wood layer over gray sand
3-8	1	230	9/19/2002	1515	15	Thin brown layer wood layer over and at depth
	2	227	9/19/2002	1520	17	Thin brown layer over gray silt no wood
	3	227.0	9/19/2002	1530	18	"
3-4	1	279	9/19/2002	1550	17	"
	2	275	9/19/2002	1600	17	"
	3	276	9/19/2002	1615	18	"
3-6	1	97	9/19/2002	1630	12	Brown to gray silt, some wood debris at depth
	2	115	9/19/2002	1640	14	"
	3	115	9/19/2002	1645	14	"

Recorder: ***DN***

Surface Sediment Sample Field Log

Site: Lake Whatcom Sediments Hg - Basin 3

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
3-9	1	266	9/20/2002	0830	17	Light brown surface layer, gray silt with some sand and wood at depth
	2	266	9/20/2002	0840	17	"
	3	266	9/20/2002	0845	17	" wood layer at about 8cm
3-3	1	48	9/20/2002	0910	12	Brown to gray silt with sand and wood debris
	2	49	9/20/2002	0920	17	" mussels present
	3	50	9/20/2002	0925	15	Light brown surface layer gray to black silt with wood at depth
3-7	1	271	9/20/2002	0940	17	Light brown surface layer <1 cm over gray silt, wood fiber at depth
	2	270	9/20/2002	0950	17	"
	3	271.0	9/20/2002	0955	14	Light brown oxidized layer on surface, gray silt below
3-5	1	43	9/20/2002	1015	12	Light silt layer over sand and gravel
	2	50	9/20/2002	1025	17	" more silt than #1, wood debris at depth
	3	52	9/20/2002	1040	5	Light silt over gravel and some organics 1 mussel
3-11	1	42	9/20/2002	1055	16	Fine brown silt, some organics and wood at depth
	2	47	9/20/2002	1100	16	Wood at depth, slight H_2S smell
	3	46	9/20/2002	1110	17	" Wood and sand at depth, thick silt on surface

Recorder: ***DN***

Surface Sediment Sample Field Log

Site: Lake Whatcom Sediments Hg - Basin 3

Station	Grab No.	Depth (ft)	Date	Time	Sediment Penetration (cm)	Sample Description
3-1	1	32	9/20/2002	1130	16	Soft brown to gray silt with wood debris
	2	36	9/20/2002	1135	17	"
	3	37	9/20/2002	1140	17	"
Recollect 3-4 and 3-10						
3-4	1	84 (m)	9/25/2002	1550	13	Brown silt no wood
	2	84 (m)	9/25/2002	1600	13	"
	3	84 (m)	9/25/2002	1615	13	" Oxidized chunks on surface, clumps of organic material
3-10	1	76 (m)	9/25/2002	1650	11	Dark brown layer over gray brown silt
	2	76 (m)	9/25/2002	1700	9	Similar to #1 with wood debris
	3	76 (m)	9/25/2002	1715	9	Dark to light brown surface, some wood at bottom

Recorder: ***DN***

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Sediment Core Field Logs

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Sediment Core Field Log

Date = 9/25/2002
Time = 0935
Station = C-1 (Lake Whatcom Basin 1)
Location=
Lat- 48° 45.674
Long- 122° 24.629
Datum- NAD 83
Water Depth (total ft) = 74 (22.6 meters)
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 50

Core Description
Interval (cm) Description

General- Core intact on 1st drop. Red worms present on surface of grab down to 3cm.

0-16cm- Uniform brown silt
16-19cm- wood debris present
19cm- contact change to light brown fine silt

19- bottom- light brown compacted clay

Sediment Core Field Log

Date = 9/25/2002
Time = 1132
Station = C-2 (Lake Whatcom Basin 2)
Location=
  Lat- 48° 44.632
  Long- 122° 22.788
  Datum- NAD 83
Water Depth (total ft) = 70.3 (21.4 meters)
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 49

Core Description
Interval (cm) Description

Sediment filled to within 2cm of surface
1-4cm – some small wood and black particles (small wood fibers)

grey silt throughout core
core uniform throughout column

Sediment Core Field Log

Date = 9/25/2002
Time = 1420
Station = C-3 (Lake Whatcom Basin 3)
Location=
  Lat- 48° 41.829
  Long- 122° 18.214
  Datum- NAD 83
Water Depth (total ft) = 102 meters
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 43

Core Description
Interval (cm) Description

Perfect core
Top 2 cm watery
0-6cm – light brown silt with some oxidation, watery
below 6 light grey clay (some brown)

>20cm – sand layer @ bottom with plant material
16cm – begin of bark and wood fibers (plant debris)
17cm – wood fibers increase in size (plant debris)
18cm – bark (plant debris)

---

last 6cm – sand and clay, black layers

Sediment Core Field Log

Date = 9/26/2002
Time = 1139
Station = Baker-1
Location = Baker Lake Core
Lat- 48° 43.700
Long- 121° 37.082
Datum- NAD 83
Water Depth (total ft) = 50.3 meters
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 32.5

Core Description

Interval (cm) Description
Light brown fine silt and clay uniform consistency Reducing layer starts at approximately 3cm (black streaks)
Wood debris at 16cm

Sediment Core Field Log

Date = 9/24/2002
Time = 0930
Station = TER-1 (Lake Terrell)
Location = center of lake
  Lat- 48° 51.819
  Long- 122° 41.182
  Datum- NAD 83
Water Depth (total ft) = 7.0 (2.1 meters)
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 27.5

Core Description
Interval (cm) Description

Silty layer on top 1cm
16-21cm – wood fibers and plant material
9-17cm – limb vertical in core

22-bottom - compacted silt and clay
#1 top
#22 bottom

Discarded bottom 2 cm

Sediment Core Field Log

Date = 9/23/2002
Time = 1430
Station = SAM1
Location = Lake Samish
  Lat- 48° 39.898
  Long- 122° 23.099
  Datum- NAD 83
Water Depth (total ft) = 71.5 (21.8 meters)
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 32.5

