BRITISH
COLUMBIA

FILE NUMBER: 105719

August 12, 2013

Victor Wyprysky, CEO & President
Chieftain Metals Inc.
2 Bloor Street West Suite 2000
Toronto, Ontario, M4W 3E2

Dear Mr. Wyprysky:

RE: Tulsequah Chief Mine, Authorization # 105719, Risk Assessment of Current Mine Effluent Discharge into the Tulsequah River

On Aril 3, 2012 the Ministry of Environment issued *Environmental Management Act* (EMA) authorization #105719 that requires the interim collection and treatment of acid waters coming from the excavation/removal of historical waste rock, portals 5200, 5400 and 5900 at the Tulsequah Chief Mine site. The intent was that the plant would serve as an interim solution to the treatment of acid waters originating from the construction phase of the project. The operational phase of the mine was to have addressed the long term collection and treatment of acid mine water. The water treatment plant (WTP) was commissioned and operated for a 3 month period (April to June 2012) prior to Chieftain Metals Inc. (Chieftain) shutting the plant down due to design problems and the inability to pay for necessary improvements and continued operation.

As a result, Chieftain has been out of compliance with the EMA authorization #105719 since shutting down the WTP at the Tulsequah Chief Mine site in June of 2012. In an official warning letter issued July 24, 2012, the Ministry of Environment required Chieftain to implement onsite water management strategies to minimize potential impacts and to conduct water quality sampling to assess the effectiveness of the mitigation measures.

Since then, the Ministry has been receiving regular water quality submissions, and communicating with Chieftain to review the status of the project and obtain updates on their action plan to come into compliance with the EMA authorization.

The February 2013 updates identified that the feasibility of optimization, re-commissioning and operating the WTP was contingent on the project receiving financing and proceeding to production. Recent updates from Chieftain are that flow through funding is in place for the project's 2013 exploration campaign and that a new timeline has been set for construction (2014 - Q1 2016), commissioning and production (Q1/Q2 of 2016).

Considering all available information regarding the status of the project, Chieftain Metals Inc., under Section 16 of the EMA is being directed to hire a qualified professional, with experience in aquatic impact assessment and in particular, fisheries impact assessment, to provide the Ministry with a risk assessment of the current mine effluent discharge into the Tulsequah River from the Tulsequah Chief mine site. The study terms of reference is attached, as agreed to by the Ministry, Chieftain and their qualified professional on August 8, 2013. A draft of the assessment report shall be submitted to the Director for review and comment by September 30, 2013 and the final assessment report shall be submitted to the Director by October 31, 2013.

The goal of the risk assessment is to provide the Ministry with an evaluation of the success of the current onsite water management strategies implemented by Chieftain to minimize potential impacts and to gather information regarding the extent of aquatic environmental risk to the Tulsequah River as a result of not operating the interim acid water treatment plant.

Please contact Lisa Torunski at (250) 847-7455 should you have any questions or concerns. We look forward to the update call, to be scheduled for September 9, 2013.

Yours truly,

Ian D Sharpe

Ian Sharpe
For Director, *Environmental Management Act*
Environmental Protection Division
Ministry of the Environment
Ministry of Environmental, EPP

ec: Doug Flynn, Senior Inspector of Mines, Ministry of Energy & Mines, Smithers, BC
Jennifer Stalker, Project Manager, FLNRO, Smithers, BC
Wade Comin, Enforcement Officer, Environment Canada, Whitehorse, Yukon
Deb Portman, Enforcement Officer, Environment Canada, Smithers, BC
Kyle Moselle, Large Project Coordinator, Alaska Dept. of Natural Resources, Juneau
John Ward, Spokesperson, Taku River Tlingit First Nation, Atlin, BC
Eric Morrison, Environmental Manager, Douglas Indian Association, Juneau Alaska

LT ML/lt

Terms of Reference for Risk Assessment
For the Tulsequah Chief Mine

- Provide the details on Chieftain's attempts to mitigate impacts associated with the shutdown of the WTP.

- Provide a summary of mine effluent quality that was discharged to the WTP and is now being discharged to the exfiltration pond, including statistical interpretation of any seasonal or annual trends.

- Describe the Environmental Setting:
    - Map and document all known aquatic resources in the Tulsequah River (in the vicinity of the mine and a reasonable distance downstream – i.e. to the confluence with the Taku).
    - Map and document all potential sensitive habitats in that area – i.e. clear water channels, spawning and rearing areas, and wetlands.

- Identify the zone of influence from the discharge of untreated mine effluent (recognizing that this will include non point source loadings from historical waste rock and tailings disposal). Incorporate the seasonal variability of the zone of influence. Complete the same exercise for when the WTP was operating and compare the results of the two.

- Identify the contaminants of concern and their fate and transport mechanisms at site.
    - Describe the mechanisms of ecotoxicity associated with the contaminants of concern and likely categories of receptors that could be affected. This should include both primary and secondary impact pathways (water column and deposition / remobilization).
    - Using all assessment work completed to date (water quality, sediment, benthics, fish) provide an assessment of the potential for impact on those resources at risk.

- The ecotoxicity interpretations should be based on both lethal and non lethal endpoints.

- Given what is known about the sources, pathways and receptors give an assessment of the possible impacts to aquatic resources on the zone of influence and in the Tulsequah River as a whole.

Your reference: Authorization # 105719

Mr. Ian Sharpe
For Director*, Environmental Management Act*
Environmental Protection Division
Ministry of the Environment
Ministry of Environment, EPP

Sent via e-mail

December 20th, 2013

RE: Risk Assessment of Current Mine Effluent Discharge into the Tulsequah River

Dear Mr. Sharpe,

In reference to your letter dated August 12th, 2013, this cover letter is to outline the steps taken by Chieftain Metals to meet your directive as outlined in your letter (attached).

Hire Qualified Professional to Conduct the Aquatic Ecological Risk Assessment

In response to your direction to hire a qualified professional with experience in aquatic impact assessment, with particular fisheries impact assessment, Chieftain has engaged the services of the following specialists to compile the Aquatic Ecological Risk Assessment:

Mike Whelen, R.P. Bio, Project Manager / Lead
Triton Environmental Consultants Ltd

Mike is a Registered Professional Biologist with over thirty years of experience in fish and fish habitat environmental effects assessments, baseline data collection, watershed restoration and resource management programs related to Pacific and Arctic fisheries in marine, estuary, and freshwater environments. Mike has conducted environmental assessments, fisheries inventory and compensation planning projects in watersheds throughout interior and coastal BC, Alberta, Yukon, Northwest Territories, Nunavut and Alaska for the forestry, mining, hydro, transportation and oil and gas and government sectors.

May Quach, MSc, RPBio, Aquatic Ecologist
Palmer Environmental Consulting Group

May is a Registered Professional Biologist with six years of experience in aquatic ecosystem studies for mining, hydroelectric and water management related projects. Her work focuses on design, field studies and data evaluation of water quality, benthic invertebrates, fish and fish habitat and limnological aspects for projects in Western Canada. May's water quality experience ranges from baseline studies and environmental impact assessments to site-specific water quality objectives. Aquatic resource experience includes benthic invertebrate ecology as well as periphyton and plankton community and sediment quality evaluations. May's experience combines high-quality scientific work with an environmental management skillset that includes workshop organization, participation in community open houses, environmental assessment coordination and project management.

Marc Cameron, MSc, RPBio, CSAP, Senior Risk Assessor

Core6 Environmental Ltd

Marc is a Contaminated Sites Approved Professional (Risk Assessment Specialist) and a Registered Professional Biologist in British Columbia with over 18 years of diverse experience. He has supported, completed, and managed contaminated sites investigations, remedial option evaluations, site remediations, development of long term monitoring plans, environmental impact assessments, risk communication projects, and negotiation with regulators. Marc specializes in human health and ecological risk assessment for contaminated sites and environmental impact assessments. Marc holds a Master's Degree in environmental science specializing in water resources and resource.

Geoff Wickstrom, MASc, RPBio, Senior Environmental Scientist

Core6 Environmental Ltd

Geoff is a Registered Professional Biologist with a Master's Degree in toxicology and a Bachelor's Degree in ecology and environmental biology. With over 16 years' experience consulting to industry and government across Western Canada and the US. Geoff focuses primarily on assessing and communicating the potential for impacts on human health and the environment. This often takes the form of human health risk assessment, health impact studies, terrestrial and/or aquatic ecological risk assessment, environmental monitoring projects, due diligence/liability assessments and adaptive management strategies in support of contaminated site and environmental impact assessment projects. Geoff has worked on projects in a variety of sectors including mining, oil and gas, forestry, ports and harbours, transportation, real property, legal, military, as well as municipal, provincial, and federal government projects.

Chieftain's Synopsys of the Aquatic Ecological Risk Assessment Conclusions

Chieftain has reviewed the Aquatic Ecological Risk Assessment and our synopsis of the report is as follows:

- Overall, the potential risk to aquatic receptors as a result of historic mine discharge is considered low.
- Regardless of whether the IWTP was operating or not, the HQs were less than 1 for the majority of the year including the critical time periods when Chinook, Sockeye and Coho salmon are migrating to spawn and the eggs are incubating and hatching.

- Resident fish such as Dolly Varden/Bull Trout can be present all year round, but as fish tissue studies show, they are not affected by the mine discharge.

As stated in your letter of August 12, 2013 *"The goal of the risk assessment is to provide the Ministry with an evaluation of the success of the current onsite water management strategies implemented by Chieftain to minimize potential impacts and to gather information regarding the extent of aquatic environmental risk to the Tulsequah River as a result of not operating the interim acid water treatment plant."* Based on the completed Aquatic Ecological Risk Assessment, Chieftain Metals is of the opinion that the extent of aquatic environmental risk is very low for the majority of the year and low to moderate during the winter and spring thaw events because some evidence is lacking as to whether fish use the Tulsequah river during the winter and spring thaw. The risk profile above is whether the Interim Water Treatment Plant is operational or not.

Closure

We are pleased to provide the full Aquatic Ecological Risk Assessment and look forward to working with you in the future. Please do not hesitate to contact me should you have any questions regarding this or any other matter.

Yours sincerely,

Victor Wyprysky
CEO & President – Chieftain Metals, Inc.

CC: Keith Boyle, COO, Chieftain Metals, Inc.
Lisa Torunski, Ministry of Environment
Doug Flynn, Senior Inspector of Mines
Jennifer Stalker, Forests, Lands and Natural Resource Operations
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Wade Comin, Environment Canada
Kyle Moselle, Alaska Dept. of Natural Resources
Nicole Gordon, Taku River Tlingit First Nation
John Ward, Taku River Tlingit First Nation
Eric Morrison, Douglas Indian Association

AQUATIC ECOLOGICAL RISK ASSESSMENT

Tulsequah Chief Mine

Prepared for:

CHIEFTAIN METALS INC.

1515 Broadway Street, Suite 118
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CONTRIBUTING AUTHORS

This report was prepared through contributions by the following parties:

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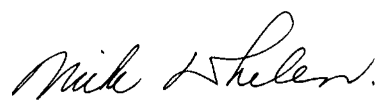
Senior Risk Assessor



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December 20, 2013

EXECUTIVE SUMMARY

An aquatic ecological risk assessment (AERA) was conducted in the Tulsequah River to evaluate potential risks to aquatic resources as a result of mine discharge from the historic Tulsequah Chief Mine. The AERA combined historic literature with current water quality data of the mine effluent and receiving environment to evaluate potential impacts on salmonids, which were chosen as the primary receptors due to their cultural, economic and recreational importance to the associated fisheries. Salmonids are also appropriate primary receptors as they are understood to be the most sensitive fish receptor.

Summary of Mine Effluent Quality

The mine effluent is primarily made up of discharge from historic mine portals (5200, 5400 and 5900). These portal discharges are piped downhill to the Interim Water Treatment Plant (IWTP). While the IWTP is not operating, the mine portal discharge converges with runoff from the historic waste rock dumps into a Site Exfiltration Pond (SE-2), before discharging into the Tulsequah River. Current water quality of the effluent in SE-2 is comparable to historic portal discharge water quality which indicates the water quality has not undergone noticeable change since the mid-1990s.

Four sites within the Tulsequah River were evaluated in this AERA (Figure 2):

- **W10** – 4.5 km upstream from mine site discharges; used as background conditions;
- **W46** – immediately downstream from the IWTP effluent discharge;
- **W51** – approximately 325 m downstream from SE-2; and
- **W32** – approximately 2.7 km downstream from SE-2.

Primary Receptor Selection

Of the aquatic resources in the Tulsequah River, fish are likely the primary receptors with the highest risk of exposure to mine discharge. Available data on benthic invertebrates are limited and the hydrologic regime of the Tulsequah River (i.e. seasonal major glacial outbursts) would likely preclude the presence of stable benthic invertebrate communities or sediment quality over the years. Of the eleven species of fish known to occur in the Taku and Tulsequah rivers, the AERA focused on the three most common and abundant species in the Tulsequah drainage: Coho Salmon (*Oncorhynchus kisutch*), Sockeye Salmon (*O. nerka*); and Dolly Varden/Bull Trout (S*alvelinus malma/S. confluentus*). These species occur ubiquitously throughout the potentially affected area either seasonally (spawning, rearing and/or overwintering) or perennially. While not ubiquitous in the Tulsequah watershed, Chinook Salmon (*O. tshawytscha*) was chosen as the fourth key receptor as they likely use the Taku River/Tulsequah River confluence and therefore potentially occur within the zone of influence.

Contaminants of Potential Concern

A list of contaminants of potential concern (COPCs) was screened using water quality data from April 2012 to July 2013. These dates represent the time period when the IWTP was operational (February 2012 to June 2012) and when it was not operational (August 2012 to July 2013/present). Cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) were identified as the only contaminants of potential concern. These were carried forward for quantitative evaluation in the risk characterization to evaluate the potential for risk as a result of aqueous mine effluent releases from the historic Tulsequah Chief mine site when the IWTP at the mine site was operational and when the IWTP was not operational.

Risk Assessment

Potential risks to selected fish receptors exposed to the COPCs in the surface waters of the Tulsequah River were evaluated using the Hazard Quotient (HQ) approach, widely used in ecological risk assessments. When HQs that are less than or equal to one (1), no unacceptable risks will occur in the exposed aquatic population. When HQs are greater than one, unacceptable risks may occur with the probability and/or severity of the adverse effect tending to increase as the value of HQ increases.

At station W51 and W32, HQs were considerably lower during IWTP operational conditions compared to when the IWTP was not operating. Hazard quotients for all chemicals were consistently highest at station W51, which appears to be the station most affected by discharge from the mine site. At this location the HQs for all COPCs were greater than one (HQ > 1) under both IWTP operational and nonoperational conditions, with the exception of lead, which had an HQ consistently less than one during the IWTP operational period. Of the downstream stations, HQs were generally lowest at station W32, which is the station located 2.7 km downstream from the mine site. Under IWTP operational conditions, only copper had HQs greater than or equal to 1 at station W32; the HQ results for all other COPCs were less than 1 at station W32.

Seasonally, the highest HQs at stations W51 and W32 occurred during late April and early May for all COPCs. This is the result of snow melt and precipitation causing the annual flush of the historic waste dumps into the river. As water from the historic waste dumps is not collected and would not be directed to the IWTP, this peak in COPC surface water concentrations and subsequent peak in HQs will occur whether or not the IWTP is operational.

Until such time that the historic waste rock is capped to reduce infiltration, it does not appear possible to prevent occurrences of HQs exceeding the threshold of 1. However, and perhaps most importantly, is that whether or not the IWTP was operating, the HQ was less than 1 for the majority of the year at all sites, including the critical time periods when Chinook, Sockeye and Coho are migrating to spawn and the eggs are incubating and hatching.

Potential impacts to salmon spawning are one of the key issues that were evaluated in this risk assessment. Chinook Salmon enter the Taku River between May and early June with known spawning areas in the Nakina, Nahlin, Tatsatua and Kowatua Rivers. There appears to be negligible use of the Tulsequah watershed by Chinook (Boyce and Gagnon, DFO pers. comm., 2013; Rescan (1997)). Furthermore, it has been observed that by the time Chinook Salmon do enter the Taku River in mid-May, the highest flush of COPC loadings in the Tulsequah River would have already been diluted to HQ < 1 in the Taku River.

Coho Salmon enter the Taku River between mid-July and November and spawn in the watershed between August and December (DFO 2001). Similarly, Sockeye return to the Taku River to spawn between mid-June and August (DFO 2001). Both of these spawning periods are during a time of low HQs for COPCs and therefore result in relatively lower exposure levels. Moreover, when they do enter the Tulsequah River, they are more likely to be found in the clear water side channels, accessible wetlands and lower tributary reaches than in the mainstem.

Based on the seasonal trends of metal concentrations in the Tulsequah River and the lifecycles and habitat preferences of the receptors of concern, the risk is considered low for anadromous (migrating salmon) species. The risk to resident fish receptors (Dolly Varden/Bull Trout) of concern is considered greater (i.e. moderate) due to increased potential for exposure to COPCs. However, the metals tissue residue study completed by Hitselbeger (2012) on juvenile Dolly Varden char from the Tulsequah River found that the discharges from the mine site were not causing elevated metals in these fish suggesting that either the exposures were not significant or that the exposure levels were within a range that the fish could readily bioregulate.

Zone of Influence

The zone of influence for mine discharge includes the area where HQ results for receptors of concern were greater than a threshold of 1. As the maximum HQ for dissolved copper (HQ=2.8) was greater than 1 at station W32, the zone of influence extends downstream within the braided mainstem beyond station W32. Dilution estimates based on annual river flow data indicate that the Tulsequah River would be diluted six times when mixed with Taku River at their confluence. This dilution would be more than required to reduce the maximum HQ to less than 1. Therefore the zone of influence would not extend into the Taku River.

Conclusions

Fish were chosen as the main receptor of concern due to their ubiquitous distribution and relative abundance, throughout the Tulsequah River watershed, and, sensitivity as receptors particularly during the juvenile life stages. Specifically, the three most common and abundant species in the Tulsequah drainage were the focus of the study – these included Coho Salmon, Sockeye Salmon, and Dolly Varden/Bull Trout. Chinook Salmon was chosen as the fourth receptor as they likely occur in the Taku River/Tulsequah River confluence and therefore potentially occur within the zone of influence.

A systematic screening of all measured surface water quality parameters resulted in the identification of four contaminants of potential concern (COPCs): total concentrations of cadmium, copper, lead and zinc. Using the hazard quotient (HQ) methodology, evaluation of the mine effluent showed that the highest HQs in the Tulsequah River coincided with the period of snowmelt and is believed to be the result of the annual flushing of the historic waste rock during the spring thaw. During the annual flushing period most juvenile salmonids will be overwintering in the preferred habitats of the clear water side channels.

With respect to the effectiveness of the IWTP, it was evident from surface water quality monitoring that during its operation it did lower the HQs at sites downstream from the point of discharge. However, during the annual flush period, select HQs (Cu and Zn) were still greater than 1. Until such time that the historic waste rock is capped to reduce infiltration, it does not appear that the IWTP is capable of reducing mine discharge to levels where resulting HQs do not exceed the threshold of 1. That said, regardless of whether the IWTP was operating or not, the HQs were less than 1 for the majority of the year including the critical time periods when Chinook, Sockeye and Coho are migrating to spawn and the eggs are incubating and hatching. Resident fish such as Dolly Varden/Bull Trout can be present all year round, but as the fish tissue studies show, they were not affected by the mine discharge (Hitselberger, 2012).

Overall, the potential risk to aquatic receptors as a result of mine discharge is considered low. As HQs at some sites were greater than 1 (e.g., Site W51), the risk to mainstem aquatic receptors would be considered moderate during those times. However, as most migratory species are known to utilize clear water side channels, removed from direct influences of the mine discharge, and resident species (Dolly Varden/Bull Trout) are shown to bioregulate COPCs, the moderate risk designation for the selected aquatic receptors is considered conservative.