Core Description
Interval (cm) Description

1 = 1cm top
2 = 2cm

Bottom 6cm of core brownish fine material

Sediment Core Field Log

Date = 9/24/2002
Time = 1750
Station = WIS-1
Location = Wiser Lake
    Lat- 48° 54.207
    Long- 122° 28.790
    Datum- NAD 83
Water Depth (total ft) = 7.5 (2.3 meters)
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 50

Core Description
Interval (cm) Description

Top 1cm may have been disturbed
Uniform material black to brown silt with some organic brown silt layer at bottom 15cm

14-16cm – woody debris layer

Sediment Core Field Log

Date = 9/24/2002
Time = 1340
Station = FAZ-1
Location = Lake Fazon
  Lat- 48° 51.908
  Long- 122° 22.039
  Datum- NAD 83
Water Depth (total ft) = 16 (4.9 meters)
Equipment = Box Core
Sediment Penetration (cm) =
Sediment Recovery (cm) = 50

Core Description
Interval (cm) Description

Uniform fine silt top to bottom

Appendix B

Quality Assurance

Table B1 - Recommended Containers, Preservatives, and Holding Times used for Sediment Samples

Table B2 - Quality Control Samples and Frequency of Analysis

Table B3 - Field and Laboratory Duplicate Analysis for Sediments

Table B4 - Blind Reference and Split Sample Results for Mercury in Sediment

Table B5 - Quality Assurance Data for Water

Case Narratives for Individual Analyses

- Surface Sediment
- Sediment Cores
- Tributary Surface Water

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Table B1. Containers, Preservatives, and Holding Times for Sediment Samples (PSEP, 1996).

Analyte	Container	Preservation Technique	Maximum Holding Time
TOC	2oz Glass	Freeze, -18°C Refrigerate, 4°C	6 months 14 days
Grain Size	8oz Glass	Refrigerate, 4°C	6 months
Total Lead	4oz Glass[1]	Freeze, -18°C Refrigerate, 4°C	2 years 6 months
Total Mercury	4oz Glass[1]	Refrigerate, 4°C	28 days
Methylmercury	4oz Glass[2]	Freeze, -18°C	For storage beyond 1 day
Pb-210	4oz Glass[2]	Refrigerate, 4°C	-
Cs-137	4oz Glass[2]	Refrigerate, 4°C	-

[1] Recommended in Manchester Laboratory Users Manual (MEL, 1994)

[2] Recommended by the Contract Laboratory

Table B2. Minimum Quality Control Samples and Frequency of Analysis.

Parameter	Field Bottle Blank	Field Replicate	Method Blank	Analytical Replicates	Lab Control Standard	Matrix Spike	Matrix Spike Duplicate
Sediment							
TOC	-	1/20	1/20	1/20	1/batch	-	-
Grain Size	-	1/20	-	1/20	-	-	-
Total-Hg	-	1/20	1/20	1/20	1/batch	1/20	1/20
Methyl-Hg	-	1/20	1/20	1/20	-	1/20	1/20
Total-Pb	-	1/20	1/20	1/20	1/batch	1/20	1/20
Pb-210	-	-	1/20	1/20	1/20	-	-
Cs-137	-	-	1/20	1/20	1/20	-	-
Water							
Total-Hg	1/per 2 batches	1/batch	1/20	1/batch	1/2 batches[1]	1/batch	1/batch

Batch = Sampling event

- Not applicable

[1] NIST 1641d diluted to 0.032 ug/l and analyzed in duplicate/batch

Table B3. Field and Laboratory Duplicate Analysis for Sediment.

Field Duplicates for Percent Solids (%)

Station	Sample No	Dup 1	Dup 2	RPD
C-1-3	408502/11	18.8	18.9	0.1
C-2-6	408517/22	17.7	17.8	0.1
C-3-7	408529/33	36.5	37.2	0.5

Field Duplicates for TOC@70°C (%)

Station	Sample No	Dup 1	Dup 2	RPD
C-1-3	408502/11	7.9	7.9	0.0
C-2-6	408517/22	5.6	5.6	0.0
C-3-7	408529/33	5.6	4.6	4.9

Laboratory Duplicates for TOC@70°C (%)

Station	Sample No	Result	Lab Dup 1	Lab Dup 2	RPD
TER-1-5	2418570	25.1	26	23.0	12
C-1-6	2408506	9.56	9.55	9.5	0.6
C-3-4	2408526	2.88	2.82	2.8	2.8
SAM-1-3	2408579	4.9	4.9	5.1	4
SAM-1-10	2408586	6.6	6.5	6.5	1.5
WIS-1-8	2418551	21.6	23.1	24.8	14.0

Field Duplicates for TOC@104°C (%)

Station	Sample No	Dup 1	Dup 2	RPD
C-1-3	408502/11	8.3	8.2	0.3
C-2-6	408517/22	5.7	5.7	0.0
C-3-7	408529/33	5.7	4.6	5.3

Field Duplicates for Total Mercury (mg/kg, dry)

Station	Sample No	Dup 1	Dup 2	RPD
C-1-3	408502/11	0.22	0.226	0.3
C-2-6	2408517/22	0.11	0.11	0.0
C-3-4	2408526	0.11	0.0933	4.8

Field Duplicates for Total Lead (mg/kg, dry)

Station	Sample No	Dup 1	Dup 2	RPD
C-1-3	408502/11	93	95	0.5
C-2-6	2408517/22	6.33	6.59	1.0
C-3-4	2408526	14.4	14.2	0.3

Table B4. Blind Reference and Split Sample Results for Mercury in Sediment (mg/kg, dry)