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Appendix C	Source Analytical Laboratory Results
Appendix D	Toxicity Data considered for TRVs
Appendix E	Descriptive Statistics for Hazard Quotients

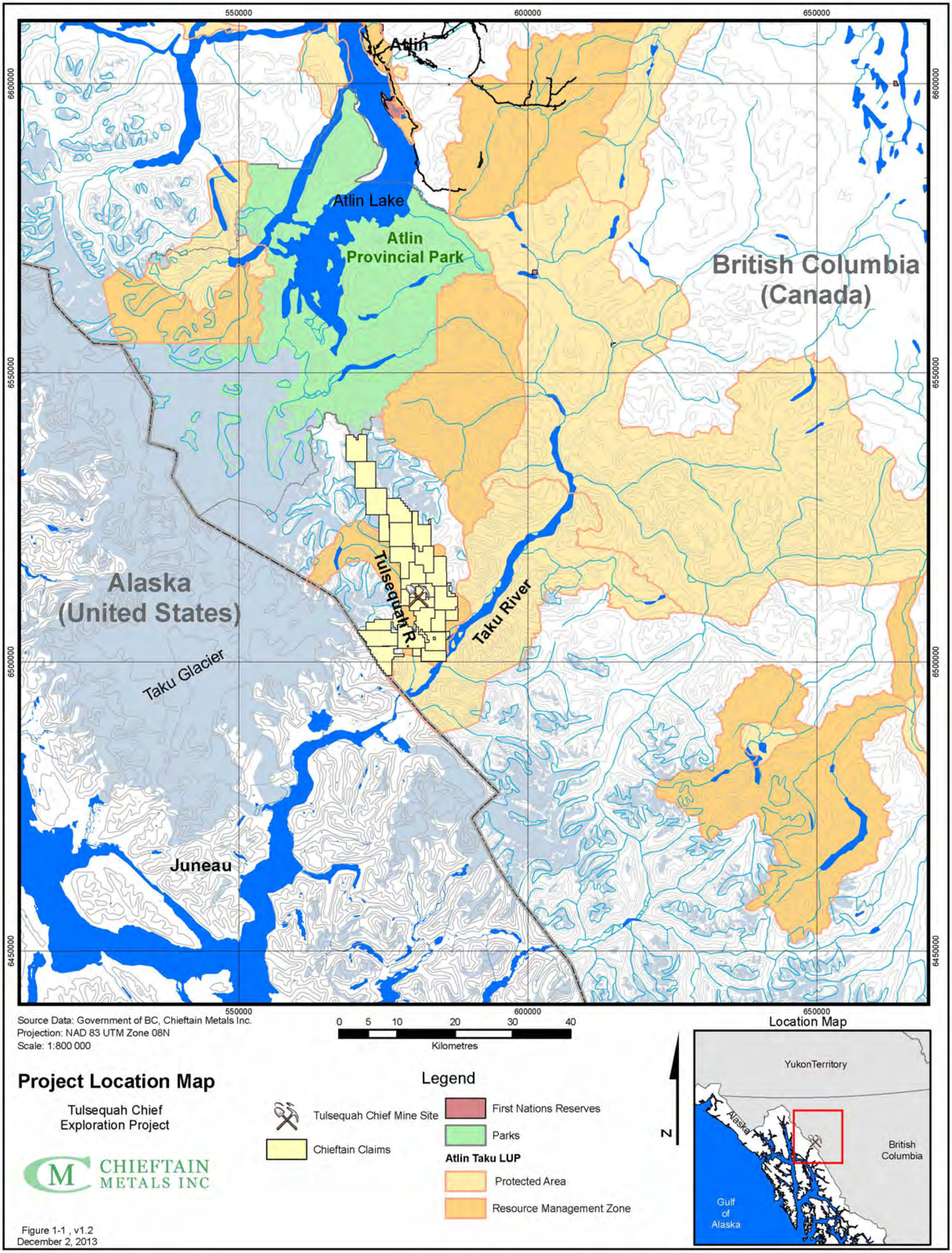
ACRONYMS

ARD	Acid Rock Drainage
ASL	Above Sea Level
BC	British Columbia
BCF	Bioconcentration Factor
BCMOE	British Columbia Ministry of Environment
BCWQO	British Columbia Water Quality Objectives
BGC	Biogeoclimatic
CEAA	Canadian Environmental Assessment Act
CCME	Canadian Council of Ministers of the Environment
COC	Contaminant of Concern
COPC	Chemical of Potential Concern
CMI	Chieftain Metals Inc.
CSR	Contaminated Sites Regulation
DFO	Fisheries and Oceans Canada
EA	Environmental Assessment
EEC	Estimated Environmental Concentration
EEM	Environmental Effects Monitoring
EMA	Environmental Management Act

HQ	Hazard Quotient
ICPMS	Inductively coupled plasma mass spectrometry
IWTP	Interim Water Treatment Plant
LC50	Lethal Concentration, 50%
LD50	Lethal Dose, 50%
LOAEL	Lowest Observed Adverse Effects Level
LOEC	Lowest Observed Effect Concentration
NAG	Non-Acid Generating
NOAEL	No Observed Adverse Effects Level
NOEC	No Observed Effect Concentration
PAG	Potentially Acid Generating
RME	Reasonable Maximum Exposure
ROC	Receptor of Concern
SSWQO	Site-Specific Water Quality Objectives
TRV	Toxicity Reference Value
USEPA	United States Environmental Protection Agency
WSC	Water Survey Canada

1 REGULATORY SETTING

On February 5th, 2013, representatives of Chieftain Metals, Inc. (CMI) met with the British Columbia Ministry of Environment (BCMOE) to provide an update on activities at the Tulsequah Chief Project, which included environmental monitoring, and to specifically discuss future plans for activities at the Tulsequah Chief Interim Water Treatment Plant. During the course of this meeting, CMI committed to delivering a plan for returning to compliance with *Environmental Management Act* (EMA) Permit #105719. This plan was submitted to BCMOE on July 27th, 2013, with an update on October 24th, 2012, and is included in this report as Appendix A. The request for an Aquatic Effects Risk Assessment was requested by BCMOE by letter to CMI on July 12th, 2013. A draft terms of reference (Appendix B) was accepted by CMI on August 8th, 2013. The mine is located in northwestern British Columbia (BC) on the Tulsequah River near its junction with the Taku River, approximately 100 kilometres south of Atlin, BC and 65 kilometres northeast of Juneau, Alaska (Figure 1).


Atlin
Atlin Lake
Atlin
Provincial Park
British Columbia
(Canada)
Alaska
(United States)
Tulsequah R.
Taku River
Taku Glacier
Juneau
550000
600000
650000
6600000
6550000
6500000
6450000
Source Data: Government of BC, Chieftain Metals Inc.
Projection: NAD 83 UTM Zone 08N
Scale: 1:800 000
0 5 10 20 30 40
Kilometres
Location Map
YukonTerritory
Alaska
British Columbia
Gulf of Alaska
N
Project Location Map
Tulsequah Chief Exploration Project
CHIEFTAIN METALS INC
Legend
Tulsequah Chief Mine Site
Chieftain Claims
First Nations Reserves
Parks
Atlin Taku LUP
Protected Area
Resource Management Zone
Figure 1-1 , v1.2
December 2, 2013

1.1 Tulsequah Chief Project History

CMI acquired the Tulsequah Chief Mine project, located in northwestern BC, from receivership in September 2010.

The Tulsequah Chief Mine project has a valid Environmental Assessment Certificate (M02-01) under the *BC Environmental Assessment Act* and a *Canadian Environmental Assessment Act* (CEAA) Screening (2004, FEAI 36077) under CEAA. On February 27, 2009, the Environmental Assessment Certificate was amended to provide for an alternative access to the site via air-cushioned barge along the Taku River. This access option has since been reassessed by CMI and an amended road access route has been approved by the BC Environmental Assessment Office, Ministry of Forests, Lands and Natural Resource Operations and BCMOE.

Redfern Resources (Redfern) was issued the *Mines Act* permit M-232 on February 28, 2008, which approved pre-construction site cleanup of historic waste rock dumps in preparation for mine site construction. The specifics of this work included the relocation of historic waste rock dumps to a contained facility, the construction of the containment facility, the installation of an Interim Water Treatment Plant (IWTP), plus the construction of required water management structures. This permit was subsequently amended on September 2, 2008 to allow for the development of the Paddy's Flats area for storage of materials and supplies required in construction, and two borrow sources. A further amendment was issued on November 7, 2008 approving limited construction activities. These activities were mainly focused on preparatory work at the mill site and underground. Upon receipt of its *Mines Act* permit, Redfern initiated construction activities at the Tulsequah Chief Mine site and these activities continued throughout 2008.

In January 2011 an amendment requesting the transfer of Permit M-232, and all reclamation liability held under Permit M-232, to CMI was approved. The amendment reconciled some site disturbances, originally authorized under Redfern's exploration Permit MX-1-355, with the M-232 permit. Disturbances created under MX-1-355 that were transferred to M-232 included the construction of 14.7 km of temporary exploration access road that includes the north and south causeways, construction of a 1.2 km exploration airstrip (of which 1.06 km has been completed to date) and geotechnical drilling in the area of the proposed tailings management facility. CMI sought an additional amendment to the *Mines Act* permit during 2011 to revise the location of the acidic water treatment plant and to construct a temporary lime sludge pond alongside the airstrip. The amendment was approved on July 7, 2011.

1.2 Interim Water Treatment Plant History

CMI provided BCMOE with a detailed discussion of the factors leading up to CMI's decision to curtail operations at the Tulsequah Chief IWTP in February 2013. This section summarises the information contained in Appendix A.

The plant was originally envisaged though an EA commitment to provide an interim treatment facility for the incremental loading that might occur as the historical potentially acid generating (HPAG) waste rock was removed from the site to facilitate mill construction. It was anticipated that the plant might need to run for a year or so while mill construction was underway, but at a rate of only 10 m^3/h.

The current facility was designed to treat acidic discharge from the historic Tulsequah Chief Mine as part of a full mine project, until the upper workings could be back-filled as part of the designed operating mine plan, treating both the drainage from the HPAG and also acidic drainage from the historic underground workings.

As part of the acquisition of the Tulsequah Chief property from Redfern's receivers in 2010, CMI acquired the IWTP and transported it back to the Tulsequah Chief by barge in June 2011 to meet the obligations of the Inspector's Direction dated February 22, 2011. The IWTP was constructed and commissioned onsite between June 2011 and March 2012.

The BCMOE issued EMA Permit #105719 on the April 1, 2012 upon completion of commissioning activities. Prescribed discharge water quality criteria were achieved but design parameters were not being met, operating costs were significantly higher than anticipated and it was apparent that water discharge quality criteria could not be assumed. CMI curtailed plant operations on 22 June 2012 due to corporate financial constraints.

The IWTP was designed to treat an average of 40 m^3 of influent per hour annually, with plant throughput expected to be lower during winter months and higher during the Spring freshet. Had activities at the plant continued over the course of a year, the expected average flow would have been realised. In the time period from March 1, 2012 to May 31, 2012, sludge was being produced at an average rate of 1 m^3 sludge per 52.8 m^3 treated water, or 1,200% of design output. Sludge production rates were similar in the 90 days prior to shut down (March 25 to June 22, 2012, at 1 m^3 per 56.3 m^3 of water). CMI did not anticipate that such large sludge volumes would be generated as a by-product of water treatment activities, and the additional pressures that such production rates would place on personnel and equipment at the site.

During the 92 day operating period from March 1, 2012 to May 31, 2012, the IWTP treated 89,000 m^3 of water and produced 1,704 m^3 of sludge, for an average rate of 52.2 m^3 of treated water per m^3 of sludge.

During the 90 day period immediately prior to shutting down the IWTP (March 25, 2012 to June 22, 2012) the IWTP treated 100,452 m^3 of water and generated 1,783 m^3 of sludge, for an average rate of 56.3 m^3 of treated water per m^3 of sludge produced.

The designed operating expectation for the IWTP was to treat water at a rate of 40 m^3/h (960 m^3/d) and generate 1 m^3 per day of sludge. Actual sludge production was 17 times higher than design.

The best sludge ratio the IWTP was able to managed was from June 5 to June 19, 2012. Over this period 17,291 m^3 of water was treated and this generated 143.5 m^3 of sludge (120.5 m^3 water per m^3 of sludge). This ratio is 8 times higher than design, but still necessitated a full-time dayshift personnel dedicated to hauling sludge from the IWTP.

Another operational cost implication is that during that "good" period just mentioned the IWTP was consuming 17 gallons per day of $FeCl_3$. The IWTP did manage to run from May 29 to June 5 consuming 9.7 gal per day on average. The design of the IWTP should be operating with only minor $FeCl_3$ consumption (i.e., less than a gallon per day). One aspect for this over usage is the IWTP requires a suitable recirculating load of sludge.

1.3 Actions taken by CMI to Mitigate Loss or Damage

In brief, activities undertaken to mitigate any potential environmental and financial impacts of IWTP shutdown include:

- ***Reduction of site workforce***
    - The site workforce was reduced to immediately reduce operating costs. The site is currently in Care and Maintenance mode and is operating with a 4-strong workforce on a 2 in/2 out rotation.
- ***Staged shutdown of plant operations***
    - Plant operations ceased on 22 June 2012. Since this time, numerous activities have been undertaken, including a comprehensive flushing of the IWTP, removal of sludge from the temporary IWTP Sludge Storage Pond adjacent to the plant, site-wide winterization programs and preparations for the eventual re-start of the plant.
- ***Review of IWTP Operating Plan***

    - The IWTP Operating Plan has been reviewed and a comprehensive process review, involving a plant restart and testing program, was undertaken in November 2012. The outcomes of this investigation have been provided under separate cover and are detailed below. CMI envisions additional planning and works prior to plant re-commissioning.

- ***Catchment assessment***
    - A catchment assessment was completed to identify potential sources of buffering and dilution for mine-impacted water on site. The findings of this assessment informed surface hydrology works at the site.
- ***Surface hydrology works***
    - Surface water diversions were implemented to provide some buffering and dilution on site, and to increase the residence time of impacted water on site prior to diffusion into the Tulsequah River. These works were undertaken with a view to reducing total metals loading.
- ***IWTP Sludge Storage Pond cleanout***
    - The IWTP Temporary Sludge Storage Pond has been emptied and all sludge has been deposited at the Airstrip Sludge Storage Pit.
- ***Increased monitoring and surveillance***
    - An intensive monitoring and surveillance program has been developed in consultation with the BCMOE Environmental Protection Unit to collect data monitor the effects of the IWTP shutdown on the receiving environment. Monthly letter reports are provided to BCMOE, along with the updated CMI Water Quality Database.
- ***Investigation of sludge thickening options***
    - Sohan Basra of SGS, an experienced high-density sludge plant designer and operator, was engaged to conduct a review of the IWTP and was directly involved in the re-start and testing undertaken in November 2012. Several CMI employees have visited the Britannia Mine Water Treatment Plant to review sludge thickening options which may be applicable to the Tulsequah Chief IWTP.

- ***Cost reduction in other areas of CMI's business***
    - A comprehensive cost review has been taken across all of CMI's business units. Cost saving and austerity measures have been implemented across the Company's business units to ensure that the Company remains viable while project financing is secured. Furthermore, extensive efforts have been made to reduce energy consumption at the site and to ensure that environmental effects of site activities are kept to a minimum. This campaign has resulted in a 90% reduction in fuel consumption rates and cost since plant activities were curtailed. Plant re-start will see an increase in fuel consumption, but CMI is confident that efficiency measures will realize continued savings over the coming months.
- ***Engagement of an external consultant to review plant operations and recommend improvements.***

2 RISK ASSESSMENT INTRODUCTION

This risk assessment provides the relevant background information, methodology, and findings of an Aquatic Ecological Risk Assessment (AERA) conducted specifically to address potential impacts to fish in the Tulsequah River as a result of the mine discharge from the Tulsequah Chief Mine. The effort was completed to allow for comparison of risks between the period of when the IWTP was in operation and when it was not.

2.1 Objective

This objective of this AERA was to determine the potential for risk to aquatic species in the Tulsequah River resulting from exposure to metals contamination from the Tulsequah Chief Mine. A second objective was to attempt to assess the effectiveness of the IWTP that was operated briefly in 2012.

2.2 Scope of Work

The scope focused on consideration of surface water quality with respect to its potential risk to salmonid species. Surface water quality as an exposure pathway was used due to the availability of an extensive dataset that ranged from June 2008 to ongoing monthly sampling. Since the objective of this AERA is to evaluate the potential impacts of shutting down the IWTP, it is necessary to use information collected during both the IWTP operational and IWTP non-operational periods. Data for both of these time periods was available for surface water quality. Of the aquatic resources in the Tulsequah River, fish are likely the primary receptors with the highest risk of exposure to mine discharge. Available data on sediment and benthic invertebrates are limited and the hydrologic regime of the Tulsequah River (i.e. seasonal major glacial outbursts) would likely preclude the presence of stable benthic invertebrate communities or sediment quality over the years. The focus of the risk assessment on salmonids was due to the known presence of salmonids in the Tulsequah River. Salmonids are also of cultural, economic, recreational and/or ecological importance, and they are understood to be the most sensitive fish receptor.

Specific scope-of-work for the risk assessment consisted of the following tasks:

- Documentation of relevant receptor information (e.g., life histories, presence in Tulsequah River);
- Compilation of available historical water quality and relevant environmental documentation for the Tulsequah River and Tulsequah Chief Mine;

- Identification of water quality screening levels and determination of constituents of potential concern (COPCs);
- Estimation of environmental concentration (EEC) for each COPC;
- Determination of appropriate toxicity reference values (TRVs) specific to the receptors of concern and exposure media;
- Characterization of potential adverse effects associated with each COPC;
- Characterization of risk through estimation of hazard quotients and consideration of uncertainties; and,
- Documentation of methodology and findings.

2.3 Regulatory Framework

As the mine is located in BC, Canada it is subject to provincial and federal laws with respect to environmental matters and release of toxic substances into the environment. The principal provincial and federal statutes are the *Fisheries Act*, *Environmental Management Act* and the *Canadian Environmental Protection Act*, respectively. Water quality criteria considered in the screening level selection included provincial and federal criteria as described in Section 3.3.5.

2.4 Risk Assessment Approach

The approach used for this AERA was as follows.

1. Water quality screening levels were derived for the identification of COPCs through consideration of provincial and federal criteria, and with consideration to background water quality (i.e., water representing regional levels but not affected by Tulsequah Chief Mine discharge – upstream monitoring station W10, Figure 2). Where background levels were greater than regulatory criteria, the 90th percentile background value for each relevant parameter was selected as the COPC screening level. This is consistent with BC Ministry of Environment guidance for completing risk assessments and was considered a conservative approach given that there were generally 47 or more monitoring events available for the background parameters.

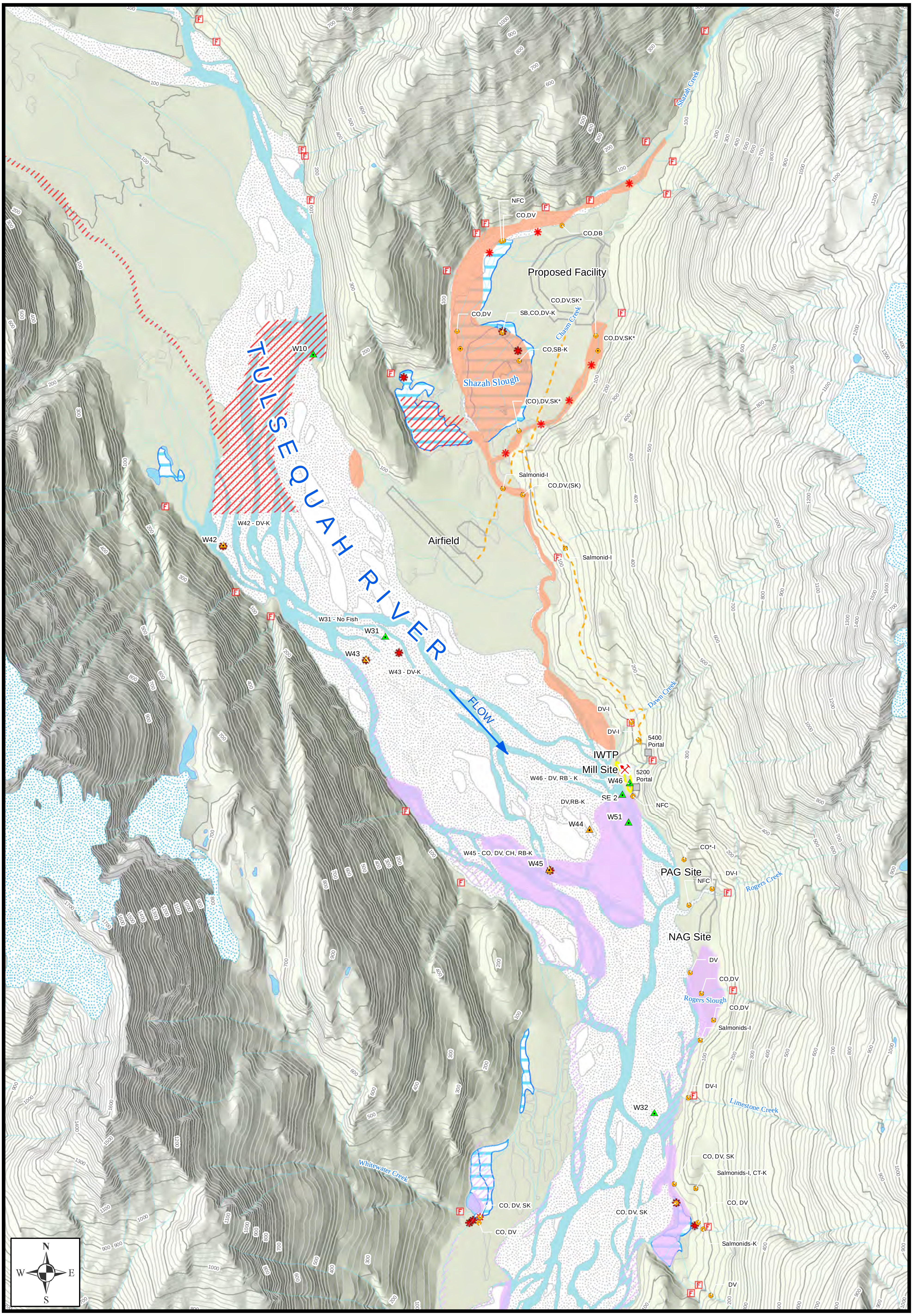
2. Water quality for the monitoring location located nearest to the point of discharge to the river (SE-2, Figure 2) was selected for the identification of COPCs that would be considered in the aquatic receiving environment with respect to their potential to cause adverse effects in fish.

3. Summary statistics and trend graphs were generated for the measured COPCs at each of the monitoring stations (W46, W51, and W32, Figure 2) located within the river to gain an improved understanding of COPCs within the aquatic receiving environment and to form the basis for fish exposure levels. The EEC for each COPC at each receiving environment location was the 90th percentile values for the available data sets.

4. Project-specific TRVs were derived through consideration of published toxicity literature specific to freshwater fish. Salmonid data, where available, was prioritized in keeping with the project scope.

5. Risk estimates were generated in the form of hazard quotients (HQs) for each COPC at each of the three monitoring locations in the receiving environment, for both dissolved and total metals. Hazard quotient results greater than one indicate that there exists the potential for unacceptable adverse effects, and suggests that more refined consideration may be warranted to reduce uncertainty and/or mitigate the risk.

6. The collective HQ results, particularly those with results greater than one, were given further consideration prior to forming a conclusion with respect to mine discharge and its potential to adversely affect fish as a whole in the Tulsequah River.



Chieftain Metals Inc	300 150 0 300 600 900 Meters **Scale:** 1:30,000	**Fish Species Code** CC - Sculpin (General) CH - Chinook Salmon CM - Chum Salmon CO - Coho Salmon CT - Cutthroat Trout DV - Dolly Varden RW - Round Whitefish TSB - Three Spine Stickleback SK - Sockeye Salmon ST - Steelhead K - Known I - Inferred * - Spawning UNWN - Unknown NFC - No Fish Caught

NO.	DATE (yyyy/mm/dd)	REVISION	BY
1	2011/11/13	Initial Draft	DP

Figure 2a - Water quality and fish and fish habitat sample site locations and fish distribution in the Tulsequah River BC. (adapted from Gartner Lee Ltd., 2007)

Legend

- Falls
- Inferred Spawning
- Known Spawning
- Fish Sampling w/Species
- Mainstem Water Quality Site
- Clearwater Channel Water Quality Site
- Infrastructure Points
- Tulsequah Chief Mine
- Infrastructure
- Road
- Treatment Plant
- Intermediate Contour (20m)
- Index Contour (100m)
- Intermediate Contour (500ft)
- Intermediate Contour (100ft)
- Stream
- Known Overwintering
- Known Rearing
- Inferred Overwintering
- Inferred Rearing
- Sandbar
- River
- Lake
- Wetland
- Glaciers
- Island

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Project No:	4933
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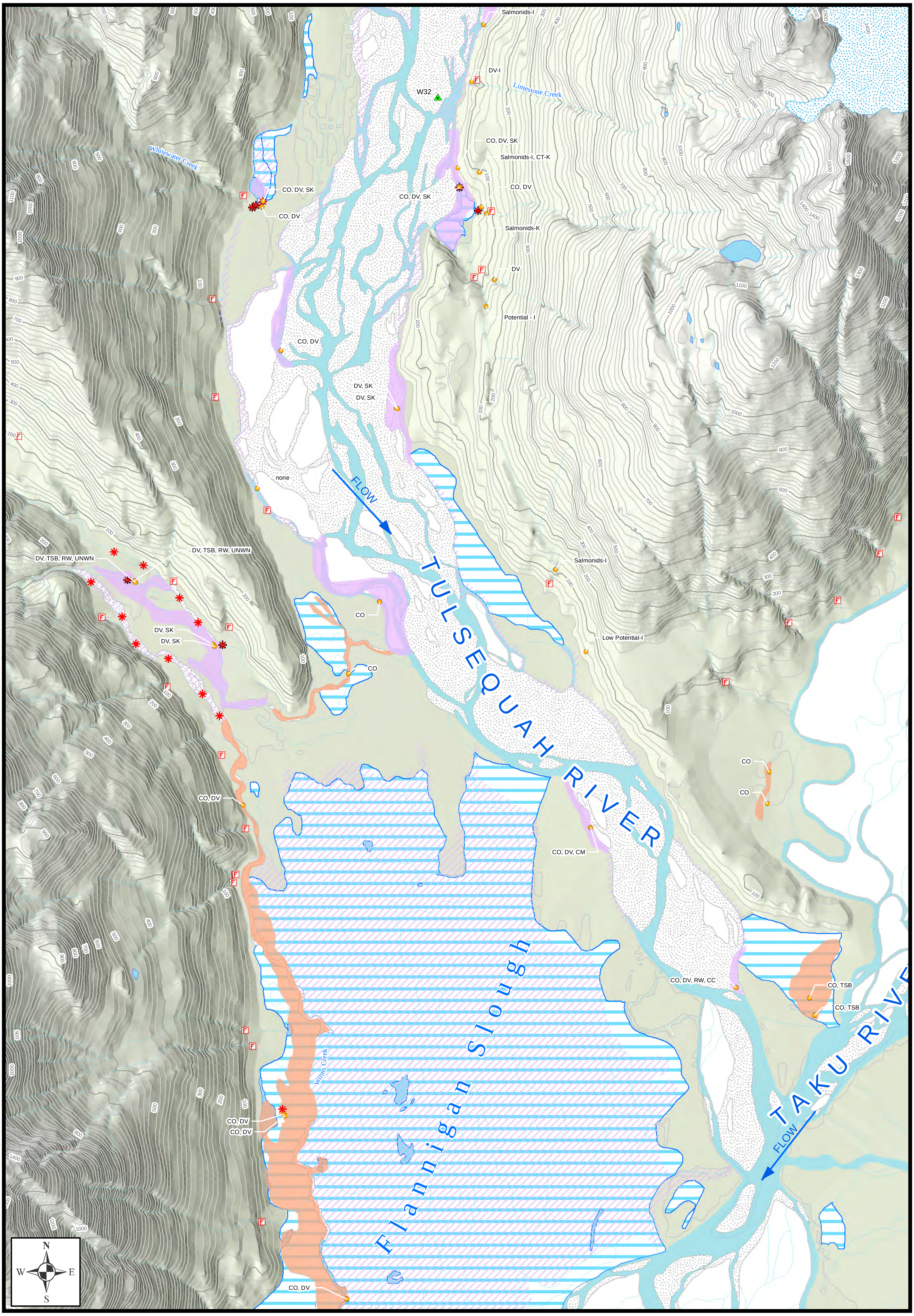

Chieftain Metals Inc	300 150 0 300 600 900 Meters Scale: 1:30,000	Fish Species Code CC - Sculpin (General) CH - Chinook Salmon CM - Chum Salmon CO - Coho Salmon CT - Cutthroat Trout DV - Dolly Varden RW - Round Whitefish TSB - Three Spine Stickleback SK - Sockeye Salmon ST - Steelhead K - Known I - Inferred * - Spawning UNWN - Unknown NFC - No Fish Caught

NO.	DATE (yyyy/mm/dd)	REVISION	BY
1	2011/11/13	Initial Draft	DP

Figure 2b - Water quality and fish and fish habitat sample site locations and fish distribution in the Tulsequah River BC. (adapted from Gartner Lee Ltd., 2007)

Legend

- Falls
- Inferred Spawning
- Known Spawning
- Fish Sampling w/Species
- Mainstem Water Quality Site
- Clearwater Channel Water Quality Site
- Infrastructure Points
- Tulsequah Chief Mine
- Infrastructure
- Road
- Treatment Plant
- Intermediate Contour (20m)
- Index Contour (100m)
- Intermediate Contour (500ft)
- Intermediate Contour (100ft)
- Stream
- Known Overwintering
- Known Rearing
- Inferred Overwintering
- Inferred Rearing
- Sandbar
- River
- Lake
- Wetland
- Glaciers
- Island

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Project No:	4933
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Basemap Source:	Orthophoto
Map Datum:	NAD 1983 UTM Zone 8N

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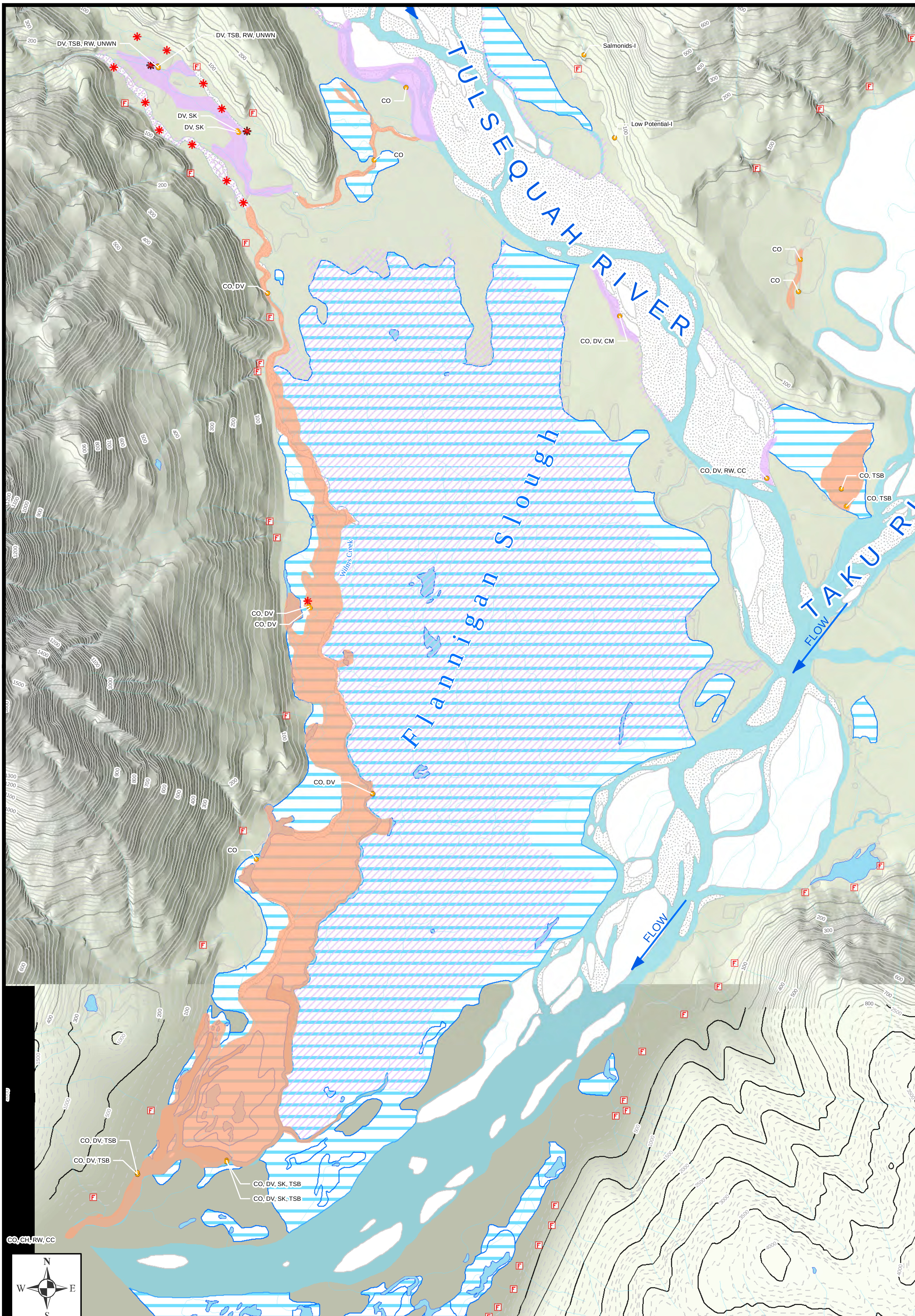

Chieftain Metals Inc	300 150 0 300 600 900 Meters **Scale:** 1:30,000	Fish Species Code CC - Sculpin (General) CH - Chinook Salmon CM - Chum Salmon CO - Coho Salmon CT - Cutthroat Trout DV - Dolly Varden RW - Round Whitefish TSB - Three Spine Stickleback SK - Sockeye Salmon ST - Steelhead K - Known I - Inferred * - Spawning UNWN - Unknown NFC - No Fish Caught

NO.	DATE (yyyy/mm/dd)	REVISION	BY
1	2011/11/13	Initial Draft	DP

Figure 2c - Water quality and fish and fish habitat sample site locations and fish distribution in the Tulsequah River BC. (adapted from Gartner Lee Ltd., 2007)

Legend

- Falls
- Inferred Spawning
- Known Spawning
- Fish Sampling w/Species
- Mainstem Water Quality Site
- Clearwater Channel Water Quality Site
- Infrastructure Points
- Tulsequah Chief Mine
- Infrastructure
- Road
- Treatment Plant
- Intermediate Contour (20m)
- Index Contour (100m)
- Intermediate Contour (500ft)
- Intermediate Contour (100ft)
- Stream
- Known Overwintering
- Known Rearing
- Inferred Overwintering
- Inferred Rearing
- Sandbar
- River
- Lake
- Wetland
- Glaciers
- Island

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Project No:	4933
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Basemap Source:	Orthophoto
Map Datum:	NAD 1983 UTM Zone 8N

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2.5 Aquatic Monitoring History

Aquatic monitoring of the Tulsequah Chief Mine area began with the data collection for the EA certificate between 1994 and 1996. Before this time, one other study was conducted in the Taku River watershed, which included two stations in the Tulsequah River watershed. Since the 1997 EA certificate was achieved, various Environment Effects Monitoring (EEM) studies were conducted as follow up to the EA or for pre-construction activities at the mine site. Other studies targeted specific issues related to fish health or contaminant loadings and were completed by various private and regulatory bodies.

Studies 1, 2, 4, 6 and 7 summarized below were the focus of fish compilation maps developed by Gartner Lee (2007). Information from these maps was summarized in Section 3.1.2.5 and illustrated in Figures 2a, 2b and 2c in this report. Studies 3 and 5 were used as overall references to environmental site conditions and historical information related to the Tulsequah Chief Mine. Lastly, the Hitselberger (2012) study was used as a line of evidence for assessment of toxicity in the tissue of resident fish in the Tulsequah River. Below is a summary of each of the studies completed in the Tulsequah River watershed with a brief synopsis of their findings.

1. Karanka and Associates, 1988: Aquatic biophysical surveys were first carried out in the Tulsequah Chief mine area by Karanka and Associates in 1988 for BCMOE. This aquatic biophysical inventory survey provides a broad summary of the information regarding fisheries resources in the Taku River watershed in 1988. Although only two sample points in this study are within the Tulsequah River watershed (Shazah Slough and Wilms Creek), this document does provide important habitat characteristic information for all salmonids and other fish species that are present in the project area.

2. Rescan Environmental Services Ltd, 1997: The Environmental Assessment for the Tulsequah Chief Mine site project was completed by Rescan in 1997. Aquatic baseline studies were conducted around the Tulsequah Chief Mine site (Shazah Creek, Chasm Creek, Tulsequah River, Rogers Creek, Windy Creek and the Taku River) between 1994 and 1996.

3. Gartner Lee, 2000: An aquatic EEM was conducted by Gartner Lee Ltd. in 1998 and 1999 as an obligation associated with the EA certificate issued in 1998. Hydrology, water quality, sediment quality, periphyton, benthic invertebrate and ground water data was collected in the Tulsequah River, Chasm Creek, Shazah Creek and Shazah Slough.

4. Alaskan Fish and Game Department, Unpublished: In participation with BCMOE, the Alaskan Fish and Game Department developed a map outlining a qualitative fish distribution survey

that was conducted in 2000 and 2001 within the immediate area of the Tulsequah Chief Mine site along the Tulsequah River.

5. Lough and Sharpe, 2003: BC Ministry of Water Land and Air Protection conducted a focused water quality monitoring between 2001 and 2003 to develop a mass balance model that would assess the metals mass loadings from the three historic mine sites in the Tulsequah and Taku valleys: Tulsequah Chief, Polaris-Taku and the Big Bull. The study concluded that sequestering and flushing of metals through the system occurs and that a mass balance model on its own does not give a realistic picture of what is occurring in the watershed. General trends show higher proportions of total metals during high flows and greater attenuation with higher proportions of dissolved metals during low flows. Furthermore, the Tulsequah Chief mine appears to contribute the greatest percentage of dissolved zinc to the system, followed by Big Bull mine and then Polaris Taku mine. The upper Taku is a major contributor of metals to the system during high flows and the Tulsequah Chief mine is the major contributor of metals loading during low flows.

6. Cambria and Gordon Ltd, 2007: Two stream survey reports were conducted in support of temporary access road (Tulsequah Chief camp to the proposed airstrip and Tulsequah Chief camp south to Big Bull) construction at the mine site. The reports characterized bearing status, quality and extent of fish habitat on 18 stream crossings along the two lengths of road.

7. Gartner Lee, 2008a: Pre-construction EEM was carried out by Gartner Lee Ltd. between May 2007 and October 2008. The study program for this time period was designed to collect baseline data relative to the anticipated EEM program prior to the IWTP going into operation. As well, the data collection served to test the anticipated sampling program in the dynamic environment of the Tulsequah River. Sampling involved hydrology, water quality, benthic invertebrates and fisheries data collection in the mainstem and clear water side channels of the Tulsequah River, as well as within the Shazah Slough area.

8. Hitselberger, 2012: The State of Alaska conducted an assessment of the Acid Rock Drainage (ARD) from Tulsequah Chief mine by testing whole body metals concentrations in a resident fish, Dolly Varden. Tissue samples were collected upstream and downstream of the ARD source and were compared to a study conducted for the Hecla Greens Creek Mine on Admiralty Island. Generally, results of the study show that mean metal concentrations in juvenile Dolly Varden char samples collected above and below Greens Creek Mine operations were all greater than the mean concentrations for the Upper Tulsequah, below the Tulsequah Mine and at the Taku Border.

3 PROBLEM FORMULATION

3.1 Site Description

3.1.1 Physical Setting

The Tulsequah Chief mine is located at latitude 58°43'N and longitude 133°35'W, on the Tulsequah River in northwestern BC. The project is located 100 kilometres south of the town of Atlin, BC, (59°35'N, 133°40'W), the nearest Canadian community. Juneau (58°18'N, 134°24' W), the capital of Alaska, is situated 64 kilometres southwest of the property. The project is located on the east bank of the Tulsequah River. The property is accessible by aircraft and by water from Juneau.

The Tulsequah River joins the Taku River about five kilometres upstream of the Canada-United States border. The Taku River is a transboundary river originating in northwest British Columbia, flowing 266 km before emptying into the Taku Inlet just south of Juneau, Alaska. The Taku River has a large drainage basin with its headwaters largely inland and consequently experiences less influence from coastal systems than Shazah Creek or the Tulsequah River. The Taku River flows into Stephens Passage and eventually into the Pacific Ocean. The Taku River is recognized as an International River and is managed accordingly under the *International Rivers Improvement Act*, International Pacific Salmon Fisheries Commission and *International Boundary Treaty Act*.

3.1.2 Aquatic Ecological Setting

The Tulsequah River is one of the major tributaries to the Taku River. It is approximately 20 km in length from the toe of the Tulsequah Glacier to its confluence with the Taku River, 9 km upstream from tidewater. The Taku River Tlingit people have occupied the watershed for hundreds of years, and the salmon fishery and wildlife are vital to the traditional and subsistence-based lifestyles of these people. The Taku River also supports a commercial salmon fishery at its mouth and upstream as far as the Tulsequah River.

3.1.2.1 Hydrology

Throughout much of the year the local hydrograph is snow and glacial melt driven; however, on at least one occasion per year the river is subject to extreme flood surges from a glacier impounded lake that drain quickly, and with little warning, beneath the Tulsequah glacier. These events are known as jökulhaups. Over the last few years there have been 1 – 3 jökulhaup events each summer. During a jökulhaup the sudden release of water from Lake No Lake (and previously, Tulsequah Lake) in the Tulsequah Glacier floods the entire Tulsequah River floodplain with flows ranging from 1,711 to 2,975 m^3/s (nhc, 2008). The water levels in the Tulsequah River rise over the period of 24 to 48 hours and subside to normal summer flow levels of around 100 m^3/s over a similar time period. The entire event takes four to seven days. Each year the jökulhaups result in the Tulsequah River forming new channels and abandoning others (Rescan, 1997).

At its confluence with Wilms Creek (near Taku River), the Tulsequah River has a total catchment area of 781 km^2; of this total watershed area roughly 42% is covered in glacier (nhc 2008). Based upon the catchment area as well as an estimated unit area discharge of 719 mm per year, the mean annual discharge was calculated to be 19.13 m^3/sec (HKP 1990).

3.1.2.2 Channel Morphology

The Tulsequah River travels within a very broad, flat floodplain. The mainstem gradient is estimated at approximately 1.0 to 2.5% (Rescan 1997). The Tulsequah River is considered one reach, as no obvious breaks, based on gradient or other important hydraulic/habitat features, occur within the study area. As is typical with rivers in glaciated valleys, the Tulsequah River contains elevated concentrations of suspended sediments and a larger bedload. This abundance of sediment, supplied by the glacier immediately upstream, and wide floodplain has allowed the channel to develop the braided morphology that it exhibits. Under typical conditions this morphology exhibits dynamic and active channel migration, usually associated with seasonal high flows. Within the Tulsequah River, the principal channel forming flows are associated with annual jökulhaup events, that may increase discharge up to 30 times above estimated "normal" annual maximum discharges (HKP 1990; nhc 2008).

3.1.2.3 Biogeoclimatic (BGC) zone

Between sea level and 600 m above sea level (ASL) the Tulsequah River and Taku River valleys lie in the Coastal Western Hemlock BGC zone (*CWHwm*) (Fuller and Forest Information Systems, 2002). This area is commonly associated with Western Hemlock overstorey and blueberry, false azalea, fern and step moss understory. Along the alluvial floodplain, Black cottonwood and Sitka spruce may also be common. Above 600 ASL the biogeoclimatic zone shifts to the Leeward Moist Maritime Mountain Hemlock Variant (MHmm2) BGC. This zone exhibits a patchy mountain hemlock and subalpine fir canopy, interspersed between areas of alpine parkland. The shrub and herb layer is dominated by blueberries, liverworts and mosses. Above the MHmm2, lies the Alpine Tundra (AT) zone, which may be found in areas above roughly 1200m ASL. This zone may contain dwarf willow and stunted hemlock and sub-alpine fir, however more commonly it exhibits rocky outcrops or ice fields.