Sample ID	Sample No	Type	SRM	MEL Total Hg	USGS Total Hg	RPD	Brooks Rand Methyl Hg	USGS Methyl Hg	RPD	Certified Value	95% Confidence
1-6	38-8447	Reference	IAEA-405	NA	NA		0.005063	NA		0.00549	0.00496-0.00602
1-7	38-8449	Reference	NRC MESS-3	0.107	NA		NA	NA		0.091	0.082-0.10
1-8	38-8450	Reference	IAEA-405	0.804	NA		NA	NA		0.81	0.77-0.85
WIS-1-11	41-8554	Reference	IAEA-405	0.918 J	NA		NA	NA		0.81	0.77-0.85
FAZ-1-11	41-8565	Reference	NRC MESS-3	0.147 J	NA		NA	NA		0.091	0.082-0.10
TER-1-11	41-8576	Reference	IAEA-405	0.826 J	NA		NA	NA		0.81	0.77-0.85
3-12	38-8448	Reference	IAEA-405	NA	NA		0.00435	NA		0.00549	0.00496-0.00602
SAM-1-11	40-8587	Reference	NRC MESS-3	0.071	NA		NA	NA		0.091	0.082-0.10
1-4	38-8418	Split	-	0.218	0.198	9.6	0.00307	0.00668	74.1	-	-
1-4 (Dup)	38-8445	Eco Dup	-	0.230	NA		0.00213	NA		-	-
2-5	38-8425	Split	-	0.202	0.154	27.0	NA	NA		-	-
3-8	38-8440	Split	-	0.139	0.123	12.2	0.00097	0.00101	3.8	-	-

NA = Not analyzed

MESS-3 = National Research Council of Canada, Marine Sediment Reference Material for Trace Metals and Other Constituents

IAEA = International Atomic Energy Agency- Trace Elements and Methyl-Mercury in Estuarine Sediment

RPD = Relative Percent Difference

Table B5. Quality Assurance Data for Water.

I. Field Duplicate Results for Total Recoverable Mercury (ug/l).

Location	Round	Date	Duplicate 1		Duplicate 2		RPD
ANC-W	1	7/16/2002	0.0055		0.0072		13.4
SB-W	2	9/17/2002	0.0041		0.0031		13.9
BC-W	3	11/12/2002	0.0092		0.0088		2.2
BCC-W	4	11/7/2002	0.002	u	0.002	u	0.0
SC-W	5	3/19/2003	0.002	u	0.0023		7.0
ANC-W	6	5/28/2003	0.0026		0.0024		4.0

u = Not detected at detection limit shown Mean= 6.75%

II. Field Blank Results for Total Recoverable Mercury (ug/l).

Round	Date	T. Hg
1	7/16/2002	NA
2	9/17/2002	0.002 u
3	11/12/2002	NA
4	1/7/2003	0.002 u
5	3/19/2003	NA
6	5/28/2003	0.002 u

u = Not detected at detection limit shown

NA = Not Analyzed

III. Analysis of Reference Materials for Total Recoverable Mercury (ug/l).

Date	Result 1	Result 2	Certified Value
11/12/02	0.032	0.0314	0.0308
1/07/03	NA	0.032	0.0308

NIST #1641 = Mercury in Water diluted to 0.0308 ug/l

NA = Not Analyzed

Case Narratives for Individual Analyses

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Data Qualifier Codes

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.

UJ - The analyte was not detected at or above the reported estimated result.

REJ - The data are unusable for all purposes.

NAF - Not analyzed for.

N - For organic analytes there is evidence the analyte is present in this sample.

NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

NC - Not Calculated

E - The concentration exceeds the known calibration range.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

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Case Narratives

Surface Sediment

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Manchester Environmental Laboratory

7411 Beach Drive
East Port Orchard WA 98366

September 6, 2002

Project: Lake Whatcom

Samples: 38-8412-20, 8422-43, 8445-46

Laboratory: Rosa Environmental

By: Pam Covey

Case Summary

These samples required thirty-three (33) Grain Size analyses on sediment samples using Puget Sound Estuary Protocol (PSEP) method. Two samples were analyzed in triplicate. The samples were received at the Manchester Environmental Laboratory and sent to the contract lab on October 17, 2002 for Grain Size analyses.

The analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness. See narrative from Rosa for further explanation on sample analysis anomalies.

The results are acceptable for use as reported.

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Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

October 10, 2002

Subject: Metals Lake Whatcom Mercury - 38

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. Samples were digested and analyzed for mercury following method EPA 245.5 (CVAA).

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 09/24/02 and 09/27/02. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition and where applicable, were properly preserved.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. All calibration correlation coefficients were greater than 0.995. The instrument was calibrated with NIST traceable standards and verified to be in calibration with a second source NIST traceable standard. Balances are professionally calibrated yearly and calibrated in-house daily. Soil drying oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

All internal standard recoveries were within acceptance limits.

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

February 27, 2003

Subject: General Chemistry Lake Whatcom Mercury - 38

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used with the qualification noted in this memo. The following method was used in the analyses of these samples: EPA 160.3 for percent solids and PSEP – TOC for total organic carbon (TOC).

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 9/24/02 and 9/27/03. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition. Thirty four (34) samples were received and assigned laboratory identification numbers 388412 – 388443, 388445 and 388446. Samples were frozen before analysis.

Holding Times

All samples except 388436 and 388442 were analyzed out of hold time for percent solids. The results were qualified as estimates. All other analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. Calibration correlation coefficients for TOC were greater than the acceptance limit of 0.995. The instrument was calibrated with a NIST traceable standard and verified to be in calibration with a second source NIST traceable standard.

Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

NA

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

U	-	The analyte was not detected at or above the reported result.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

WDOE Manchester Environmental Laboratory

7411 Beach Drive East, Port Orchard, Washington 98366

October 28, 2002

Subject:	**Lake Whatcom**
Samples:	02- 388415 through 388420, 388422 through 388425, 388434, 388435, 388436, 388438, 388440, 388442, 388445, 388447, 388448
Project ID:	1860-02
Laboratory:	Brooks Rand LLC
Project Officer:	Dale Norton
By:	Karin Feddersen

Methyl Mercury

Summary

Quality control samples are evaluated below. See Brooks Rand's narrative for more detailed information. Brooks Rand flags have been replaced with Manchester Laboratory qualifiers following EPA protocols.

Analytical Methods

These samples were analyzed using Brooks Rand's version of EPA method 1630.