3.1.2.4 Geology

The Tulsequah Chief mine is located in the Boundary Range of the Coastal Mountains (Fuller and Forest Information Systems, 2002). This range is characterized by high relief and landforms associated with alpine glaciation processes. The Boundary ranges are underlain by the Coast Plutonic Complex, which consists of many individual plutons. In many locations this plutonic complex contains intrusive materials comprised of granite, quartz monzonite, granodiorite and monzodiorite. In many locations volcanic greywacke, sandstone, limestone, shale and chert outcrops may also be observed in the Boundary Range.

The presence of the sedimentary and meta-sedimentary rocks in an area tends to give rise to elevated levels of fine grained sediments (silts and clays), which in turn may contribute to increased suspended sediments in the watercourses. Alternatively, the coarse grained intrusive granites tend to contribute coarser sands to the watercourses.

3.1.2.5 Tulsequah Fisheries

A comprehensive fish and fish habitat compilation report was developed by Gartner Lee (2007). The report includes two detailed maps that document all known fish species presence and distribution in the Tulsequah watershed. This report combines data from five reports between 1989 and 2007. This report represents the most up-to-date compilation of fish and fish habitat studies, as the area has been well characterized. This report was used to re-create Figure 2 with the addition of relevant monitoring stations for this assessment.

The Tulsequah and Taku rivers are known to support up to nine salmonid and several non-salmonid species (e.g., Stickleback and Sculpin) at any one time (Gartner Lee 2007), including all five pacific salmon species (*Oncorhynchus sp.*), anadromous and resident Dolly Varden and Bull Trout (*Salvelinus malma and S. confluentus*), and Steelhead/Rainbow and Cutthroat trout (*O. mykiss* and *O. clarki*). Juvenile life history stages of many of these species occur in both watersheds throughout the entire year (e.g., Coho Salmon and Dolly Varden). Other salmonid species known to occur in both watersheds include Arctic Grayling (*Thymallus arcticus*), and Round Whitefish (*Prosopium cylindraceum*). Within the Tulsequah watershed, juvenile Coho Salmon (*O. kisutch*) and Dolly Varden were the most common and ubiquitous species captured during previous studies (Gartner Lee 2007).

Fish habitat quality throughout a large portion of the Tulsequah River floodplain is limited by elevated turbidity during most of the open water season, and extreme turbidity and flow during seasonal glacial outburst floods (Jökulhlaups), and the extremely dynamic braided channel morphology. Although the Tulsequah River is used primarily as a migration corridor, which allows fish access to several minor tributaries, and to Shazah Creek, as well as other wetland and clear water side channel habitat, Chum are known to spawn in the lower mainstem and juvenile Coho and Sockeye salmon and Dolly Varden/Bull Trout were captured in mainstem habitats upstream and downstream from the mine site (Rescan 1997). Previous studies carried out by the Taku River Tlingit First Nation also identified widespread utilization by Dolly Varden and Coho Salmon within the Tulsequah floodplain (Scannell Scientific, 2012).

Clear Water Side Channels

Given the unique nature of the Tulsequah River that includes high turbidity levels and frequent channel migration from jökulhaups, much of the mainstem of the river is primarily a migration corridor and only provides temporary refuge habitat for salmonids and other local fish species. It does not provide high value habitat such as rearing or spawning habitat (Gartner Lee, 2007). However, there are well defined, clear water side channels along some sections of the Tulsequah floodplain, mostly located south (downstream) of the mine on the west side of the river valley. These two distinct aquatic environments offer different types and quality of habitat for both resident and anadromous fish.

Clear water side channels occur along the western bank of the Tulsequah mainstem, upstream from the mine site and along both banks between the mine site and Taku/Tulsequah river confluence. Clear water side channels consist of pool, riffle and glide type habitat and originate from either tributaries subsurface flow (upwelling). Although these channels may be mildly inundated during a jökulhaup, they persist following the event and provide stable habitat throughout much of the year.

Compared with the mainstem, the clear water side channels have exceptional fish habitat quality. They are frequently associated with overhanging vegetation and instream large woody debris, clear water, higher food and nutrient inputs and low levels of fine sediment. Streamside vegetation protects water quality, stabilizes stream banks, regulated stream temperatures and provides a continual source of wood debris

Rearing Habitat

Within the Tulsequah River floodplain, the highest quality salmonid rearing and overwintering habitat is known to occur in clear water side channels along the river margins (both banks) and to a lesser degree in mid-channel areas. These clear water side channels likely originate from a combination of hyporheic flow (surfacing groundwater) and/or small tributaries draining the valley walls. Clear water side channels were first identified in a joint BCMOE and Alaska Department of Environmental Conservation fish habitat study and are generally located southwest of the Tulsequah Chief mine site (Gartner Lee, 2007). Extensive juvenile salmonid rearing also occurs in accessible wetland areas and in the initial (downstream) reaches of tributaries of the Tulsequah River (Rescan 1997).

Overwintering Habitat

Important overwintering salmonid habitat in the Tulsequah River drainage includes clear water (groundwater upwelling) side channels, accessible wetlands and the lower reaches of larger tributaries (e.g. Shazah Creek), not subject to freeze-up. These areas are important habitats because they provide consistently warmer water temperatures over the winter, which prevents freezing.

Within the Tulsequah River watershed suitable overwintering areas were broadly identified within Shazah and Flannigan sloughs and Shazah Creek and in selected clear water pool habitats south and west of the mine site (Rescan 1997). To a lesser extent, some deeper pools in the mainstem, primarily at channel convergences and outside meanders, provide limited overwintering habitat (Rescan 1997).

Spawning habitat

Salmonid spawning habitat quality is species-specific but is generally determined by a suitable combination of substrate (gravels and cobbles with low fines composition), water depth (0.3 – 1.7 m) and velocity (0.2 – 1.0 m/s). Frequently, preferred spawning areas are observed to coincide with areas of upwelling, which may maintain more consistent water levels and temperatures.

Salmonid spawning is known to occur in several Tulsequah River tributaries, including Chasm, Shazah, Windy, Wilms and Whitewater creeks (e.g., Sockeye and Coho Salmon; Gartner Lee 2007). Spawning is also known to occur in clear water side channels along the mainstem margins to the south and west of the mine site airstrip (Rescan 1997).

In summary, clear water side channels, accessible wetlands and lower tributary reaches (e.g., Shazah Creek) within the Tulsequah watershed are known to support important rearing, overwintering and spawning habitat for salmonid species of economic, cultural and recreational significance. Most clear water side channels occur along the mainstem margins (east and west banks) downstream from and to a lesser degree, upstream from the mine site.

3.2 Receptor Description

Of the 11 species of fish known to occur in the Taku and Tulsequah rivers, the risk assessment focused on the four most common and abundant species in the Tulsequah drainage:

- Chinook Salmon (*Oncorhynchus tshawytscha*);
- Coho Salmon (*O. kisutch*);
- Sockeye Salmon (*O. nerka*); and
- Dolly Varden/Bull Trout (S*alvelinus malma/S. confluentus*)

Three of the four species (Coho Salmon, Sockeye Salmon and Dolly Varden/Bull Trout) were selected as key receptors in this assessment as they occur ubiquitously throughout the potentially affected area either seasonally (spawning, rearing and/or overwintering or resident) or perennially. Chinook Salmon are not ubiquitous in the Tulsequah watershed, but likely use the Taku/Tulsequah confluence area, and therefore potentially occur within the zone of influence. For this reason, we have decided to include Chinook Salmon as a key receptor.

All key receptor species are of economic, cultural and/or recreational importance to marine and freshwater fisheries. Juveniles from all three salmon species spend at least 18 months in freshwater before migration to the ocean. Dolly Varden/Bull trout comprise both anadromous and resident forms. As such, all four species would be subject to any ARD effects attributable to the mine. Further, salmonid species tend to be more sensitive to environmental or chemical disturbances, compared to non-salmonid species, and are therefore more representative of receptor species that best measure potential risks.

The relative tolerances (96h LC50) of juvenile Chinook Salmon and Steelhead Trout (alevins, swim-up, parr and smolts life stages) to Cadmium (Cd), copper (Cu) and zinc (Zn) were evaluated by Chapman (1978). The research determined that newly hatched alevins were much more tolerant to Cd and to a lesser extent Zn than were later juvenile forms (e.g., parr and smolts). However, with respect to Cu concentration, steelhead smolts, the oldest juvenile form was the more tolerant (96h LC50: 29 µg/L) than the younger forms while Chinook parr (96h LC50: 38 µg/L) were the most tolerant form for that species. Chapman (1978) recommends that when a sensitive life stage for acute toxicity with metals is required, that the use of the more resistant newly hatched alevins be avoided, and that the more sensitive later juvenile forms be considered.

Table 1 provides approximations of the residence timings and durations of juvenile (and adult) forms of the four selected receptor species in the Tulsequah watershed as it relates to potential levels and periods of exposure to the identified COPCs, and therefore to risks.

3.2.1 Chinook Salmon

The Taku River produces the greatest number of Chinook Salmon of any system north of the Skeena River in British Columbia (Boyce et al. 2006), however, there are no confirmed data to suggest that they us the Tulsequah River. Adult Chinook Salmon enter the Taku River between early May and early July (DFO 2001; Table 1). The majority of Taku River Chinook return to the river as 4 (37%), 5 (33%) and 6 year old (17%) adults, with older fish more likely to be female (DFO 2001). Spawning occurs from late July throughout September. The primary spawning tributaries in the Taku watershed include the Nakina, Nahlin, Tatsatua and Kowatua Rivers.

Following emergence during spring, most Taku watershed Chinook fry will spend an additional year rearing in natal streams or non-natal streams/river prior to seaward emigration from approximately April through June in their second year (age 1+ years) (Thedinga et al. 1998).

Table 1. Approximate timing of receptor species presence by life-stage in the Tulsequah River (adapted from DFO 2001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon												
Adult Migration[1]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Sockeye Salmon												
Adult Migration[1]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Coho Salmon												
Adult Migration[1]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												
Dolly Varden/Bull Trout												
Adult Migration[1,2]												
Spawning												
Egg Incubation												
Emergence												
Rearing												
Overwintering												

[1] *timing of fish through the lower Taku River at Canyon Island*

3.2.2 Coho Salmon

Coho Salmon enter the Taku River between mid-July and November, with spawning generally taking place between August and December (DFO 2001). The returning mature Coho are predominantly aged 3 or 4 years, having spent an average of two years as juveniles rearing and overwintering in fresh water (DFO 2001).

Coho Salmon spawning habitat is distributed throughout the Taku River watershed, including the Tulsequah River. Spawning occurs in clear water side channels adjacent to the mainstem as well as in small to large tributaries (Gartner Lee 2007). Coho salmon alevins probably emerge between mid-April and mid-June (DFO 2001). Rearing typically occurs in beaver ponds and side channels and sloughs (Murphy et al. 1989). The peak juvenile Coho abundance in these habitats occurs in the early summer months and declines thereafter throughout the fall and winter (Thedinga et al. 1998). Taku watershed Coho smolts emigrate to the ocean between late April and late June, with peak migration occurring from May 15 to May 30 (DFO 2001).

3.2.3 Sockeye Salmon

Mature Sockeye Salmon return to the Taku River to spawn between mid-June and August (DFO 2001). The majority (50%) of the fish return as 4 year olds, after spending an average of 1 to 2 years in freshwater and 1 to 4 years in the ocean (DFO 2001). Typically, Sockeye spawn in lake-bearing rivers and tributaries, in which the juveniles rear prior to leaving as smolts (lacustrine rearing). Atypically, the species will spawn in systems that are not lake bearing and may utilize clear water side channels or backwaters (riverine rearing) (Eiler et al. 1992). The Taku River represents one of the few exceptions where Sockeye juveniles exhibit both riverine and lacustrine rearing life histories, however the majority (63%) does occur in the riverine environments (Eiler et al. 1992). The major Sockeye Salmon spawning waterbodies within the Taku watershed include Little Trapper, Tatsamenie and Kuthai Lakes as well as in clear water side channels in the lower Nakonake, lower Tulsequah, Chasm, Sockeye, Twin Glacier and Wilms creeks.

Sockeye spawning in the Taku River system takes place in both mainstem locations as well as off-channel habitats (Mitchell et al. 1989). Spawning in the mainstem is commonly associated with areas of groundwater influences (60%) with average water velocities of 0.15 m/sec (Mitchell et al. 1989). Riverine rearing Sockeye rely heavily upon the clear water side channels, channel edges, beaver ponds and sloughs that are found along both the Taku and Tulsequah River (Thedinga et al. 1988). In November, population densities of Sockeye peaked in side channels, suggesting that juveniles overwinter in these areas (Thedinga et al. 1988). Smoltification and seaward outmigration of Taku River Sockeye occurs in spring with peak migration from late May through June (DFO 2001).

3.2.4 Dolly Varden

In British Columbia, Dolly Varden is a species of special concern. They can exhibit three different life-history strategies: anadromous - spending portions of the life in both fresh and salt water, stream resident – spending their life in flowing water, and adfluvial – spending the majority of their life in lakes but migrating to flowing water to spawn (McPhail 2007). Within the Taku drainage it is possible that all three life histories are represented.

Spawning occurs in the late fall/early winter and is usually in association with upwelling groundwater. Egg incubation lasts until the following spring (April to May). Juvenile rearing in the Tulsequah and Taku drainages occurs in the clear water side channels, tributaries and sloughs (Gartner Lee 2007).

Sexual maturity for all of the different life histories likely occurs in fish that are in their fourth or fifth growing season (McPhail 2007). During the maturing process, anadromous populations may migrate back and forth between the ocean and rivers on an annual basis.

Dolly Varden is the most ubiquitous species in the Tulsequah and Taku drainages, occurring in both anadromous and non-anadromous reaches of all major tributaries. Initial mitochondrial DNA analysis of char captured in the non-anadromous reaches of the upper Nakonake and Sloko rivers, lower Nakina and Tulsequah indicated all individuals were Dolly Varden, however, further analyses indicated the species in reaches above migration barriers to be Bull Trout (*S. confluentus*) (Gartner Lee 2007).

3.3 Source Description

3.3.1 Acid Rock Drainage

Acid Rock Drainage (ARD) has been leaching from historical sources at Tulsequah Chief mine into the Tulsequah River since historic mining ceased in 1957. During operations in the 1950s, there were five portals developed on the slopes rising up from the Tulsequah River to access the 5200, 5400, 5900, 6400 and 6500 portal levels (Rescan, 1997). Existing waste rock currently located at the 5200, 5400 and 5900 is a result of historic mining between 1951 and 1957 and from later underground development to support exploration activities in the 1990's and in 2004.

An aerial view of the extent of historical mining disturbance is included in Figure 3. Under existing conditions, water drains from historical underground workings at the 5200 and 5400 level portals. Discharge from the 5200 and 5400 portals are piped by gravity to the Site Exfiltration pond where they converge and drain via the Tulsequah River floodplain. Since the IWTP shutdown, neutral pH mine water discharging from the historical underground workings is combined with the 5400 discharge. As of early January 2012, the 5900 level was redirected to stay underground and now discharges via the 5200 level portal. Prior to 2012, the 5900 level was allowed to discharge to either Camp Creek or Portal Creek. On average, approximately 6.8 L/s drains from the 5200 level portal, approximately 1 L/s drains from the 5400 level portal, and approximately 5 L/s used to drain from the 5900 level portal.

The existing waste rock currently located at the 5400 and 5200 portal levels is referred to as potentially acid generating (PAG) although the lower portions of these piles are expected to composed of non-acid generating material (NAG) (Rescan 1997). Geochemical analysis of the waste rock was completed by Gartner Lee (2008b). They conclude the major metals present in the samples are aluminum, calcium, iron, magnesium and sodium (Gartner Lee 2008b). Short-term leach testing showed the PAG waste rock materials have the potential to leach several years of accumulated oxidation products whereas the accumulated load on the NAG waste rock appears to have already been flushed (Gartner Lee 2008b). Field bin testing showed leachate from the PAG is acidic pH <3.5 and with elevated zinc and copper concentrations (23-162 mg/L and 4.0-52 mg/L, respectively) (Rescan 1997).

Figure 3. Photographs of Historical Waste Rock (HPAG) and Portals

3.3.2 Data Sources

The Tulsequah Chief WQ Database provided by CMI was used as the main source of data for this risk assessment. Available data range from June 28, 2008 to July 20, 2013. For the purposes of this risk assessment, five stations were of interest and are illustrated on Figure 2:

- **W10** in the Tulsequah River, 4.5 km upstream of mine site discharges (background)
- **SE-2** in the Site Exfiltration pond
- **W46** in the Tulsequah River, downstream of the IWTP effluent discharges
- **W51** in the Tulsequah River, approximately 325 m downstream of the Site Exfiltration pond
- **W32** in the Tulsequah River, approximately 2.7 km downstream of the Site Exfiltration pond

The full data set for these five stations are in Appendix C. The Tulsequah River stations were part of the 2007-2008 EEM program that Gartner Lee Ltd. developed for pre-construction activities at the mine site, including the installation of an interim water treatment plant. As part of the EEM program, samples were collected approximately monthly between June 2008 and February 2009. Monitoring ceased when Redfern Resources went into receivership. More recently, under direction of CMI, these stations were monitored for the IWTP discharge permit application under EMA. The IWTP was commissioned from November 2011 until April 2, 2012, then operated from April 3, 2012 to June 22, 2012. When the IWTP was shut down, the acidic discharges from the historic portals were re-routed from the IWTP to the Site Exfiltration pond (SE-2) and thus, monitoring at SE-2 began on June 22, 2012. Water in SE-2 is a mixture of historic portal discharges, neutral mine water and waste rock and site runoff.

It is important to note that June 22, 2012 samples were obtained while the plant was undergoing shut-down procedures, such as line cleaning and flushing, and therefore was not considered representative of water quality during either the ITWP Operating period or the Non-Operating period and was removed from the data sets for the purposes of COPC identification and risk evaluation.

During the August 2012 – July 2013 sampling period stations W10 and W32 were sampled bi-weekly in August – December 2012, and sampled weekly in January – June 2013, for a total of 37 samples taken during the monitoring period from each site. Samples were taken from stations W46 and W51 weekly in September 2012 – July 2013, inclusively, for a total of 47 samples taken during the monitoring period at each site. Additionally, all four stations have been monitored weekly for field pH and conductivity and weekly samples are analyzed for dissolved metals. Every second week samples are also analyzed for pH, conductivity, hardness, alkalinity/acidity and total metals.

3.3.3 Mine Effluent Quality (SE-2)

Since the shutdown of the IWTP on June 22, 2012, discharge from the historic portals has been directed to the Site Exfiltration pond, along with site runoff, waste rock runoff and neutral mine water discharges. Weekly sampling (for dissolved metals) and bi-weekly (for pH, conductivity, hardness, alkalinity/acidity and total metals) sampling at SE-2 was conducted from September 2012 to August 2013, with monitoring reports submitted to BCMOE on a monthly basis. Regular sampling has been returned to monthly as of mid-August.

Limited mitigation options exist on site since the shutdown of the IWTP. The piping of the 5400 and 5200 portal discharges to the Site Exfiltration pond does prevent infiltration through the waste rock dumps and overland flow, which could pick up particulate matter and continually flush oxidation products from the waste rock. Redirecting the 5900 portal to the 5200 portal also eliminates infiltration through the 5900 waste rock dump as well as impacts to Camp Creek, where it was previously discharging to. In addition, now the Site Exfiltration pond is currently the only point of collection of the various water sources before discharging into the Tulsequah River, it does have filter fabric incorporated to reduce particulate matter and when the discharge goes into the River, it is diffused over approximately 10 meters instead of a single point.

Effluent quality in SE-2 is summarized in Figure 4 to Figure 11 below. Discharge from SE-2 is made up of mostly 5200 portal water in a 6:1 ratio with the 5400 portal. Comparison of SE-2 with the historic portal discharge quality shows that for the majority of the year the SE-2 water quality is between the 5200 data and the 5400 data (5400 tends to be a little more acidic than 5200, so has higher metals content). During periods of high runoff, the SE-2 values may drop below the 5200 portal values. These figures show that the current water quality of the portal discharge (i.e. the mine effluent) is comparable to the historic portal discharge water quality from 1994 to 1996 and 2005 to 2011. Although runoff from the waste dumps also contribute load to SE-2, it does so only in April/May and September/October, when there is substantial snowmelt or rainfall. This periodic loading from the waste rock dumps does not appear to have an obvious influence in the SE-2 water quality data set.

Figure 4 shows very little seasonal variation in sulphate concentrations. Snowmelt begins in mid-April and throughout the summer months appear to dilute the sulphate concentrations in the site exfiltration pond. Copper, cadmium and zinc concentrations do not fluctuate greatly although some reduction in concentrations is discernible in spring and fall months from dilution.