Holding Time

Samples were analyzed within 24 days of receipt. Four samples were received by Brooks Rand in broken jars. Brooks Rand does not believe the quality of the data was likely compromised by this condition. However, to be conservative, the Brooks Rand "H" qualifier has been replaced with a "J" indicating the values for samples 388416, 388419, 388440 and 388442 are estimates.

Calibration

Continuing Calibration Verification (CCV) standards and instrument blanks were analyzed every 10 samples. The standard recoveries were within ± 25% of the true value. The analyte levels of in the blanks (when detected) were well below the sample levels.

Blanks

A low level of Methyl Mercury was detected in some of the method blanks at a level far below that detected in the samples. No qualification was warranted for this condition.

Laboratory Control Sample

Recoveries for the fortified blank and Certified Reference Material (CRM) were within acceptable limits.

Duplicate Samples

Duplicate analyses were performed on samples 388415 and 388417. The Relative Percent Differences (RPD) between the results for each pair were < 20%.

Matrix Spikes

An aliquot of sample 388415 was spiked with Methyl Mercury. The recovery was within Brooks Rand acceptance limits of 60 to 120%.

Case Narratives

Sediment Cores

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Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

February 6, 2003

Subject: General Chemistry Lake Whatcom Mercury – 40 & 41

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. The following method was used in the analyses of these samples: PSEP - TOC for total organic carbon (TOC).

The analysis requested was evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 10/03/02. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition. Thirty three (33) samples were received and assigned laboratory identification numbers 408500 – 408502 and 408504 - 408533.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. All calibration correlation coefficients were greater than 0.995. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

NA

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

U	-	The analyte was not detected at or above the reported result.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

March 07, 2003

Subject: General Chemistry Lake Whatcom Mercury 40 & 41

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used with the qualifications noted in this memo. The following methods were used in the analyses of these samples: EPA 160.3 for % solids and PSEP - TOCM for total organic carbon (TOC).

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 10/03/02 and 10/09/02. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition. Eighty three (83) samples were received and assigned laboratory identification numbers 408500 - 408502, 408504 – 408533, 418534 – 418553, 418555 – 418564, 418566 - 418575 and 408577 - 408586. Samples were frozen until analyzed.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. Calibration correlation coefficients were greater than the acceptance limit of 0.995. The instrument was calibrated with a NIST traceable standard and verified to be in calibration with a second source NIST traceable standard.

Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

NA

Replicates

All associated duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

For % solids, samples are dried at 104ºC and analyzed. For TOC analysis, samples are dried at 70ºC, the % solids determined and the samples are analyzed. The % solids at 70ºC is used in calculating the TOC concentration.

Samples 408578 and 408579 for % solids (104º) analysis were inhomogeneous. The results were qualified as estimates. The % solids (70º) used to calculate the TOC concentration correlated with the % solids from prior mercury analysis. Therefore the TOC results for these samples were not qualified.

Samples 418541, 418543 and 418545 for TOC analysis were inhomogeneous. The results were qualified as estimates. The % solids (104º) were verified by the % solids from prior mercury analysis. Therefore the % solids results for these samples were not qualified

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.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

November 18, 2002

Subject: Metals Lake Whatcom Mercury 40 and 41

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. Samples were digested and analyzed for mercury following method EPA 245.5 (CVAA). Samples were digested and analyzed for lead following EPA method 3050 and EPA method 200.8 (ICPMS), respectively.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 10/03/02, 10/09/02 and 10/16/02. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition.

Holding Times

Samples 418542 – 418576 for mercury analysis were analyzed out of hold time. The results were qualified as estimates. All other analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. All calibration correlation coefficients were greater than 0.995. The instruments were calibrated with NIST traceable standards and verified to be in calibration with a second source NIST traceable standard.

Balances are professionally calibrated yearly and calibrated in-house daily. Soil drying oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

For lead analysis, a SRM (ERA 247) was used as the laboratory control sample (LCS). A fortified blank was used for mercury analysis. All LCS recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

All internal standard recoveries were within acceptance limits.

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.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

August 8, 2003

Subject: Metals Lake Whatcom Mercury - 28

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. The samples were analyzed and/or digested using the following methods: EPA method 245.5 (CVAA) for the digestion and analysis of mercury and EPA method 3050B and 200.8 (ICPMS) for the digestion and analysis of lead.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 07/09/03. All samples were received in good condition. Five (5) samples were received and assigned laboratory identification numbers 284005 - 284009.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. All calibration correlation coefficients were greater than the acceptance limit of 0.995. The instruments were calibrated with NIST traceable standards and verified to be in calibration with a second source NIST traceable standard. Balances are professionally calibrated yearly and calibrated in-house daily. Soil drying oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All associated matrix spike recoveries were within the acceptance limits of 75% - 125%.

Replicates

All associated duplicate relative percent differences were within the acceptance limit of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within the acceptance limits of 85% - 115% for ICPMS and 80% - 120% for CVAA.

Other Quality Assurance Measures and Issues

All internal standard recoveries were within acceptance limits.

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Drive East, Port Orchard, Washington 98366

October 28, 2002

Subject: Lake Whatcom
Samples: 02248005 and 02248007
Laboratory: STL Richland
Project Officer: Dale Norton
By: Karin Feddersen

Lead-210

Summary

See the contract laboratory's case narrative for more details.

Analytical Methods

These samples were analyzed using STL's method RC-5017. Routine QA/QC procedures were performed.

Calibration

Calibration standards were within ± 3 standard deviations of the mean.

Blanks

No activity was detected in any of the method blanks.

Duplicate Samples

Duplicate analyses were performed on the sample. The Relative Percent Difference (RPD) between the results was 17%.

Laboratory Control Sample

Recovery for the LCS was 104%.

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Manchester Environmental Laboratory
7411 Beach Drive East, Port Orchard, Washington 98366

November 7, 2003

Subject:	Lake Whatcom
Project:	193302
Laboratory:	STL Richland
Project Officer:	Dale Norton
By:	Dean Momohara

Cesium – 137 & Lead-210

Summary

See the contract laboratory's case narrative for more details.

Analytical Methods

These samples were analyzed using STL's method RC-5017. Routine QA/QC procedures were performed.

Calibration

The instruments were calibrated with NIST traceable standards. The instruments were checked for calibration prior to daily use. All checks were in control.

Blanks

No activity was detected in the method blanks associated with these samples.

Duplicate Samples

The relative percent differences for samples with concentrations greater than five times the reporting limit were < 20%.

Laboratory Control Sample

All recoveries were within the acceptance range of 80%-120%.

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Manchester Environmental Laboratory

7411 Beach Drive East, Port Orchard, Washington 98366

November 7, 2003

Subject:	Lake Whatcom
Project:	193302
Laboratory:	STL Richland
Project Officer:	Dale Norton
By:	Dean Momohara

Cesium – 137 & Lead-210

Summary

See the contract laboratory's case narrative for more details.

Analytical Methods

These samples were analyzed using STL's method RC-5017. Routine QA/QC procedures were performed.

Calibration

The instruments were calibrated with NIST traceable standards. The instruments were checked for calibration prior to daily use. All checks were in control.

Blanks

No activity was detected in the method blanks associated with these samples.

Duplicate Samples

The relative percent differences for samples with concentrations greater than five times the reporting limit were < 20%.

Laboratory Control Sample

All recoveries were within the acceptance range of 80%-120%.

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Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

August 7, 2002

Subject: Metals Quality Assurance Memo for Lake Whatcom Mercury

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 07/17/02 in good condition.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. All calibration correlation coefficients were greater than 0.995

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

U	-	The analyte was not detected at or above the reported result.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

September 25, 2002

Subject: Metals Quality Assurance Memo for Lake Whatcom Mercury - 38

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 09/18/02. All samples were received in good condition and where applicable, were properly preserved.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. The calibration correlation coefficient was greater than 0.995. Balances are professionally calibrated yearly and calibrated in-house daily.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

December 4, 2002

Subject: Metals Lake Whatcom Mercury - 46

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. Samples were digested and analyzed for mercury following EPA method 245.7 (CVAA).

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 11/13/02. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition and where applicable, were properly preserved.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibration and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. The calibration correlation coefficient was greater than 0.995. The instruments were calibrated with NIST traceable standards and verified to be in calibration with a second source NIST traceable standard. Balances are professionally calibrated yearly and calibrated in-house daily.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

In addition to a fortified blank, standard reference material NIST 1641D was diluted to 0.0308 ppb and was analyzed in duplicate. All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

All internal standard recoveries were within acceptance limits.

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative
January 14, 2003

Subject: Metals Lake Whatcom Mercury

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. The following methods were used in the analyses of these samples: EPA method 245.7 (CVAA) for mercury digestion and analysis.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 01/08/03. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition and where applicable, were properly preserved. Twelve (12) samples were received and assigned laboratory identification numbers 028015 – 028026.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. The calibration correlation coefficient was greater than 0.995. The instrument was calibrated with an NIST traceable standard and verified to be in calibration with a second source NIST traceable standard. Balances are professionally calibrated yearly and calibrated in-house daily.

Method Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences of samples with concentrations greater than 5 times the reporting limit were within acceptance limits of less than 20%.

Laboratory Control Samples

In addition to a fortified blank, standard reference material NIST 1641d diluted to 30 ppt was also analyzed. All laboratory control sample recoveries were within acceptance limits.

Other Quality Assurance Measures and Issues

All internal standard recoveries were within acceptance limits.

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

March 27, 2003

Subject: Metals Lake Whatcom Mercury - 12

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. The following method was used in the analyses of these samples: EPA method 245.7 (CVAA) for mercury digestion and analysis.

The analysis requested was evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 03/20/03. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition. Eleven (11) samples were received and assigned laboratory identification numbers 128080 - 128090.

Holding Times

The analysis was performed within established EPA holding times.

Calibration

Instrument calibration and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. The calibration correlation coefficient was greater than the acceptance limit of 0.995. The instrument was calibrated with a NIST traceable standard and verified to be in calibration with a second source NIST traceable standard. Balances are professionally calibrated yearly and calibrated in-house daily.

Method Blanks

No analytically significant level of analyte was detected in the method blank associated with these samples.

Matrix Spikes

The matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

The duplicate relative percent difference was within the acceptance limit of less than 20%.

Laboratory Control Samples

The laboratory control sample recovery was within acceptance limits.

Other Quality Assurance Measures and Issues

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

June 5, 2003

Subject: Metals Lake Whatcom Mercury - 22

Officer: Dale Norton

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification. The samples were analyzed using the following method: EPA method 245.7 (CVAA) for mercury digestion and analysis.

The analysis requested was evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 05/29/03. All coolers were received at the proper temperature of between 2°C - 6°C. All samples were received in good condition. Twelve (12) samples were received and assigned laboratory identification numbers 234080 – 234091.

Holding Times

The analysis was performed within established EPA holding times.

Calibration

Instrument calibration and calibration checks were performed in accordance with the appropriate method. All calibration checks were within control limits. The calibration correlation coefficient was greater than the acceptance limit of 0.995. The instrument was calibrated with a NIST traceable standard and verified to be in calibration with a second source NIST traceable standard. Balances are professionally calibrated yearly and calibrated in-house daily.

Method Blanks

No analytically significant level of analyte was detected in the method blank associated with these samples.

Matrix Spikes

The matrix spike recoveries were within the acceptance limits of 75% - 125%.

Replicates

The duplicate relative percent difference was within the acceptance limit of less than 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within the acceptance limits of 80% - 120%.

Other Quality Assurance Measures and Issues

U - The analyte was not detected at or above the reported result.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Appendix C

Analytical Results

Table C1. Analysis of Surface Sediment Samples from Lake Whatcom, September 2002.

Table C2. Analysis of Sediment Core Samples Collected from Lake Whatcom on September 25, 2002.

Table C3. Analysis of Surface Water Samples from Tributaries to Lake Whatcom, July 2002 to May 2003.

Table C1. Analysis of Surface Sediment Samples from Lake Whatcom, September 2002.