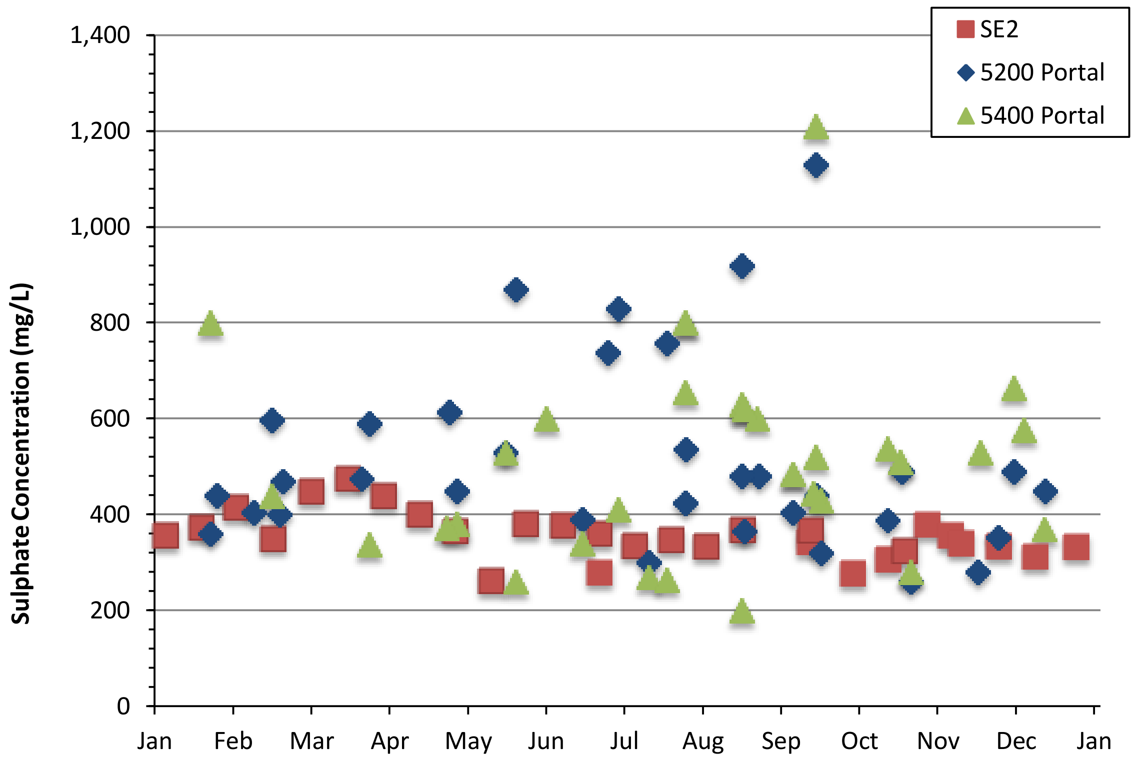


Figure 4. **Monthly Sulphate Concentrations at SE-2, 5200 Portal and 5400 Portal**

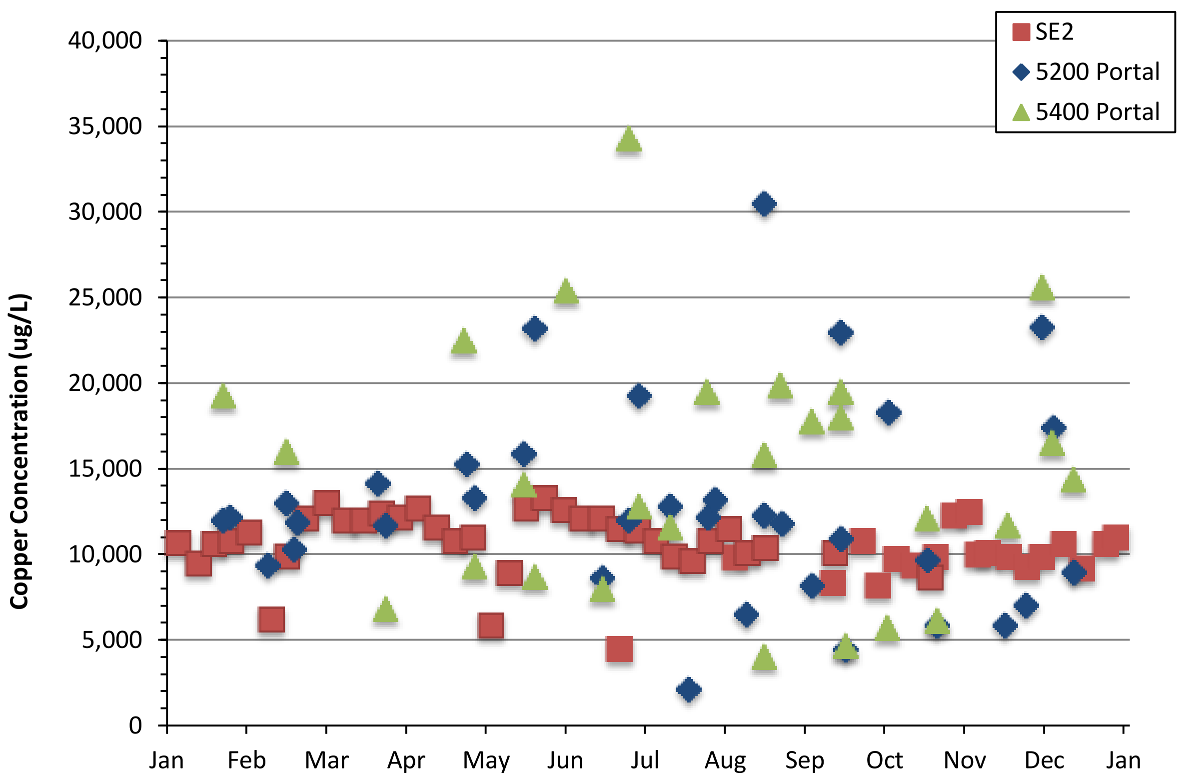


Figure 5. **Monthly Copper Concentrations at SE-2, 5200 Portal and 5400 Portal**

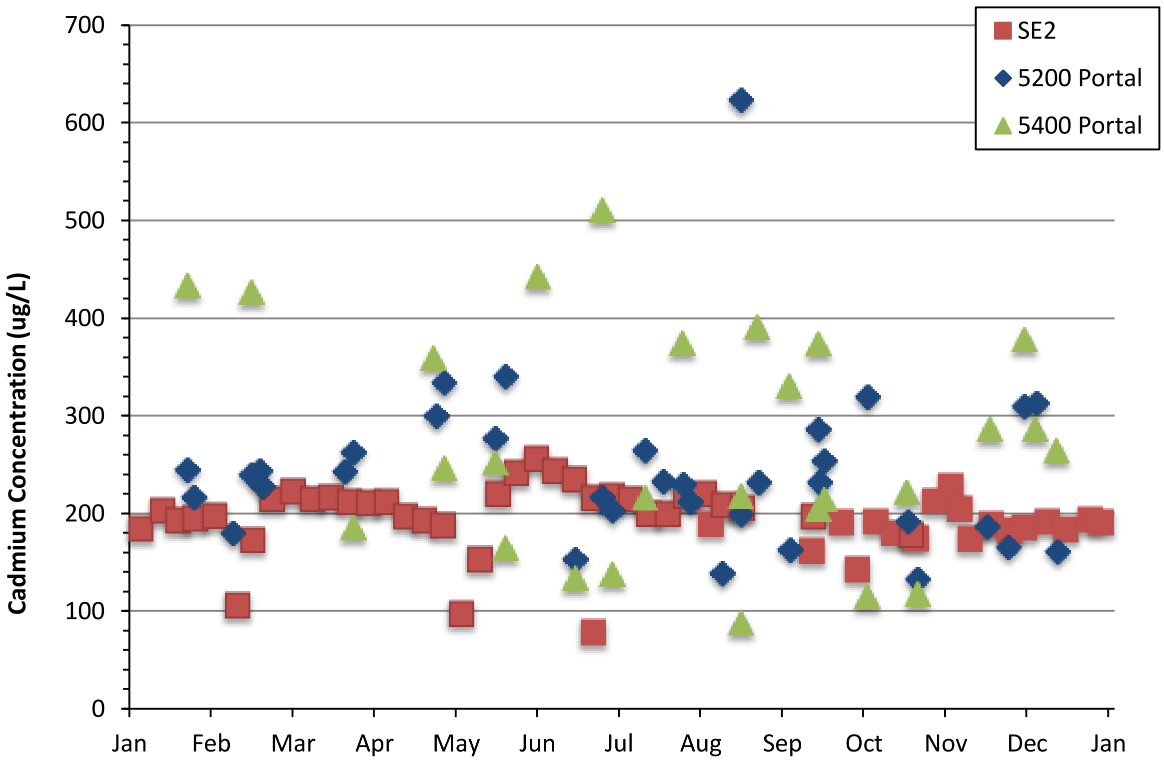


Figure 6. Monthly Cadmium Concentrations at SE-2, 5200 Portal and 5400 Portal

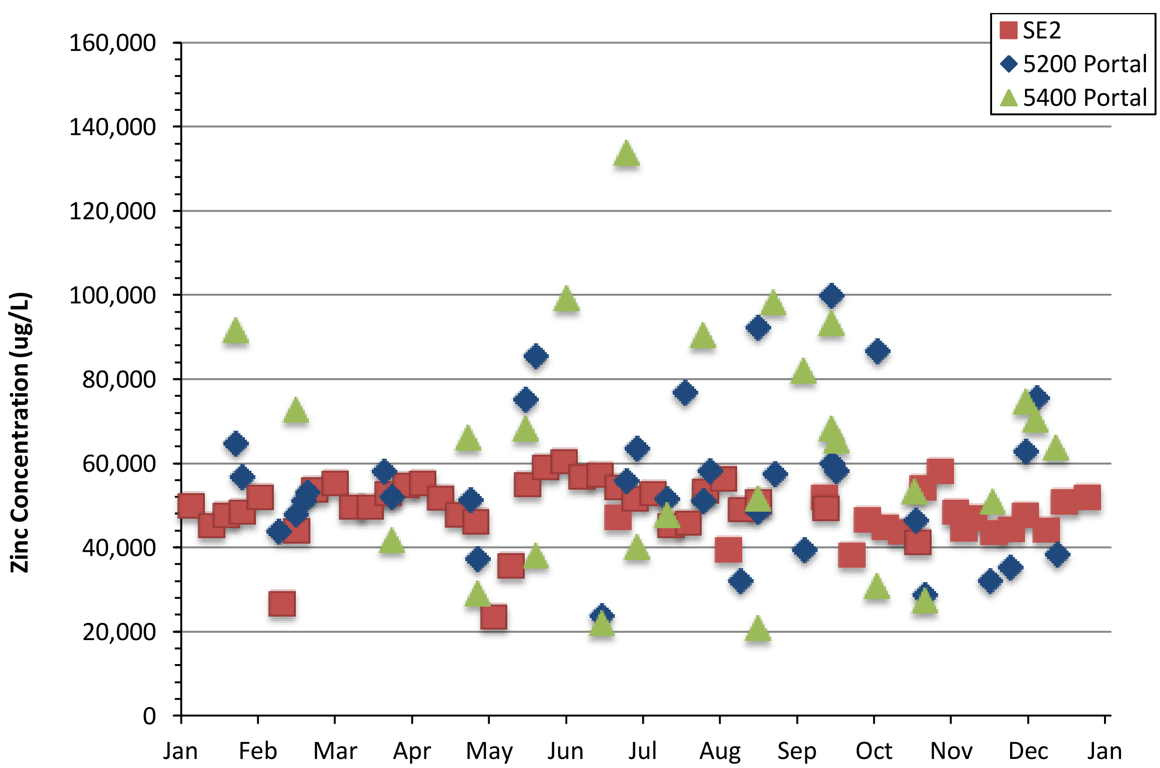


Figure 7. Monthly Zinc Concentrations at SE-2, 5200 Portal and 5400 Portal

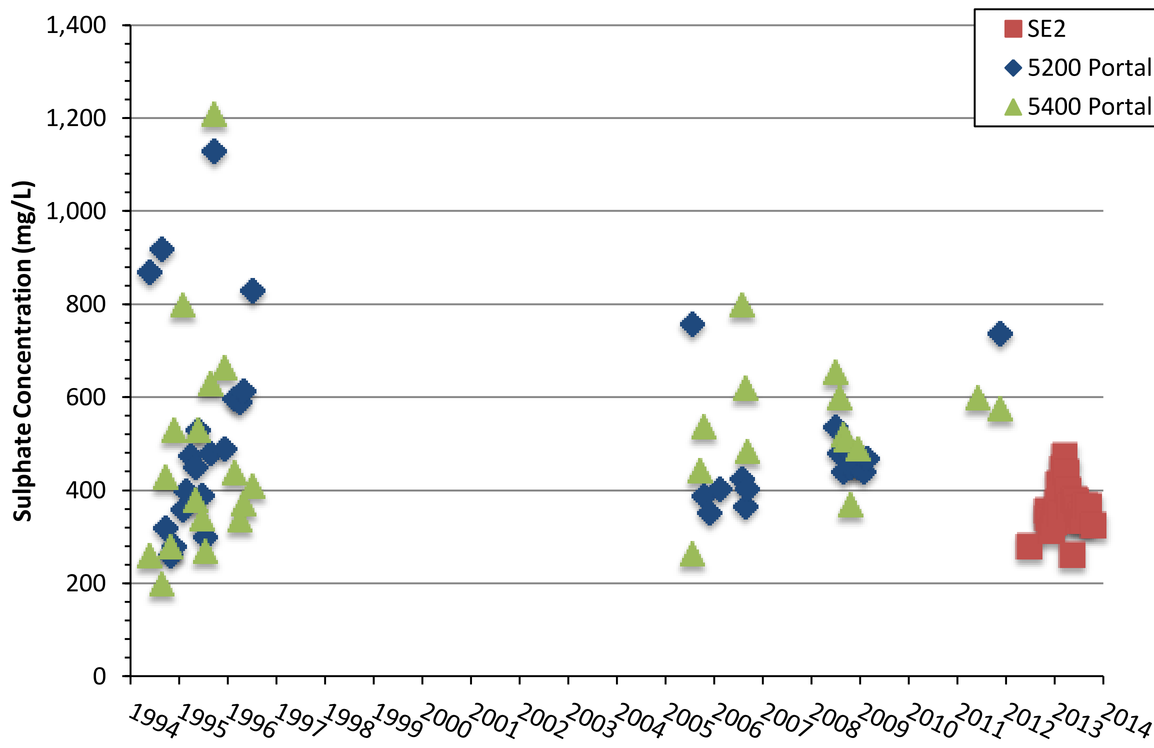


Figure 8. **Annual Sulphate Concentrations at SE-2, 5200 Portal and 5400 Portal**

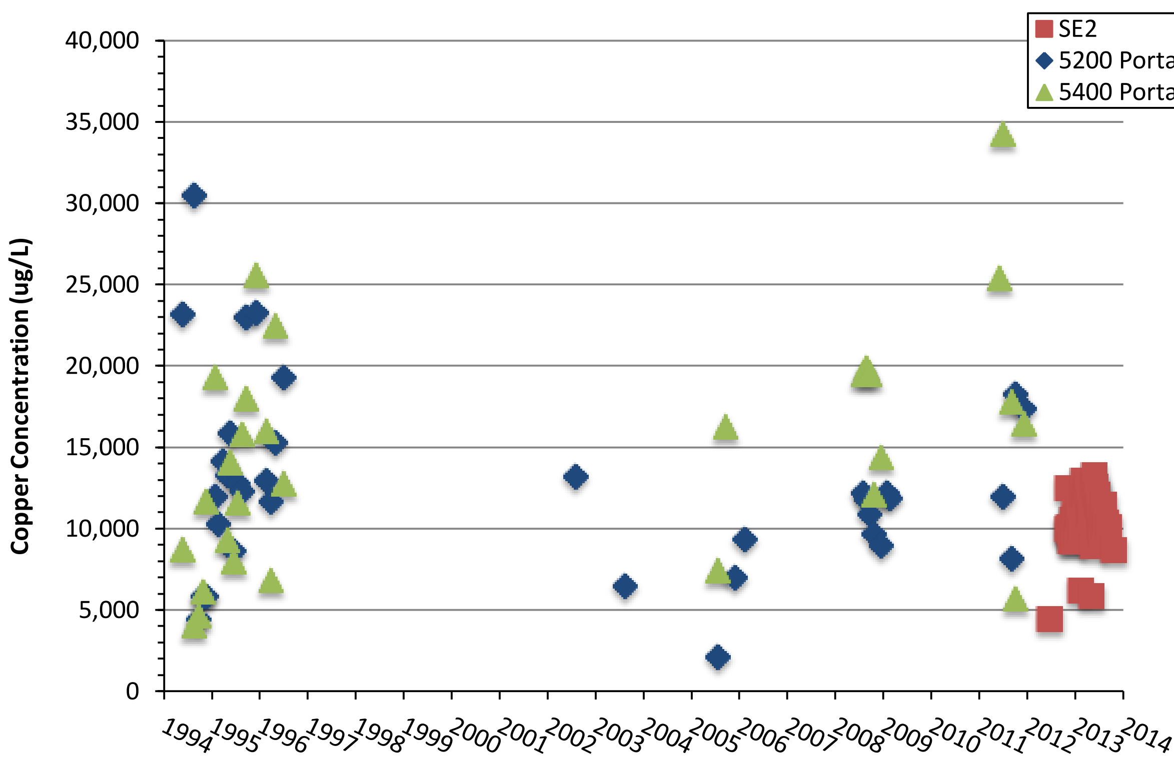


Figure 9. **Annual Copper Concentrations at SE-2, 5200 Portal and 5400 Portal**

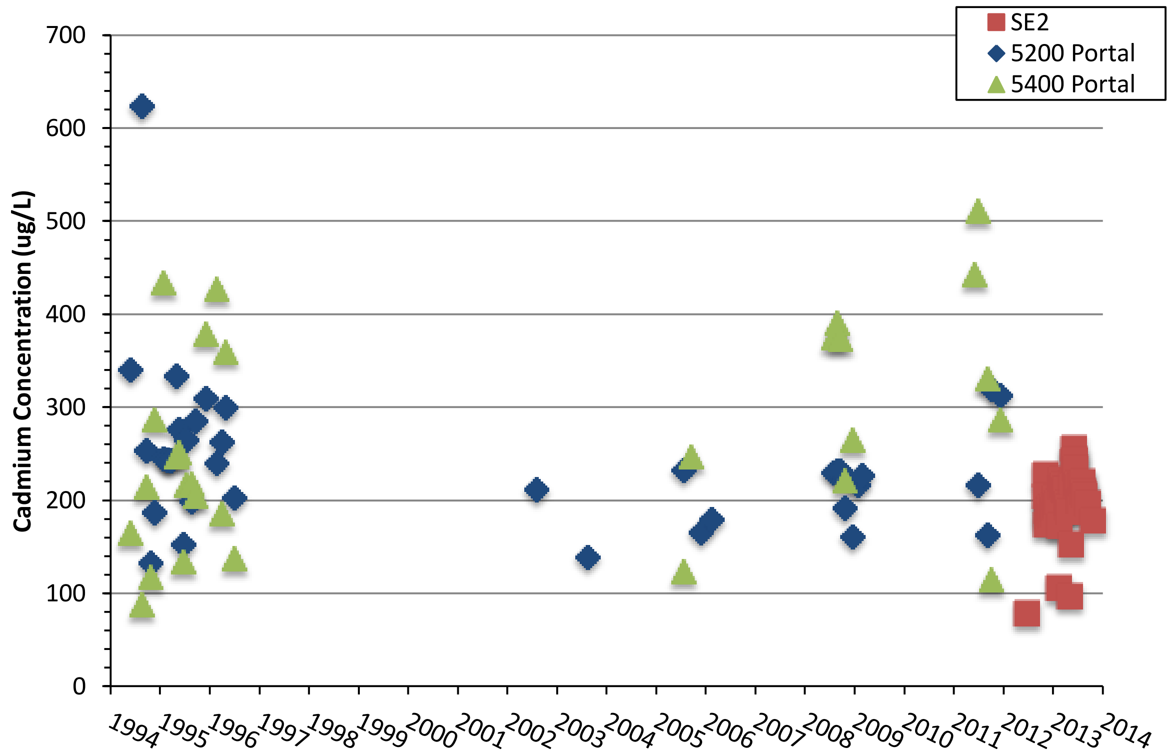


Figure 10. **Annual Cadmium Concentrations at SE-2, 5200 Portal and 5400 Portal**

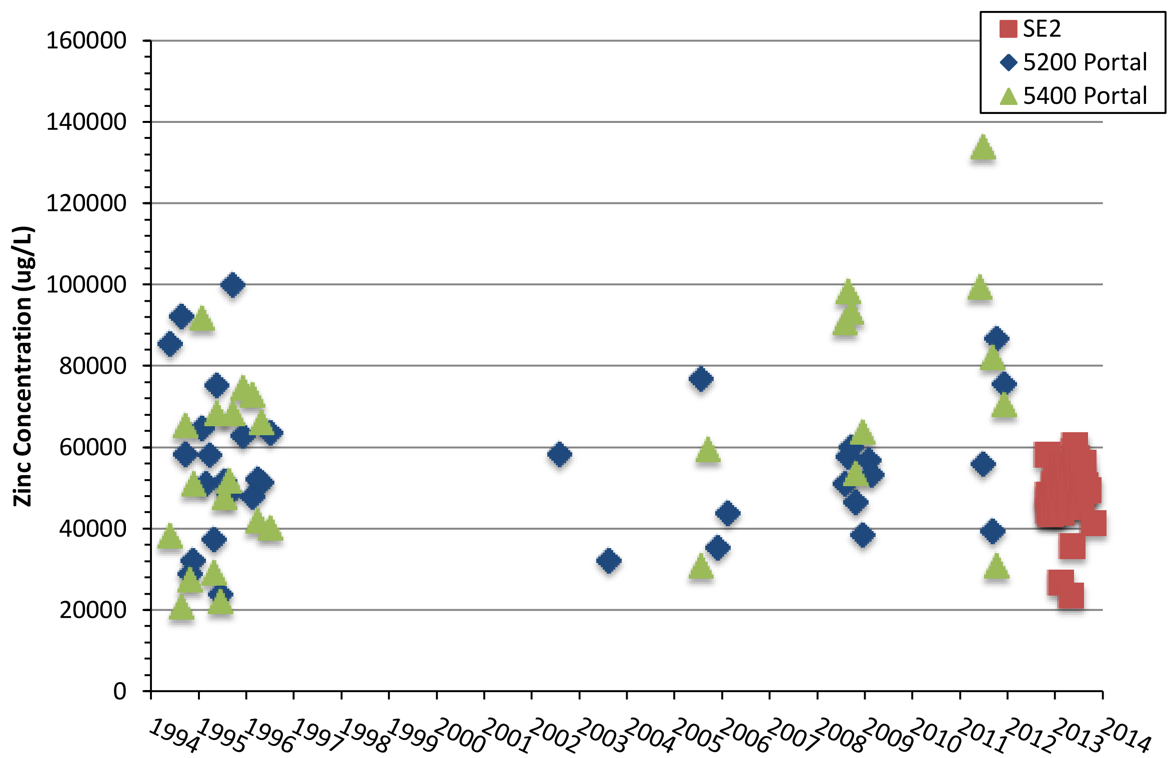


Figure 11. **Annual Zinc Concentrations at SE-2, 5200 Portal and 5400 Portal**

Error! Reference source not found. shows pH, dissolved aluminum, dissolved copper, dissolved lead and dissolved zinc exceed the IWTP discharge permit limits on every sampling event between August 5, 2012 and July 20, 2013. Note that Permit Limits were developed under EMA discharge permit #105719 and apply to *treated* discharge. Permit Limits do not apply to the effluent from SE-2 as it is *untreated* discharge. They are shown in **Error! Reference source not found.** as a point of reference only.