Basin 1 - Focused Surface Sediment Sites

Station ID	Sample No (38-	Collection Date	Time	Depth (ft)	Depth (m)	Total Solids (%)	TOC @ 70°C	TOC @ 104°C	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Total Hg (mg/kg, dw)	Methyl Hg (mg/kg, dw)
MW-S	8412	9/18/02	1115	9.2	2.8	16.4	16.1	16.3	0	37.9	47.100	15	0.178	NA
SB-S	8413	9/18/02	1355	4.5	1.4	38.7	2.28	2.3	1.4	55.5	33.300	9.9	0.041	NA
EC-S	8414	9/18/02	1440	7.0	2.1	25.2	6.48	6.6	0.1	29.2	61.300	9.3	0.134	NA
Mean				6.9	2.1	26.8	8.3	8.4	0.5	40.9	47.2	11.4	0.118	-

Basin 1 - Random Surface Sediment Sites

Station ID	Sample No (38-	Collection Date	Time	Depth (ft)	Depth (m)	Total Solids (%)	TOC @ 70°C	TOC @ 104°C	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Total Hg (mg/kg, dw)	Methyl Hg (mg/kg, dw)
1-1	8415	9/19/02	1020	22	6.7	16.7	7.33	7.3	0.1	24.4	57.800	17.8	0.180	0.00244
1-2	8416	9/19/02	1055	9	2.7	14.9	10.1	9.9	0	29.1	58.800	12.1	0.150	0.00286
1-3	8417	9/19/02	0925	30	9.1	14.4	13.6	13.6	0.3	23.7	63.100	13	0.211	0.00716
1-4	8418	9/19/02	0855	40	12.2	17.1	8.29	8.6	0	20.2	56.500	23.3	0.218	0.00307
1-4 (Dup)	8445	9/19/02	0855	40	12.2	17.2	8.29	8.5	0.2	17.2	59.700	22.8	0.230	0.00213
1-5	8419	9/19/02	0950	23	7.0	16	16.3	16.5	0	28.6	56.200	15	0.193	0.00547
Mean				27.3	8.3	16.1	10.7	10.7	0.1	23.9	58.7	17.3	0.197	0.0039

Basin 2 - Random Surface Sediment Sites

Station ID	Sample No (38-	Collection Date	Time	Depth (ft)	Depth (m)	Total Solids (%)	TOC @ 70°C	TOC @ 104°C	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Total Hg (mg/kg, dw)	Methyl Hg (mg/kg, dw)
2-1	8420	9/19/02	1300	33	10.1	24.5	8.37	8.4	0	40.9	48.600	10.5	0.152	0.00334
2-2	8422	9/19/02	1125	40	12.2	21.3	4.36	4.4	0	9.1	67.700	23	0.173	0.00185
2-3	8423	9/19/02	1325	43	13.1	18.7	4.98	5.0	0	19.5	54.800	25.7	0.202	0.0022
2-4	8424	9/19/02	1230	35	10.7	16.5	4.61	4.8	0	27.2	56.900	15.8	0.150	0.00223
2-5	8425	9/19/02	1145	45	13.7	18.2	4.62	4.8	0	17.3	57.100	25.8	0.202	0.00273
Mean				39.2	11.5	20.3	5.6	5.6	0.0	24.2	57.0	18.8	0.169	0.0024

Table C1. Analysis of Surface Sediment Samples from Lake Whatcom, September 2002.

Basin 3 - Focused Surface Sediment Sites

Station ID	Sample No (38-	Collection Date	Time	Depth (ft)	Depth (m)	Total Solids (%)	TOC @ 70°C	TOC @ 104°C	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Total Hg (mg/kg, dw)	Methyl Hg (mg/kg, dw)
CC-S	8426	9/18/02	1530	46	14.0	50	1.73	1.8	0.6	83.4	13.800	2.2	0.038	NA
OC-S	8427	9/18/02	1625	55	16.8	48.8	1.79	1.8	0.4	65.5	31.600	2.6	0.063	NA
SC-S	8428	9/18/02	1700	45	13.7	50.7	1.77	1.7	0.8	86.2	11.700	1.2	0.055	NA
BCC-S	8429	9/18/02	1815	90	27.4	45.5	3.71	3.6	1.7	81.8	13.600	2.9	0.099	NA
ANC-S	8430	9/18/02	1845	55	16.8	28.9	6.72	6.6	0.2	69.8	25.700	4.4	0.105	NA
BC-S	8431	9/18/02	1910	96	29.3	29.2	5.51	5.6	0.9	72.4	22.700	4	0.097	NA
ASC-S	8432	9/18/02	1730	30	9.1	55.9	1.86	1.8	6.6	77.3	14.500	1.6	0.048	NA
Mean				59.5	18.2	44.1	3.3	3.3	1.6	76.6	19.1	2.7	0.072	-

Basin 3 - Random Surface Sediment Sites

Station ID	Sample No (38-	Collection Date	Time	Depth (ft)	Depth (m)	Total Solids (%)	TOC @ 70°C	TOC @ 104°C	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Total Hg (mg/kg, dw)	Methyl Hg (mg/kg, dw)
3-1	8433	9/20/02	1140	37	11.3	19.8	5.24	4.9	0.1	13.6	68.300	17.8	0.014	NA
3-2	8434	9/19/02	1410	213	64.9	37.6	2.87	2.8	0	8.2	74.800	17	0.149	0.0008
3-3	8435	9/20/02	0925	50	15.2	28.5	8	7.2	4.3	52.9	34.000	8.8	0.107	NA
3-4	8436	9/25/02	1615	276	84	24.9	2.91	2.9	0	6.6	56.200	37.2	0.213	0.0013
3-5	8437	9/20/02	1040	52	15.8	61.8	1.92	2.1	47.8	44.6	5.200	2.3	0.043	NA
3-6	8438	9/19/02	1645	115	35.1	32.2	3.89	3.9	0.1	14.7	66.700	18.3	0.171	0.0015
3-7	8439	9/20/02	0955	271	82.6	26.1	3.73	4.0	0	16.1	72.300	11.5	0.148	NA
3-8	8440	9/19/02	1530	227	69.2	31.3	3.02	3.0	0	16.8	71.000	12.1	0.139	0.0010
3-9	8441	9/20/02	0845	266	81.1	28.6	2.91	2.4	0	11.3	72.800	15.9	0.165	NA
3-10	8442	9/25/02	1715	249	76	23.1	2.98	3.0	0.1	7	70.800	22.1	0.189	0.0016
3-11	8443	9/20/02	1110	47	14.3	27.1	7.92	9.9	0.3	42	51.300	6.5	0.142	NA
3-11 (Dup)	8446	9/20/02	1110	47	14.3	27.2	7.64	8.2	0.1	37.5	54.000	8.4	0.141	NA
Mean				154.0	40.4	30.7	4.4	4.5	4.4	22.6	58.1	14.8	0.135	0.0012

Table C2. Analysis of Sediment Core Samples Collected from Lake Whatcom on September 25, 2002.