Table 2. Water Quality Summary Statistics of Site Exfiltration Pond (SE-2)

PARAMETER	Units	Permit Limit	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT
Acidity (pH 4.5)	mg/L		69	53	37	35	23	7	14	23
Acidity (pH 8.3)	mg/L		232	210	175	173	146	106	29	23
Dissolved Sulphate (SO_4)	mg/L		475	432	361	356	309	262	50	24
Conductivity	uS/cm		1,110	1,004	900	882	786	693	102	24
pH	pH	6.0-9.5	3.66	3.51	3.37	3.39	3.22	3.14	0.13	24
Physical Properties										
Total Suspended Solids	mg/L	30	43	40	30	31	20	2	9	24
Calculated Parameters										
Dissolved Hardness	mg/L		272	245	217	218	199	140	24	47
Total Hardness (CaCO3)	mg/L		269	244	219	220	194	147	26	35
Dissolved Metals by										
Dissolved Aluminum (Al)	ug/L	500	15500	13300	10637	10090	8515	7480	1975	46
Dissolved Arsenic (As)	ug/L	50	46	5	4	3	1	1	7	46
Dissolved Copper (Cu)	ug/L	50	13,300	12,540	10,660	10,800	9,086	5,860	1,613	47
Dissolved Lead (Pb)	ug/L	50	164	155	137	137	120	83	15	47
Dissolved Zinc (Zn)	ug/L	200	60,600	56,000	48,511	48,600	41,960	23,600	7,358	47

Note: Permit Limits do not apply to SE-2. They are shown here as a point of reference only.

3.3.4 Receiving Environment

Monitoring of the Tulsequah River in four locations is required under EMA Discharge Approval #105719. Water sample analysis for total and dissolved metals (by ICP/ICPMS) including mercury, as well as physical parameters: pH, conductivity, turbidity, total suspended solids, hardness, and alkalinity are required.

Station W10 is representative of water quality conditions upstream of the mine discharges and stations W51 and W32 represent the water quality downstream of the mine discharges. W46 is located directly downstream of the IWTP discharge but upstream of the SE-2. Figure 12 and Figure 13 show copper and zinc concentrations at W10, W51 and W32 between April 2012 and July 2013. Although data were available for W10 and W32 as far back as 2008 they were excluded from these figures as April 2012 to July 2013 is the only time period that data for W10, W51 and W32 were all available. Concentrations of copper and zinc remain relatively stable at station W10, however, the concentrations at station W32 and W51 increase as flow diminishes over the winter, peak in late April due to snowmelt and the first flushing of the waste rock and portal discharges into SE-2, and then decrease again with increased river flows. During the ice-free periods (May to August on Figure 12 and Figure 13), the concentrations of total and dissolved metals are similar between station W10 upstream of the mine and station W32 downstream of the mine. Even station 51 immediately downstream of the mine is comparable to stations W10 and W32. There appears to be enough dilution during high flows that mine effluent concentration in the Tulsequah River is vastly reduced (even without treatment plant operation).

There is good correlation between W32 and W51, reflecting the dilution occurring on average of about 20 to 50 - fold. Table 3 summarizes the dilution ratios from W51 to W32 for copper, cadmium, zinc and lead during pre-freshet (April 20, 2013 to May 4, 2013), high flows (September 12, 2012 to January 5, 2013; May 11, 2013 to July 20, 2013) and low flows (January 19, 2013 to April 13, 2013). Dilution ratios were based on median concentrations for each parameter for each station. The dilution ratios are lower during high flows, as compared to low (including pre-freshet) flows because abundant, rapid dilution is available, even between the mine and W51. During the open water season, one or more braids of the Tulsequah mainstem connect with the drainage from Dawn and Camp Creek and flow adjacent to the mine site, providing immediate dilution to the seepage from the Exfiltration Pond. Conversely, during the winter, there is very little mainstem flow that mixes with the mine site drainage before W51. However, intermingling does occur between W51 and W32 during all times of the year.

Table 3. Dilution Ratios from W51 to W32

Parameter	Pre-Freshet	High Flows	Low Flows
Dissolved Copper (Cu)	26	15	30
Total Copper (Cu)	67	10	46
Dissolved Cadmium	21	18	29
Total Cadmium	20	9	29
Dissolved Zinc (Zn)	22	21	34
Total Zinc (Zn)	24	11	34
Dissolved Lead	16	1	5
Total Lead	198	4	47

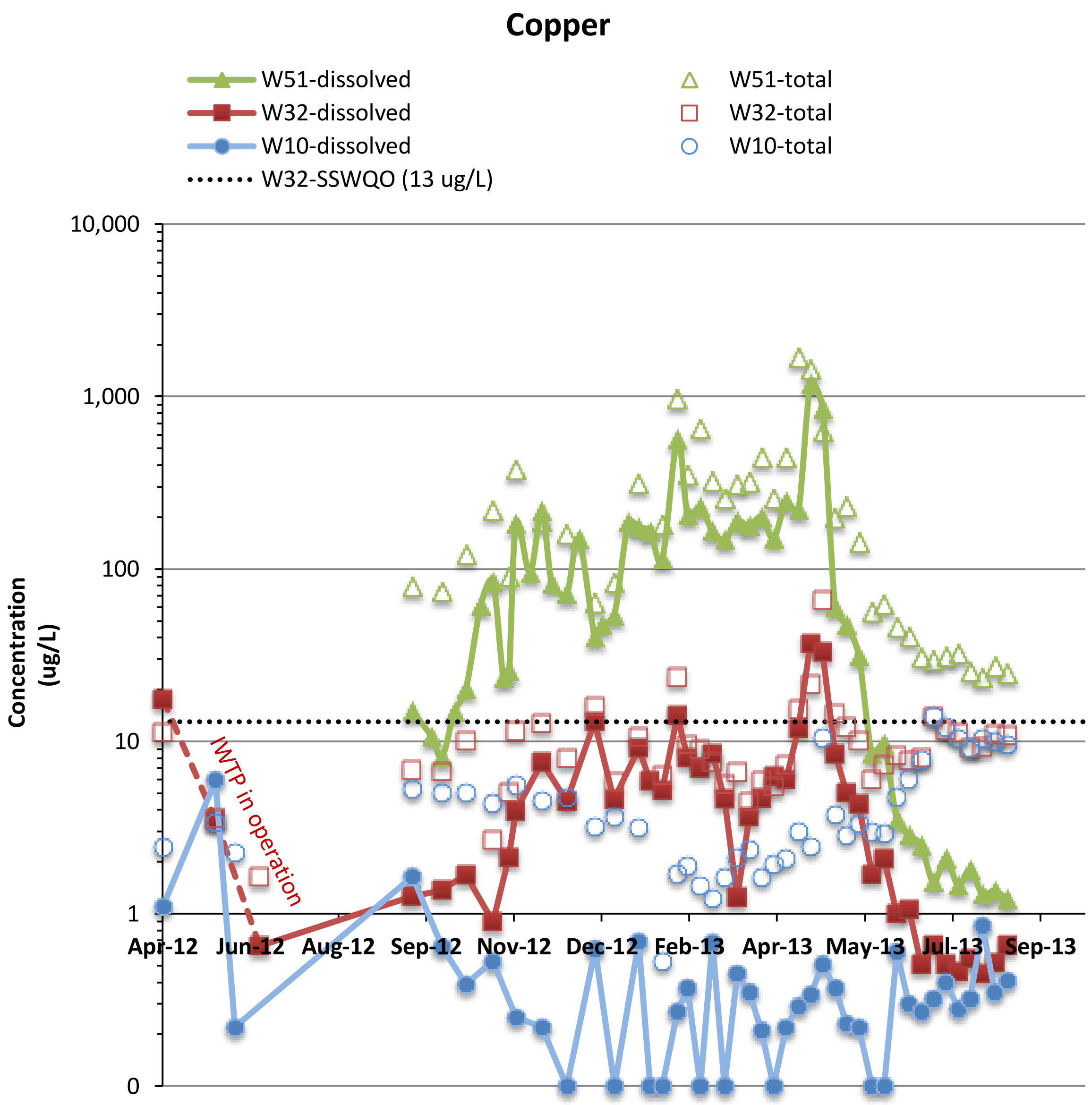


Figure 12. Copper Concentration in Tulsequah River upstream and downstream of mine discharge

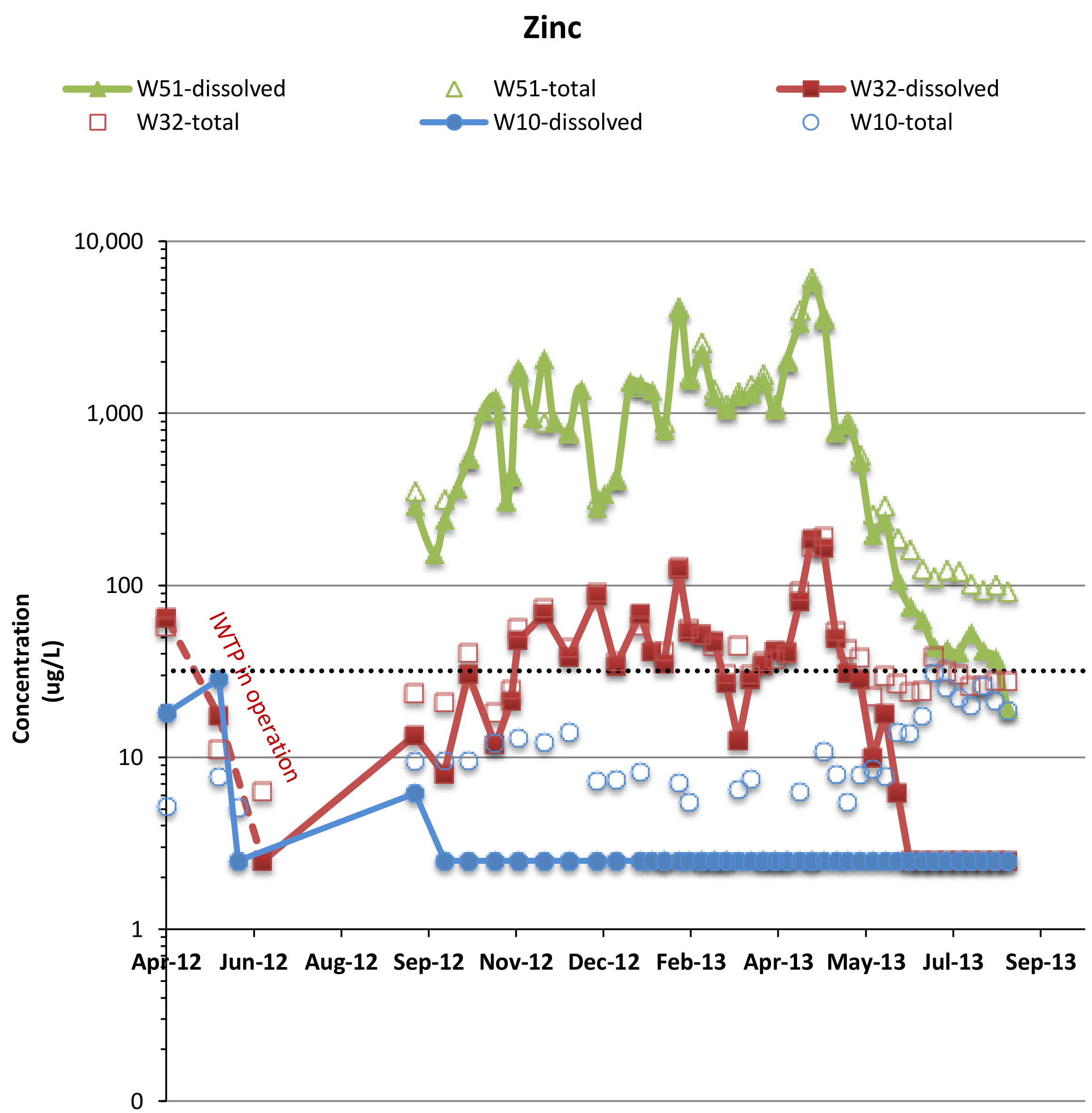


Figure 13. Zinc Concentration in Tulsequah River upstream and downstream of mine discharge

3.3.5 Screening Level Selection

Risk potential screening levels used to identify COPCs, considered provincial and federal regulatory criteria and local background water quality concentrations in the Tulsequah River. More specifically, the criteria considered included:

- British Columbia Water Quality Objectives (BCWQO);
- Site-Specific Water Quality Objectives (SSWQO) developed previously for the mine (AECOM 2008);

- Canadian Council of Ministers of the Environment (CCME) water quality guidelines; and,
- Local background concentrations as defined by the 90th percentiles for measured parameters at upstream monitoring station W10 (Figure 2).

These values and the selected screening levels used for identification of COPCs are presented in Table 4. The screening level selection approach was as follows: the previously accepted SSWQOs took precedence over the BCWQO and CCME values, otherwise the lowest of the provincial and federal values were selected as the screening levels, except where the background level exceeded regulatory criteria. In such cases, the 90th percentile for the background data was carried forward as the screening level – this was the case for only four parameters: nitrite, total aluminum, total chromium, and total vanadium.

3.3.6 Constituents of Potential Concern

The COPCs identified were based on comparison of the project screening levels (described above) with the available data representative of the worst-case water quality being discharged from the mine (Table 5). The station used for the identification of COPCs was station SE-2 which is a sampling point located prior to discharge into the aquatic receiving environment, Tulsequah River (Figure 2). This approach identified a rather broad range of COPCs that were then carried forward into the evaluation of risk to fish at the monitoring stations representative of the Tulsequah River aquatic receiving environment (stations: W32, W46, and W51; Figure 2). The preliminary COPCs identified through screening of the SE-2 results included:

- Dissolved sulphate
- Total aluminum
- Total arsenic
- Total cadmium
- Total cobalt
- Total copper
- Total iron
- Total lead
- Total mercury
- Total nickel
- Total silver
- Total uranium
- Total zinc

Table 4. Water Quality Screening Levels

Parameter	Units	CCME	BCWQO	SSWQO	Background 90th Percentile	Screening Level
Fluoride (F)	mg/L	0.12	2		0.06	0.12
Nitrite (N)	mg/L	0.197	0.02		0.03	0.03
Nitrate (N)	mg/L	13	3		0.06	3
Dissolved Sulphate (SO4)	mg/L		218 [2]		13.9	218
Dissolved Chloride (Cl)	mg/L	120	150		1.81	120
pH	pH Units	6.5-9.0	6.5-9.0		7.7	6.5 - 9.0
Total Aluminum (Al)	ug/L	100			4538	4538
Total Arsenic (As)	ug/L	5	5		2.5	5
Total Barium (Ba)	ug/L		1000		89	1000
Total Beryllium (Be)	ug/L		5.3		0.1	5.3
Total Boron (B)	ug/L	1500			25	1500
Total Cadmium (Cd)	ug/L	0.01 - 0.06 [2]	0.01 - 0.06 [2]	0.164	0.11	0.16
Total Chromium (Cr)	ug/L	1	1		7.1	7.1
Total Cobalt (Co)	ug/L		4		2.5	4
Total Copper (Cu)	ug/L	4	2	13	10.7	13
Total Iron (Fe)	ug/L	300	1000	6265	5428	6265
Total Lead (Pb)	ug/L	7	12		3.4	7
Total Lithium (Li)	ug/L		14		2.5	14
Total Manganese (Mn)	ug/L		700		116	700
Total Mercury (Hg)	ug/L	0.026	0.00125		0.025	0.00125
Total Molybdenum (Mo)	ug/L	73	1000		2.7	73
Total Nickel (Ni)	ug/L	150	25		9.2	25
Total Selenium (Se)	ug/L	1	2		0.26	1
Total Silver (Ag)	ug/L	0.1	0.05		0.04	0.05
Total Thallium (Tl)	ug/L	0.8	0.8		0.0546	0.3
Total Titanium (Ti)	ug/L		2000		264.4	2000
Total Uranium (U)	ug/L	15	300		0.8	15
Total Vanadium (V)	ug/L		6		11.8	11.8
Total Zinc (Zn)	ug/L	30	7.5 [2]	31.9	20.8	31.9

1 = Background values based on upstream monitoring location W10 which represents Tulsequah River water quality prior to being affected by the Tulsequah Chief Mine. Specifically, the 90th percentile was selected as a conservative measure of background levels.

2 = Criteria is hardness dependent.

CCME = Canadian Council of Ministers of the environment

BCWQO = British Columbia Water Quality Objective, BCWWQG = British Columbia Working Water Quality Guideline

SSWQO = Site-Specific Water Quality Objective

Where, background values were found to exceed regulatory criteria, the background was selected as the screening level. Where background was less than the regulatory criteria, the lowest of the regulatory criteria was selected as the screening level, except where a SSWQO was available.

TABLE 5

COPC Identification Using Monitoring Station SE2

Sample Site	Units	Screening Level	05-Aug-12	12-Sep-12	29-Sep-12	13-Oct-12	28-Oct-12	06-Nov-12	10-Nov-12	25-Nov-12	09-Dec-12	25-Dec-12	05-Jan-13	19-Jan-13	02-Feb-13	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13
Dissolved Sulphate (SO4)	mg/L	218		343	277	307	379	356	341	334	313	332	356	374	415		350		448	
Dissolved Chloride (Cl)	mg/L	120		5.8	4.0	5.5	4.5	4.3	6.0	7.1	8.3	8.4	9.1	7.4	8.0		5.3		6.4	
Total Aluminum (Al)	ug/L	4538	8810	10,500	7,430	9,160	10,400	10200	9530	11,100	8,740	8,910	8,680	11700	11700	10400	11800	13500	14700	15600
Total Arsenic (As)	ug/L	5	39.6	41	29	2.9	48	25.1	62.8	61	54	49	47	47.3	51.1	24.7	31.4	47.9	52.9	47.0
Total Barium (Ba)	ug/L	1000	28.5	114	33	23	27	27.7	27.0	30	26	24	23	22.5	21.1	49.8	20.6	20.9	20.3	20.8
Total Beryllium (Be)	ug/L	5.3	0.29	0.42	0.31	0.32	0.29	0.33	0.26	0.34	0.29	0.30	0.26	0.44	0.39	0.37	0.42	0.45	0.48	0.49
Total Boron (B)	ug/L	1500	65	25	25	25	25	25	50	50	50	50	50	50	65	25	25	50	50	50
Total Cadmium (Cd)	ug/L	0.164	192	167	145	172	202	210	194	220	180	189	184	190	204	108	176	211	218	218
Total Chromium (Cr)	ug/L	7.1	1.25	2.3	1.3	1.1	1.5	1.8	1	1.0	1.0	1.0	1.0	1.7	1.25	2.8	1.7	1	2.4	1
Total Cobalt (Co)	ug/L	4	6.0	9.4	6.5	7.4	7.5	6.43	7.8	8.4	6.2	6.1	6.0	8.72	8.5	9.99	9.12	9.7	10.4	10.4
Total Copper (Cu)	ug/L	13	10100	8,640	7,910	9,260	11,000	11500	10300	12,500	10,100	10,200	10,100	9020	12000	6160	9840	12700	12600	13300
Total Iron (Fe)	ug/L	6265	13500	13,400	9,220	6,530	16,200	14400	17900	19,600	16,000	15,600	14,900	18600	19000	11200	14100	20900	25000	25100
Total Lead (Pb)	ug/L	7	142	206	116	132	156	169	150	169	131	132	133	169	153	118	151	159	159	156
Total Lithium (Li)	ug/L	14	6.5	12	8.9	10	11	11.6	10	12	11	11	11	13.8	6.5	9.7	11.6	13	14	14
Total Manganese (Mn)	ug/L	700	315	502	352	374	381	328	363	407	295	305	297	385	364	422	400	415	407	432
Total Mercury (Hg)	ug/L	0.00125	0.05	0.025	0.025	0.025	0.025	0.005	0.05	0.050	0.050	0.050	0.050	0.050	0.065	0.025	0.025		0.005	0.05
Total Molybdenum (Mo)	ug/L	73	1.25	0.50	1.1	0.50	0.50	0.5	1	1.0	1.0	1.0	1.0	1.1	1.25	0.5	0.5	1	1	1
Total Nickel (Ni)	ug/L	25	8.3	14	11	12	10	9.4	10.3	11	8.8	7.9	7.8	10.7	10.0	15.2	13.1	12.5	13.2	13.1
Total Selenium (Se)	ug/L	1	0.37	0.39	0.28	0.21	0.27	0.05	0.43	0.46	0.25	0.48	0.24	0.41	0.43	0.18	0.36	0.27	0.31	0.1
Total Silver (Ag)	ug/L	0.05	0.025	0.37	0.10	0.066	0.090	0.088	0.095	0.24	0.10	0.12	0.020	0.155	0.109	0.095	0.075	0.068	0.02	0.098
Total Thallium (Tl)	ug/L	0.8	0.42	0.38	0.29	0.33	0.53	0.357	0.34	0.45	0.35	0.39	0.35	0.392	0.39	0.263	0.366	0.46	0.33	0.37
Total Titanium (Ti)	ug/L	2000	6.5	8.4	2.5	2.5	2.5	2.5	5	5.0	5.0	5.0	5.0	2.5	6.5	17.5	2.5	5	5	5
Total Uranium (U)	ug/L	15	7.36	5.2	4.2	5.8	7.0	8.47	8.05	9.3	7.3	7.4	7.2	13.8	11.0	4.68	9.95	15.1	20.8	22.0
Total Vanadium (V)	ug/L	11.8	6.5	2.5	2.5	2.5	2.5	2.5	5	5.0	5.0	5.0	5.0	2.5	6.5	2.5	2.5	5	5	5
Total Zinc (Zn)	ug/L	31.9	49300	39,800	36,400	42,600	47,200	51700	49900	55,900	46,100	48,000	48,500	40000	52500	26700	43300	54200	52400	55500
Total Potassium (K)	mg/L	373000	0.79	1.0	1.0	0.89	0.86	0.813	0.90	1.1	0.87	0.94	0.95	1.15	0.92	1.23	1.04	1.07	1.15	1.19

Values in red were reported as ND (Not Detected) and shown here at 1/2 the method detection limit

TABLE 5

COPC Identification Using Monitoring Station SE2

Sample Site	Units	Screening Level	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Dissolved Sulphate (SO4)	mg/L	218	475		439		401		366		262		380		378		361		335		347
Dissolved Chloride (Cl)	mg/L	120	7.2		7.6		6.8		4.6		3.5		5.5		5.3		5.6		5.3		
Total Aluminum (Al)	ug/L	4538	14600	14500	13100	12300	12200	12200	13200	9080	8680	10200	11200	11200	11200	12300	10900	10000	9700	9910	10000
Total Arsenic (As)	ug/L	5	46.5	45.9	41.3	36.1	34.4	31.8	44.7	21.2	35.3	72.3	76.8	64.7	60.0	142	59.1	45.9	46	45.2	49.3
Total Barium (Ba)	ug/L	1000	21.0	20.8	20.7	20.4	21.2	22.3	26.7	64.3	31.1	24.6	67.8	26.8	26.1	58.5	30.1	26.6	28.5	26.3	27.8
Total Beryllium (Be)	ug/L	5.3	0.42	0.39	0.38	0.37	0.42	0.46	0.46	0.30	0.27	0.30	0.37	0.31	0.24	0.43	0.33	0.3	0.36	0.33	0.27
Total Boron (B)	ug/L	1500	50	25	25	50	50	50	50	25	25	25	25	50	50	65	65	50	50	25	25
Total Cadmium (Cd)	ug/L	0.164	225	224	208	210	194	188	198	100	153	206	233	261	251	252	234	218	222	203	209
Total Chromium (Cr)	ug/L	7.1	1	2.5	1.9	2.1	2.2	2.1	2.5	2.4	1.7	1.7	1.7	1	1	1.25	1.25	1	1	4.4	6.3
Total Cobalt (Co)	ug/L	4	10.3	9.58	9.03	9.2	9.6	9.2	10.6	7.74	6.91	8.01	8.41	8.4	8.2	8.2	7.6	7.4	6.9	7.25	7.54
Total Copper (Cu)	ug/L	13	13300	13200	12500	12100	11400	10600	12100	6070	9230	12900	14300	13100	12500	13600	12600	11700	11000	11300	11000
Total Iron (Fe)	ug/L	6265	24900	23900	21700	19400	16700	14500	14400	8930	11900	18100	21700	22800	21600	39000	20900	16200	17000	15500	16500
Total Lead (Pb)	ug/L	7	154	138	135	131	137	136	145	103	126	148	164	162	154	151	137	139	147	147	148
Total Lithium (Li)	ug/L	14	14	13.4	12.6	13	12	12	14	7.5	8.4	10.4	11.8	10	10	13	6.5	12	13	10.2	11.3
Total Manganese (Mn)	ug/L	700	419	403	390	414	437	430	470	325	327	370	385	403	381	375	347	340	335	342	330
Total Mercury (Hg)	ug/L	0.00125	0.05	0.025	0.025	0.05	0.05	0.05	0.05	0.025	0.025	0.025	0.025	0.05	0.05	0.065	0.065	0.05	0.05	0.025	0.025
Total Molybdenum (Mo)	ug/L	73	1	1.3	1.4	1	1	1	1	0.5	0.5	0.5	1.0	1	1	1.25	1.25	1	1	5.8	8.5
Total Nickel (Ni)	ug/L	25	12.7	10.9	11.1	12.5	13.8	14.8	16.5	12.2	10.4	11.3	11.1	10.6	10.0	10.3	9.4	9.6	9.1	30.2	42.7
Total Selenium (Se)	ug/L	1	0.50	0.21	0.23	0.1	0.38	0.1	0.36	0.20	0.25	0.27	0.21	0.57	0.32	0.37	0.125	0.41	0.28	0.28	0.37
Total Silver (Ag)	ug/L	0.05	0.093	0.058	0.073	0.185	0.131	0.071	0.058	0.162	0.115	0.090	0.138	0.060	0.02	0.127	0.085	0.045	0.057	0.091	0.064
Total Thallium (Tl)	ug/L	0.8	0.41	0.341	0.352	0.43	0.40	0.34	0.27	0.242	0.345	0.392	0.485	0.32	0.34	0.52	0.45	0.42	0.39	0.502	0.52
Total Titanium (Ti)	ug/L	2000	5	2.5	2.5	5	5	5	5	2.5	2.5	2.5	2.5	5	5	6.5	6.5	5	5	2.5	2.5
Total Uranium (U)	ug/L	15	20.9	17.2	14.9	12.7	10.2	8.00	6.52	2.95	4.91	6.98	9.30	10.9	11.1	10.1	8.98	8.71	9.06	8.81	9.3
Total Vanadium (V)	ug/L	11.8	5	2.5	2.5	5	5	5	5	2.5	2.5	2.5	2.5	5	5	6.5	6.5	5	5	2.5	2.5
Total Zinc (Zn)	ug/L	31.9	55800	58000	54500	54000	48600	45900	48900	23100	36000	49200	55900	60700	59200	63200	60000	54600	53400	50500	51200
Total Potassium (K)	mg/L	373000	1.04	1.05	1.05	1.02	1.02	1.01	1.17	0.938	0.831	0.834	0.847	0.81	0.83	0.93	0.92	0.8	0.82	0.818	0.838

Values in red were reported as ND (Not Detected

Subsequent to the screening, a more detailed consideration was given to each of the preliminary COPCs. Through this process it was identified that mercury was not detected in the discharge at SE-2 or the receiving environment stations, but initially screened in because the analytical detection limit was insufficient for direct comparison with receiving environment guidelines. Given that mercury has not been detected at the mine or within the local receiving environment, it was not carried forward for quantitative evaluation in the risk assessment. Similarly, when the screening was applied to the remaining list of preliminary COPCs, only seven were found to be present at concentrations exceeding the project screening levels in the receiving environment.

- aluminum
- cadmium
- copper
- iron
- lead
- nickel and
- zinc.

Further review of theses seven metals (Tables 6 to 12) resulted in four metals being carried forward for quantitative evaluation in the risk characterization, because they exceeded the criteria in at least 10% of the samples (and more than once) at one or more of the monitoring stations:

- cadmium
- copper
- lead
- zinc

Aluminum, iron, and nickel were not carried forward in the risk assessment for these reasons:

- The aluminum maximum concentration (7850 ug/L) and 90th percentile concentration (4538 ug/L) at the background station (W10) was higher than the maximum aluminum concentration and 90th percentile concentrations at stations W46 (6900 ug/L: 4250 ug/L), W51 (6960 ug/L: 4382 ug/L), and W32 (5580 ug/L: 3575 ug/L). For this reason aluminum was not carried forward in the risk assessment.

- The iron maximum concentration (9380 ug/L) and 90th percentile concentration (5428 ug/L) at the background station (W10) was higher than the maximum iron concentration and 90th percentile concentration at stations W46 (7940 ug/L: 4660 ug/L), W51 (8190 ug/L: 4756 ug/L), and W32 (6740 ug/L: 3696 ug/L). For this reason iron was not carried forward in the risk assessment.

- The nickel screening level (25 ug/L) was higher than the nickel 90^{th} percentile concentration at stations W46 (8.95 ug/L), W51 (9.12 ug/L), and W32 (6.84 ug/L). Nickel, at 1 sample event in 36 at sample station W46 (34.3 ug/L) and 1 sample event in 35 at station W51 (30.3 ug/L), exceeded the screening level (25 ug/L). For this reason nickel was not carried forward in the risk assessment.

The screening identified total metals as the COPCs; this is primarily a function of the regulatory surface water criteria being set for total concentrations rather than dissolved. However, to provide a more comprehensive evaluation of the potential for risk in the aquatic receiving environment, hazard quotients were calculated for both the total and dissolved concentrations for each COPC as described in Section 6.

A summary of the toxicological effects associated with freshwater fish exposure to each of the preliminary COPCs (i.e., those present in discharge waters) is provided in Section 5.1.

Table 6. COPC Descriptive Statistics for Station W10

Parameter	Units	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING LEVEL
Anions										
Dissolved Sulphate (SO4)	mg/L	17	14	12	12	9	5	2.3	36	218
Physical Properties										
pH	pH Units	7.8	7.7	7.5	7.5	7.3	7.1	0.16	36	6.5-9.0
Total Suspended Solids	mg/L	120	106	36	15	2	2	40	35	
Total Dissolved Solids	mg/L	78	75	67	66	60	58	7.4	5	
Turbidity	NTU	192	142	86	88	31	20	55	9	
Calculated Parameters										
Dissolved Hardness (CaCO3)	mg/L	39	35	31	31	27	24	3.6	47	
Total Hardness (CaCO3)	mg/L	57	41	37	36	33	30	5.0	46	
Dissolved Metals by ICPMS										
Dissolved Aluminum (Al)	ug/L	379	92	62	52	30	20	56	48	4538
Dissolved Arsenic (As)	ug/L	0.81	0.63	0.51	0.50	0.38	0.32	0.095	48	5
Dissolved Cadmium (Cd)	ug/L	0.077	0.023	0.013	0.005	0.005	0.005	0.016	47	0.16
Dissolved Cobalt (Co)	ug/L	0.38	0.25	0.24	0.250	0.250	0.034	0.06	48	4
Dissolved Copper (Cu)	ug/L	6.0	1.2	0.58	0.33	0.10	0.10	0.89	48	13
Dissolved Iron (Fe)	ug/L	473	47	33	15	7	3	71	48	6265
Dissolved Lead (Pb)	ug/L	0.54	0.10	0.118	0.10	0.100	0.036	0.089	48	7
Dissolved Nickel (Ni)	ug/L	48.80	0.90	1.79	0.50	0.50	0.26	7.10	48	25
Dissolved Uranium (U)	ug/L	0.56	0.42	0.37	0.37	0.30	0.26	0.057	48	15
Dissolved Zinc (Zn)	ug/L	28.5	3.6	3.5	2.5	2.50	0.20	4.5	48	31.9
Total Metals by ICPMS										
Total Aluminum (Al)	ug/L	7,850	4,538	2,403	1,880	883	161	1,676	47	4538
Total Arsenic (As)	ug/L	3.9	2.5	1.4	1.1	0.7	0.6	0.78	47	5
Total Cadmium (Cd)	ug/L	1.52	0.11	0.08	0.030	0.012	0.005	0.219	47	0.16
Total Cobalt (Co)	ug/L	3.9	2.5	1.3	1.0	0.3	0.3	0.95	47	4
Total Copper (Cu)	ug/L	17	11	5.0	3.8	1.7	0.5	3.7	47	13
Total Iron (Fe)	ug/L	9,380	5,428	2,575	1,830	925	146	2,067	47	6265
Total Lead (Pb)	ug/L	4.9	3.4	1.7	1.2	0.5	0.1	1.3	47	7
Total Nickel (Ni)	ug/L	30	9	5.4	4.1	2.1	0.5	4.7	47	25
Total Uranium (U)	ug/L	0.91	0.82	0.54	0.49	0.40	0.34	0.16	47	15
Total Zinc (Zn)	ug/L	41	21	11	9	3	3	8	47	31.9

Table 7. COPC Descriptive Statistics for Station W46, IWTP Operational

Parameter	Units	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING LEVEL
Anions										
Dissolved Sulphate (SO4)	mg/L	58	54	31	23	19	18	16.5	7	218
Physical Properties										
pH	pH Units	7.9	7.9	7.8	7.8	7.7	7.7	0.11	7	6.5-9.0
Total Suspended Solids	mg/L	22	17	7	2	2	2	8	7	
Total Dissolved Solids	mg/L	0					0		0	
Turbidity	NTU	16	12	6	5	1	1	6	5	
Calculated Parameters										
Dissolved Hardness (CaCO3)	mg/L	99	86	67	64	53	51	17	7	
Total Hardness (CaCO3)	mg/L	103	88	67	60	53	51	19	6	
Dissolved Metals by ICPMS										
Dissolved Aluminum (Al)	ug/L	107	92	38	21	12	11.5	37	8	4538
Dissolved Arsenic (As)	ug/L	1.34	1.26	0.89	0.87	0.62	0.580	0.27	8	5
Dissolved Cadmium (Cd)	ug/L	0.6	0.6	0.25	0.15	0.07	0.05	0.2	8	0.16
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.00	8	4
Dissolved Copper (Cu)	ug/L	26	13	5.5	2.35	0.69	0.55	9	8	13
Dissolved Iron (Fe)	ug/L	148	77	35	13	4.7	2.5	49	8	6265
Dissolved Lead (Pb)	ug/L	0.51	0.48	0.20	0.10	0.10	0.10	0.18	8	7
Dissolved Nickel (Ni)	ug/L	0.5	0.5	0.50	0.50	0.50	0.50	0.00	8	25
Dissolved Silver (Ag)	ug/L	0.010	0.010	0.010	0.010	0.010	0.010	0.00	8	0.05
Dissolved Uranium (U)	ug/L	0.78	0.77	0.61	0.61	0.47	0.46	0.12	8	15
Dissolved Zinc (Zn)	ug/L	133	65	31	18.7	2.5	2.5	43	8	31.9
Total Metals by ICPMS										
Total Aluminum (Al)	ug/L	1,170	850	407	195	20	20	424	7	4538
Total Arsenic (As)	ug/L	3.0	2.5	1.5	1.3	0.95	0.90	0.8	7	5
Total Cadmium (Cd)	ug/L	0.6	0.4	0.23	0.19	0.09	0.06	0.2	7	0.16
Total Cobalt (Co)	ug/L	0.6	0.6	0.3	0.25	0.25	0.25	0.2	7	4
Total Copper (Cu)	ug/L	10.9	8.8	5.0	4.0	2.3	2.3	3.1	7	13
Total Iron (Fe)	ug/L	1,110	1,043	541	425	38	37	462	7	6265
Total Lead (Pb)	ug/L	1.0	0.8	0.5	0.5	0.10	0.100	0.3	7	7
Total Nickel (Ni)	ug/L	6	4	2.2	1.5	0.50	0.50	2.0	7	25
Total Silver (Ag)	ug/L	0.010	0.010	0.010	0.010	0.010	0.010	0.00	7	0.05
Total Uranium (U)	ug/L	0.9	0.79	0.66	0.62	0.56	0.50	0.12	7	15
Total Zinc (Zn)	ug/L	46	41	23	24	8.4	8.30	15	7	31.9

Table 8. COPC Descriptive Statistics for Stations W46, IWTP Not Operational

Parameter	Units	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING
Anions										
Dissolved Sulphate (SO4)	mg/L	24	22	17	18	12	10	4.4	25	218
Physical Properties										
pH	pH Units	7.9	7.9	7.7	7.7	7.4	7.3	0.18	25	6.5-9.0
Total Suspended Solids	mg/L	109	43	17	2	2	2	27	25	
Total Dissolved Solids	mg/L	72	72	72	72	72	72		1	
Turbidity	NTU	108	105	94	94	83.1	80.3	20	2	
Calculated Parameters										
Dissolved Hardness (CaCO3)	mg/L	94	79	56	59	31	25	19	44	
Total Hardness (CaCO3)	mg/L	158	80	61	58	41	36	22	35	
Dissolved Metals by ICPMS										
Dissolved Aluminum (Al)	ug/L	96	53	26	16	7	5.2	22	45	4538
Dissolved Arsenic (As)	ug/L	0.79	0.76	0.60	0.60	0.47	0.25	0.11	45	5
Dissolved Cadmium (Cd)	ug/L	0.5	0.1	0.05	0.035	0.008	0.005	0.1	45	0.16
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.250	0.25	0.15	0.01	45	4
Dissolved Copper (Cu)	ug/L	27	3	1.7	0.74	0.33	0.27	4	45	13
Dissolved Iron (Fe)	ug/L	86	26	17	14	5.9	2.5	15	45	6265
Dissolved Lead (Pb)	ug/L	0.73	0.10	0.12	0.10	0.10	0.10	0.10	45	7
Dissolved Nickel (Ni)	ug/L	7.7	0.8	0.83	0.50	0.50	0.50	1.22	45	25
Dissolved Silver (Ag)	ug/L	0.010	0.010	0.010	0.010	0.010	0.010	0.000	45	0.05
Dissolved Uranium (U)	ug/L	0.76	0.70	0.53	0.52	0.36	0.32	0.13	45	15
Dissolved Zinc (Zn)	ug/L	99	13	10	5.6	2.50	2.50	16	45	31.9
Total Metals by ICPMS										
*Total Aluminum (Al)**	ug/L	6,900	4,250	1,323	334	16	15	2,027	36	4538
Total Arsenic (As)	ug/L	4.2	3.3	1.4	0.9	0.64	0.56	1.1	36	5
Total Cadmium (Cd)	ug/L	0.5	0.1	0.09	0.05	0.030	0.005	0.1	36	0.16
Total Cobalt (Co)	ug/L	3.6	2.3	0.8	0.25	0.25	0.25	1.0	36	4
Total Copper (Cu)	ug/L	43	9	5	2.8	0.58	0.10	7	36	13
Total Iron (Fe)	ug/L	7,940	4,660	1,528	568	28	23	2,301	36	6265
Total Lead (Pb)	ug/L	4.4	3.0	1.0	0.4	0.10	0.100	1.3	36	7
Total Nickel (Ni)	ug/L	34	9	3.8	1.5	0.50	0.50	6.3	36	25
Total Silver (Ag)	ug/L	0.043	0.026	0.013	0.010	0.010	0.010	0.008	36	0.05
Total Uranium (U)	ug/L	1.0	0.76	0.62	0.60	0.53	0.05	0.15	36	15
Total Zinc (Zn)	ug/L	110	27	16	10	6.1	2.50	18	36	31.9

No difference between the background station W10 and W46. Aluminum concentration exceeds the screening value at three stations; however, the maximum concentration does not exceed the max background.

There is one exceedance of the standard that occurred more than 2 years ago.

No difference between the background station W10 and W46 Iron concentration exceeds the screening value at three stations one sampling event; however, the maximum concentration does not exceed the max background.