Sample No	Interval (cm)	Percent Solids (%)	TOC @70° C (%)	TOC @104°C (%)	Mercury (mg/kg, dw)	Total Lead (mg/kg, dw)	Pb-210 (pCi/g)		Cs-137 (pCi/g)	
Basin 1										
02408500	0-1	13.9	9.2	8.7	0.229	70.9	8.92		1.75	
02408501	1-2	14.3	8.5	9	0.259	84.2	10.4	U	NA	
02408502	3-5	18.8	7.9	8.3	0.223	93	7.33		3.35	
02408511 (Dup)	3-5	18.9	7.9	8.2	0.226	95	NA		NA	
02408504	7-9	19.3	10.1	10.2	0.21	90.2	3.11		3.78	
02408505	11-13	18	18.1	18.1	0.201	73.2	0.7	U	NA	
02408506	15-18	17	9.6	9.9	0.14	33.3	1.14	U	-0.11	U
02408507	21-24	14.4	8.6	8.7	0.089	6.13	0.09	U	0.13	U
02408508	27-30	14.9	8.7	9	0.093	6.4	0.38	U	NA	
02408509	33-36	16.6	7.8	7.8	0.086	5.25	-0.24	U	NA	
02408510	40- 44	17.3	7.7	7.8	0.086	4.62	-0.2	U	NA	
Basin 2										
02408512	0-1	15.3	5.2	5	0.202	48.3	7.77		1.18	
02408513	1-2	16.1	5.2	5.2	0.204	48.4	6.91		NA	
02408514	3-5	21.9	5	5	0.192	47.1	6.66		3.13	
02408515	7-9	22	5.9	5.9	0.164	38.9	4.33		2.55	
02408516	11-13	17.9	6.1	6.1	0.13	24.5	2.16	U	NA	
02408522 (Dup)	15-18	17.8	5.6	5.7	0.11	6.33	NA		NA	
02408517	15-18	17.7	5.6	5.7	0.11	6.59	0.71	U	-0.17	U
02408518	21-24	20.5	5.7	5.4	0.091	6.76	0.16	U	-0.18	U
02408519	27-30	18.6	5.4	5.4	0.095	6.1	0.24	U	NA	
02408520	33-36	20.2	5.5	5.6	0.082	4.89	-0.4	U	NA	
02408521	39-44	23.7	5	5.1	0.094	5.6	1.87	U	NA	
Basin 3										
02408523	0-1	17.6	4.3	4.8	0.204	17.8	8.46		0.2	U
02408524	1-2	27.2	3.3	3.3	0.204	17.8	8.96		NA	
03284005	2-3	NA	NA	NA	NA	NA	4.8		NA	
02408525	3-5	39.3	2.5	2.5	0.197	17.8	3.09	U	0.54	U
03284006	4-5	40.6	NA	NA	0.217	NA	NA		NA	
03284007	5-6	47.2	NA	NA	0.148	NA	1.08		NA	
02408526	6-8	50.4	2.9	2.9	0.101	9.31	0.88	U	0.05	U
03284008	6-8	51.1	NA	NA	0.096	NA	NA		NA	
02408527	10-12	41.4	4.4	4.4	0.097	11.9	1.53		0.43	J
02408528	13-14	40.6	4.5	4.5	0.104	12.5	0.02	U	NA	
02408529	15-17	36.5	5.6	5.7	0.113	14.4	0.92	U	0.97	
02408533 (Dup)	15-17	37.2	4.6	4.6	0.0933	14.2	NA		NA	
02408530	19-22	37.5	4	4	0.074	9.18	0.95	U	0.53	U
02408531	25-28	54.5	2	1.9	0.055	10.1	0.91	U	NA	
03284009	28-30	49.6	NA	NA	0.085	12	NA		NA	
02408532	29-31	NA	NA	NA	0.085	NA	NA		NA	

u= Not Detected at detection limit shown

J= Estimated value

= No data

NA= Not analyzed

Table C3. Analysis of Surface Water Samples from Tributaries to Lake Whatcom, July 2002 to May 2003.

Round		1	2	3	4	5	6
Collection Date	Station ID	7/16/02	9/17/02	11/12/02	1/7/03	3/19/03	5/28/03
Anderson Creek	ANC-W						
Diversion Status		On	On	On	On	On	On
Time		8:15	9:50	9:30	9:25	12:15	13:30
Temp		9.93	12.45	NA	4.23	5.34	8.93
DO		10.80	9.75	10.45	12.40	12.40	13.40
Flow (cfs)		ND	2.15	28.29	75.41 72	69.33	62.67
ph (s.u.)		7.33	7.23	NA	7.35	7.03	6.98
Spec Cond. (umhos/cm)		35.2	52.7	69	38.7	43.4	30
TSS (mg/l)		19	2	7	6	5	6.5
T. Mercury (ng/l)		5.5	2 U	4.3	4.1	2 U	2.6
Mercury Dup		7.2					2.4
Austin Creek	ASC-W						
Time		9:30	10:40	10:25	10:15	11:25	12:40
Temp		12.79	11.31	NA	4.67	6.13	12.43
DO		9.08	10.11	9.72	12.71	12.16	10.50
Flow (cfs)		1.24	0.62	3.65	ND	15.81	3.23
ph (s.u.)		7.53	7.47	NA	7.27	7.52	7.55
Spec Cond. (umhos/cm)		77.2	102.3	125	46.9	52.6	66.5
TSS (mg/l)		1	1 U	2	1	3	1
T. Mercury (ng/l)		4	3.8	7.3	3	3.8	2 U
Brannian Creek	BC-W						
Time		8:50	10:05	9:50	9:45	11:45	13:00
Temp		11.60	11.64	NA	4.93	6.25	11.26
DO		8.83	8.62	8.25	12.00	11.75	9.82
Flow (cfs)		1.08	0.59	3.2	11	11	1.55
ph (s.u.)		6.80	6.85	NA	7.11	7.23	6.92
Spec Cond. (umhos/cm)		37.00	54.6	63.0	35.6	37.0	32.9
TSS (mg/l)		1 U	1 U	1 U	1 U	2	2
T. Mercury (ng/l)		4.5	5.8	9.2	2 U	4.6	2 U
Mercury Dup				8.8			
Carpenter Creek	CC-W						
Time		11:30	NS	NS	12:15	9:50	9:20
Temp		14.87	NS	NA	4.67	5.79	11.67
DO		7.80	NS	NA	12.48	12.20	10.32
Flow (cfs)		0.03	0.02	0.11	2.9	2	0.83
ph (s.u.)		7.45	NS	NS	7.38	7.63	7.41
Spec Cond. (umhos/cm)		100.9	NS	NS	45.1	49.4	53.1
TSS (mg/l)		2	NS	NS	1 U	2	3
T. Mercury (ng/l)		7.9	NS	NS	7	4	4.4
Euclid Creek	EC-W						
Time		10:08	NS	11:00	10:45	11:00	12:00
Temp		13.59	NS	NA	5.39	6.95	12.10
DO		5.17	NS	8.75	11.75	11.40	9.20
Flow (cfs)		ND	ND	0.93	0.53	0.37	0.03
ph (s.u.)		7.10	NS	NA	7.21	7.51	7.34
Spec Cond. (umhos/cm)		94.5	NS	90.0	57.4	65.2	83.3
TSS (mg/l)		2	NS	1 U	1 U	3	3
T. Mercury (ng/l)		6	NS	7.4	4.3	3.2	2.7
Mill Wheel Creek	MW-W						
Time		NS	NS	NS	11:20	10:50	11:40
Temp		NS	NS	NA	4.58	7.75	18.43
DO		NS	NS	NA	11.51	11.28	11.00
Flow (cfs)		0	0	0.01	1.3	0.86	0.18
ph (s.u.)		NS	NS	NS	7.14	7.34	8.07
Spec Cond. (umhos/cm)		NS	NS	NS	64.6	72.8	101.4
TSS (mg/l)		NS	NS	NS	2	5	4
T. Mercury (ng/l)		NS	NS	NS	8.9	5.1	4.9

Table C3. Analysis of Surface Water Samples from Tributaries to Lake Whatcom, July 2002 to May 2003.

Round		1	2	3	4	5	6
Collection Date	Station ID	7/16/02	9/17/02	11/12/02	1/7/03	3/19/03	5/28/03
Olsen Creek	OC-W						
Time		11:40	11:50	12:45	12:40	9:40	8:55
Temp		14.35	11.98	NA	5.17	5.30	11.27
DO		7.40	9.85	9.85	12.39	12.35	10.50
Flow (cfs)		1	0.87	3.5	9.35	8.4	3.17
ph (s.u.)		7.65	7.97	NA	7.32	7.62	7.41
Spec Cond. (umhos/cm)		73.3	102.0	118.0	44.4	46.5	51.6
TSS (mg/l)		2	1 U	7	1	2	3
T. Mercury (ng/l)		6.7	4.9	10	3.8	2.4	2.9
Silver Beach Creek	SB-W						
Time		10:50	11:20	12:20	11:45	10:10	9:45
Temp		15.43	12.64	NA	4.79	7.04	14.10
DO		8.69	9.50	9.21	12.15	11.70	9.70
Flow (cfs)		0.07	0.09	1.59	1.2	1.1	0.3
ph (s.u.)		8.05	8.11	NA	7.69	7.79	7.94
Spec Cond. (umhos/cm)		255.0	310.0	150	121.8	128.4	176.0
TSS (mg/l)		8	5	10	2	5	6
T. Mercury (ug/l)		11	4.1	11	6.4	4.4	3.1
Mercury Dup			3.1				
Smith Creek	SC-W						
Time		12:00	12:20	13:10	13:00	9:00	8:20
Temp		14.37	12.48	NA	5.70	5.63	11.61
DO		10.00	10.28	10.15	12.26	12.28	10.55
Flow (cfs)		1.67	0.73	ND	11.2	12.87	3.11
ph (s.u.)		7.75	7.76	NA	7.35	7.67	7.7
Spec Cond. (umhos/cm)		56.9	83.6	85	45.2	45.6	47.0
TSS (mg/l)		1	1 U	4	1	2	2
T. Mercury (ng/l)		5.1	4.2	10	2.6	2 U	2.6
Mercury Dup						2.3	
Blue Canyon Creek	BCC-W						
Time		NS	930	910	910	1230	1350
Temp		NS	NS	NS	NS	NS	NS
DO		NS	NS	NS	NS	NS	NS
Flow (cfs)*		NS	0.73	ND	11.22	12.9	3.12
ph (s.u.)		NS	NS	NS	NS	NS	NS
Spec Cond. (umhos/cm)		NS	NS	NS	NS	NS	NS
TSS (mg/l)		NS	NS	NS	NS	NS	NS
T. Mercury (ng/l)		NS	3.5	17	2 U	4.6	2 U
Mercury Dup					2 U		

NS = No Sample
ND = No Data
NA = Not Analyzed
U = Not Detected at Detection Limit Shown
Flow report as hourly average values for the hour block at the time of sampling
* = Flow estimated based on watershed area and ratio with Smith Creek (Blue Canyon/Smith = 1.0024)