No difference between the background station W10 and W46 for Nickel. The Nickel concentration exceeds the screening value at one sampling eve

Table 9. COPC Descriptive Statistics for Station W51, IWTP Operational

Parameter	Units	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING LEVEL
Anions										
Dissolved Sulphate (SO4)	mg/L	24.00	23.13	19.65	19.65	16.17	15.30	6.15	2	218
Physical Properties										
pH	pH Units	7.72	7.68	7.54	7.54	7.40	7.36	0.25	2	6.5-9.0
Total Suspended Solids	mg/L	23.00	21.35	14.75	14.75	8.15	6.50	11.67	2	
Total Dissolved Solids	mg/L								0	
Turbidity	NTU								1	
Calculated Parameters										
Dissolved Hardness (CaCO3)	mg/L	59.80	59.36	55.67	57.60	51.20	49.60	5.37	3	
Total Hardness (CaCO3)	mg/L	55.20	54.66	52.50	52.50	50.34	49.80	3.82	2	
Dissolved Metals by ICPMS										
Dissolved Aluminum (Al)	ug/L	38.90	38.36	34.03	36.20	28.84	27.00	6.24	3	4538
Dissolved Arsenic (As)	ug/L	0.83	0.75	0.54	0.42	0.38	0.37	0.25	3	5
Dissolved Cadmium (Cd)	ug/L	1.94	1.83	1.14	1.41	0.34	0.07	0.96	3	0.16
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.00	3	4
Dissolved Copper (Cu)	ug/L	25.60	25.14	16.81	23.30	5.88	1.52	13.29	3	13
Dissolved Iron (Fe)	ug/L	13.00	12.94	12.73	12.70	12.54	12.50	0.25	3	6265
Dissolved Lead (Pb)	ug/L	0.22	0.20	0.14	0.10	0.10	0.10	0.07	3	7
Dissolved Nickel (Ni)	ug/L	0.50	0.50	0.50	0.50	0.50	0.50	0.00	3	25
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.00	3	0.05
Dissolved Uranium (U)	ug/L	0.54	0.48	0.33	0.23	0.21	0.21	0.19	3	15
Dissolved Zinc (Zn)	ug/L	434	409	250	310	68	7	220	3	31.9
Total Metals by ICPMS										
Total Aluminum (Al)	ug/L	1,110	1,067	897	897	727	684	301	2	4538
Total Arsenic (As)	ug/L	2.80	2.64	1.99	1.99	1.33	1.17	1.15	2	5
Total Cadmium (Cd)	ug/L	**1.80**	**1.63**	**0.96**	**0.96**	**0.29**	0.12	1.19	2	0.16
Total Cobalt (Co)	ug/L	0.67	0.66	0.63	0.63	0.59	0.58	0.06	2	4
Total Copper (Cu)	ug/L	**91**	**82**	**47**	**47**	13	4	61	2	13
Total Iron (Fe)	ug/L	1,040	1,027	975	975	922	909	93	2	6265
Total Lead (Pb)	ug/L	2.09	1.97	1.47	1.47	0.97	0.85	0.88	2	7
Total Nickel (Ni)	ug/L	3.30	3.22	2.90	2.90	2.58	2.50	0.57	2	25
Total Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.00	2	0.05
Total Uranium (U)	ug/L	0.66	0.65	0.60	0.60	0.55	0.54	0.08	2	15
Total Zinc (Zn)	ug/L	**432**	**391**	**225**	**225**	**59**	18	293	2	31.9

Table 10. COPC Descriptive Statistics for Station W51, IWTP Not Operational

Parameter	Units	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING LEVEL
Anions										
Dissolved Sulphate (SO4)	mg/L	87.20	38.05	27.26	25.00	13.15	11.10	15.80	24	218
Physical Properties										
pH	pH Units	7.81	7.77	7.53	7.55	7.33	6.67	0.25	24	6.5-9.0
Total Suspended Solids	mg/L	92.70	61.74	20.13	6.65	2.00	2.00	27.64	24	
Total Dissolved Solids	mg/L									
Turbidity	NTU								1	
Calculated Parameters										
Dissolved Hardness (CaCO3)	mg/L	99.50	84.47	61.15	68.25	32.12	25.90	21.68	44	
Total Hardness (CaCO3)	mg/L	94.70	85.91	63.56	63.15	44.53	37.40	17.35	34	
Dissolved Metals by ICPMS										
Dissolved Aluminum (Al)	ug/L	1,550	68.03	81.24	46.65	23.66	20.00	227.66	44	4538
Dissolved Arsenic (As)	ug/L	2.04	0.45	0.29	0.20	0.12	0.05	0.30	44	5
Dissolved Cadmium (Cd)	ug/L	25.20	9.07	4.89	3.90	0.49	0.20	5.04	44	0.16
Dissolved Cobalt (Co)	ug/L	2.43	0.57	0.39	0.25	0.25	0.25	0.43	44	4
Dissolved Copper (Cu)	ug/L	1,190	227	148	83	3	1	223	44	13
Dissolved Iron (Fe)	ug/L	1,520	44.41	54.10	13.95	6.80	2.50	227.22	44	6265
Dissolved Lead (Pb)	ug/L	16.10	0.80	0.81	0.32	0.10	0.10	2.49	44	7
Dissolved Nickel (Ni)	ug/L	71.50	2.67	3.24	0.50	0.50	0.50	11.32	44	25
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.00	44	0.05
Dissolved Uranium (U)	ug/L	0.91	0.42	0.28	0.28	0.05	0.05	0.17	44	15
Dissolved Zinc (Zn)	ug/L	5,770	2,196.00	1,163.24	923.00	84.53	40.90	1,186.20	44	31.9
Total Metals by ICPMS										
Total Aluminum (Al)	ug/L	6,960	4,382	1,694	1,030	268	49	1,930	35	4538
Total Arsenic (As)	ug/L	4.29	3.63	1.68	1.20	0.84	0.11	1.12	35	5
Total Cadmium (Cd)	ug/L	26.10	13.28	5.25	3.63	0.62	0.51	5.62	35	0.16
Total Cobalt (Co)	ug/L	3.83	2.40	1.01	0.68	0.25	0.25	1.00	35	4
Total Copper (Cu)	ug/L	1,700	646	311	198	36	30	378	35	13
Total Iron (Fe)	ug/L	8,190	4,756	1,700	731	160	59	2,277	35	6265
Total Lead (Pb)	ug/L	41.9	10.16	5.75	3.52	1.63	1.02	7.64	35	7
Total Nickel (Ni)	ug/L	30.30	9.12	3.95	2.30	0.50	0.50	5.87	35	25
Total Silver (Ag)	ug/L	0.04	0.02	0.01	0.01	0.01	0.01	0.01	35	0.05
Total Uranium (U)	ug/L	3.49	1.32	0.88	0.72	0.59	0.05	0.54	35	15
Total Zinc (Zn)	ug/L	6,110	3,150	1,273	890	140	112	1,353	35	31.9

No difference between the background station W10 and W51. Aluminum concentration exceeds the screening value at three stations; however, the maximum concentration does not exceed the max background.

There is one exceedance of the standard that occurred more than 2 years ago.

No difference between the background station W10 and W51. Iron concentration exceeds the screening value at three stations one sampling event; however, the maximum concentration does not exceed the max background.

No difference between the background station W10 and W51 for Nickel.

The Nickel concentration exceeds the screening value at one sampling event.

Table 11. COPC Descriptive Statistics for Station W32, IWTP Operational

Parameter	Units	MAX	P90	AVERAGE	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING LEVEL
Anions										
Dissolved Sulphate (SO4)	mg/L	26	23	16	15	9	7.8	7.6	4	218
Physical Properties										
pH	pH Units	7.9	7.8	7.7	7.7	7.7	7.6	0.09	4	6.5-9.0
Total Suspended Solids	mg/L	18	13	6	2	2	2	8	4	
Total Dissolved Solids	mg/L	0					0		0	
Turbidity	NTU	18	15	8	3	2.7	2.59	9	3	
Calculated Parameters										
Dissolved Hardness (CaCO3)	mg/L	72	66	52	48	41	40	15	4	
Total Hardness (CaCO3)	mg/L	72	66	53	48	43	42	14	4	
Dissolved Metals by ICPMS										
Dissolved Aluminum (Al)	ug/L	116	90	49	30	23.3	20.7	45	4	4538
Dissolved Arsenic (As)	ug/L	1.0	0.91	0.79	0.76	0.68	0.65	0.13	4	5
Dissolved Cadmium (Cd)	ug/L	0.30	0.24	0.125	0.088	0.037	0.027	0.121	4	0.16
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.250	0.250	0.250	0.00	4	4
Dissolved Copper (Cu)	ug/L	17.6	13.4	6.0	2.82	1.09	0.65	7.8	4	13
Dissolved Iron (Fe)	ug/L	120	95	44	25	9	8.2	52	4	6265
Dissolved Lead (Pb)	ug/L	0.28	0.26	0.17	0.16	0.100	0.100	0.09	4	7
Dissolved Nickel (Ni)	ug/L	0.50	0.50	0.50	0.50	0.50	0.50	0.00	4	25
Dissolved Silver (Ag)	ug/L	0.010	0.010	0.0100	0.0100	0.0100	0.0100	0.00	4	0.05
Dissolved Uranium (U)	ug/L	0.64	0.58	0.46	0.43	0.35	0.330	0.13	4	15
Dissolved Zinc (Zn)	ug/L	65	52	26.4	19.3	7.0	2.50	26.7	4	31.9
Total Metals by ICPMS										
Total Aluminum (Al)	ug/L	668	635	435	483	196	104	245	4	4538
Total Arsenic (As)	ug/L	1.5	1.5	1.2	1.1	0.84	0.82	0.36	4	5
Total Cadmium (Cd)	ug/L	0.28	0.23	0.130	0.091	0.062	0.054	0.103	4	0.16
Total Cobalt (Co)	ug/L	0.3	0.3	0.25	0.25	0.250	0.250	0.00	4	4
Total Copper (Cu)	ug/L	11.3	9.4	5.4	4.3	2.22	1.64	4.2	4	13
Total Iron (Fe)	ug/L	671	645	490	573	270	145	235	4	6265
Total Lead (Pb)	ug/L	0.4	0.4	0.4	0.4	0.356	0.350	0.03	4	7
Total Nickel (Ni)	ug/L	1.6	1.6	1.3	1.5	0.77	0.50	0.5	4	25
Total Silver (Ag)	ug/L	0.010	0.010	0.0100	0.0100	0.0100	0.0100	0.000	4	0.05
Total Uranium (U)	ug/L	0.68	0.63	0.54	0.50	0.47	0.47	0.10	4	15
Total Zinc (Zn)	ug/L	58	48	25	18	7.7	6.3	23.2	4	31.9

Table 12. COPC Descriptive Statistics for Station W32, IWTP Not Operational

Parameter	Units	MAX	P90	AVERAG	MEDIAN	P10	MIN	ST DEV	COUNT	SCREENING LEVEL
Anions										
Dissolved Sulphate (SO4)	mg/L	28	26	17	17	10	8.5	6.2	34	218
Physical Properties										
pH	pH	8.0	7.9	7.7	7.7	7.4	7.3	0.18	34	6.5-9.0
Total Suspended Solids	mg/L	88	57	18	5	2.0	0.50	24	33	
Total Dissolved Solids	mg/L	96	92	74	72	54	40	19	7	
Turbidity	NTU	113	95	45	50	1.0	0.80	45	7	
Calculated Parameters										
Dissolved Hardness	mg/L	93	78	56	61	31	28	19	45	
Total Hardness (CaCO3)	mg/L	83	78	57	54	40	34	15	44	
Dissolved Metals by										
Dissolved Aluminum (Al)	ug/L	1,180	70	60	36	12.2	6.4	169	47	4538
Dissolved Arsenic (As)	ug/L	1.9	0.74	0.65	0.61	0.54	0.51	0.21	47	5
Dissolved Cadmium (Cd)	ug/L	0.83	0.43	0.183	0.137	0.035	0.013	0.182	46	0.16
Dissolved Cobalt (Co)	ug/L	1.37	0.25	0.25	0.250	0.063	0.011	0.18	47	4
Dissolved Copper (Cu)	ug/L	37.0	12.3	5.6	4.10	0.58	0.40	7.3	47	13
Dissolved Iron (Fe)	ug/L	1,590	96	64	17	3	2.5	232	47	6265
Dissolved Lead (Pb)	ug/L	1.76	0.26	0.16	0.10	0.100	0.031	0.26	47	7
Dissolved Nickel (Ni)	ug/L	8.50	0.50	0.90	0.50	0.45	0.21	1.51	47	25
Dissolved Silver (Ag)	ug/L	0.025	0.01	0.0094	0.0100	0.002	0.002	0.003	47	0.05
Dissolved Uranium (U)	ug/L	0.73	0.66	0.48	0.50	0.30	0.017	0.15	47	15
Dissolved Zinc (Zn)	ug/L	185	83	36.9	28.2	2.5	0.60	40.6	47	31.9
Total Metals by ICPMS										
Total Aluminum (Al)	ug/L	5,580	3,18	1,022	366	23	12	1,525	45	4538
Total Arsenic (As)	ug/L	4.8	3.0	1.4	1.0	0.56	0.44	1.03	46	5
Total Cadmium (Cd)	ug/L	0.91	0.45	0.223	0.176	0.078	0.018	0.196	46	0.16
Total Cobalt (Co)	ug/L	3.3	1.9	0.71	0.25	0.250	0.021	0.79	46	4
Total Copper (Cu)	ug/L	66.0	15.7	10.1	7.9	3.72	0.75	9.9	46	13
Total Iron (Fe)	ug/L	6,740	3,67	1,213	441	17	3	1,780	46	6265
Total Lead (Pb)	ug/L	3.7	2.1	0.9	0.5	0.100	0.043	0.96	46	7
Total Nickel (Ni)	ug/L	19.2	6.9	2.8	1.0	0.50	0.28	3.8	46	25
Total Silver (Ag)	ug/L	0.036	0.02	0.0119	0.0100	0.006	0.002	0.007	46	0.05
Total Uranium (U)	ug/L	0.80	0.68	0.56	0.56	0.44	0.30	0.10	46	15
Total Zinc (Zn)	ug/L	192	91	45	36	11.9	4.0	38.5	46	31.9

No difference between the background station W10 and W32. Aluminum concentration exceeds the screening value at three

There is one exceedance of the standard that occurred more than 2 years ago.

No difference between the background station W10 and W32. Iron concentration exceeds the screening value at three

No difference between the background station W10 and W32 for Nickel.

The Nickel concentration exceeds the screening value at one sampling event.

3.4 Exposure Pathway(s) Description

Exposure pathways represent the routes through which species may become exposed to COPCs in the environment. For freshwater fish in river systems such as the Tulsequah River, the two principal means of exposure are from direct surface water contact and dietary uptake. A third, but considerably less relevant pathway for all but demersal fish, is direct contact or incidental ingestion of sediment.

Given that benthic invertebrates and sediment was evaluated as not being a source for uptake (see Section 2.2), this risk assessment focused on water quality and hence was the only direct contact pathway evaluated quantitatively through the estimation of hazard quotients (HQs).

4 EXPOSURE ASSESSMENT

The methods used to characterize the exposure of ecological receptors to COPCs are often dependent upon the type of receptor being evaluated and the exposure pathway of interest. Given that the focus of this risk assessment was on fish in surface water, exposures to COPCs were characterized using two methods:

1. COPC concentrations in surface water; and
2. COPC concentrations in fish tissues.

4.1 Direct Contact with Surface Water

Fish are potentially exposed to COPCs (i.e., cadmium, copper, lead, and zinc) in surface water via direct contact. Because concentrations of COPCs in surface water can vary significantly over time and location (sampling station), exposure is best characterized as a distribution of values at each location of concern. In this risk assessment each surface water sample result represents an estimated environmental concentration (EEC) from which a hazard quotient was calculated.

4.1.1 Receptor Exposure when the IWTP was Operational and was Not Operational

The risk assessment of effluent releases from the Tulsequah Chief Mine site on key fish receptor species considers two scenarios:

1. An operational IWTP (i.e., April 2012 to June 2012); and
2. A non-operational IWTP (i.e., August 2012 to July 2013)

Summary statistics for dissolved and total concentrations for each COPC at surface water sampling stations W46, W51, and W32, during the IWTP operational condition and during the IWTP not operational condition are presented in Table 7 to Table 12. The results for station W10 were considered representative of background conditions for the mine's effects on the Tulsequah River because it is located upstream of mine discharge to the river. Therefore, for comparative purposes the summary statistics for sampling results at station W10 have also been provided (Table 6).

4.1.1 Exposure to Receptors Based on Seasonality

The seasonality of the COPC surface water concentrations was also considered given fish biology (life cycle) and their habitat preferences. The seasonality of surface water COPC concentrations at stations W10, W51 and W10 was presented in Section 3.3.4. Exposure to receptors considered the approximate timing of receptor presence (by life-stage) in the Tulsequah River (data presented in Section 3.2).

4.1.1 Main Stem versus Side Channel Surface Water Concentrations

The receptors of concern are known to prefer certain habitat types and conditions over others. In 2007, Gartner Lee conducted a "Pre-EEM" program prior to the IWTP going into operation (Gartner Lee, 2008). This program included water quality monitoring in both the mainstem and clear water side channel environments. These stations are illustrated in Figure 2. Stations W10, W31, W46 and W32 are located in the mainstem channel and stations W42, W43, W45 and W44 are located in clear water side channels. Table 13 provides a summary of the Gartner Lee (2008a) results and compares selected mainstem and clear water side channel water quality parameters to guideline criteria.

In most cases, clear water side channels are isolated from mainstem surface flows and remain wetted through tributary or upwelling (sub-surface flow) sources. As such, clear water side channels are also removed to a large extent, from the influences of effluent released at the mine site as shown in Table 13. As determined in previous studies, clear water side channels provide preferred receptor species habitats compared to the mainstem channel (Rescan 1997; Section 3.1.2.5). Therefore, the effects of mine discharge on clear water side channel water quality and receptor fish and fish habitat will be comparatively lower than that of the mainstem.

Table 13. Comparison of Water Quality in Tulsequah River Mainstem and Clear Water Side Channels

Parameter	CCME Guidelines	Range in Mainstem Background Concentration	Range in Clear Water Side Channels
Hardness	-	23 – 33 mg/L	29 – 57 mg/L
Conductivity	-	54.0 – 78.2 µS/cm	68.4 – 132 µS/cm
pH	6.5-9.0	7.65 – 7.81	7.64 – 7.90
TSS	-	49 – 111 mg/L	<3 – 40 mg/L
Turbidity	-	44 – 145 NTU	0.48 – 44 NTU
Total Aluminum	0.005-0.1[1]	0.89 – 2.9 mg/L	0.01 – 0.51 mg/L
Total Cadmium	0.000017[1]	<0.000070 – 0.000070 mg/L	0.000021 – 0.000026 mg/L
Total Chromium	0.001	0.0014 – 0.0046 mg/L	<0.0010 – 0.0011 mg/L
Total Copper	0.002-0.004[1]	0.0047 – 0.0076 mg/L	<0.0010 – 0.0033 mg/L
Total Iron	0.30	0.94 – 2.95 mg/L	<0.03 – 0.69 mg/L
Total Lead	0.0010-0.0070[1]	0.0015 – 0.0028 mg/L	<0.0005 – 0.0007 mg/L
Total Zinc	0.03	0.009 – 0.0160 mg/L	<0.0050 mg/L

[1.] *Hardness dependent*

4.1.1 COPC Zone of influence

The COPC zone influence extends to the point where HQs for all receptors is less than 1 as a result of surface water exposures. Station W32 is located the farthest downstream from the site. If the HQ for receptors for any chemical was greater than 1 at station W32 then the zone of influence of the mine site was assumed to extend further downstream beyond W32. The additional dilution to COPCs that occurs when the Tulsequah River joins the Taku can be estimated by using the stream flow data from two Water Survey Canada (WSC) gauges on the Taku River, WSC gauge (Station 08BB001; Figure 14) located just upstream of the Tulsequah River confluence and WSC gauge (Station 08BB005; Figure 15) located downstream of the Tulsequah River confluence near the Canada US Border, and the basin area for Tulsequah River at the confluence with the Taku and the basin area for the two WSC gauge stations.

Table 14. Basin area, annual runoff and flows in the Taku and Tulsequah rivers

Station	Basin Area (km^2)	Normal Annual Runoff (mm)	June-Sept 7Q10 (m^3/s)	Annual 7Q10 (m^3/s)
Taku R. just upstream from Tulsequah R. confluence with the Taku	15351	568	127.3	20.8
Taku R. downstream from Tulsequah R. confluence near the Canada US border.	16842	740	246.1	27.8

7Q10 – the seven day low flow on a 10 year recurrence interval

Between WSC gauge (Station 08BB001) and WSC gauge (Station 08BB005) there is an increase in drainage area of 1491 km^2. There is also a corresponding 25% increase of stream flow (i.e., as calculated using the 7-day low flow, 10 year occurrence interval; [7Q10]) between the two stations. The runoff relationship changes at different times of the year. The June-September stream flow (using 7Q10) is much higher (almost double) for the downstream station on the Taku, reflecting the relatively higher glacial melt influence on the Taku summer stream flow.

If we assume that half of the increase in the flow of the Taku at the Canada-US border is related to the Tulsequah River drainage, then the flow from the Tulsequah River can be estimated by dividing the difference in flow at the WSC gauge (Station 08BB001) and WSC gauge (Station 08BB005) by 2. If we use annual flow rates then the 7Q10 flow coming from the Tulsequah River would be approximately 3.5 m^3/s.

Using the annual flow data the following dilutions were estimated:

- 20.8 m^3/s / 3.5 m^3/s = 6 at the confluence of the Taku and Tulsequah Rivers

- 27.8 m^3/s / 3.5 m^3/s = 8 at the Canada-US border on the Taku River

During the high flow period of the year (June to September) the dilution is lower:

- 127.3 m^3/s / 59.4 m^3/s = 2 at the confluence of the Taku and Tulsequah River
- 246.1 m^3/s / 59.4 m^3/s = 4 at the Canada US border on the Taku.

Figure 14. Daily Discharge for Taku River Near Tulsequah

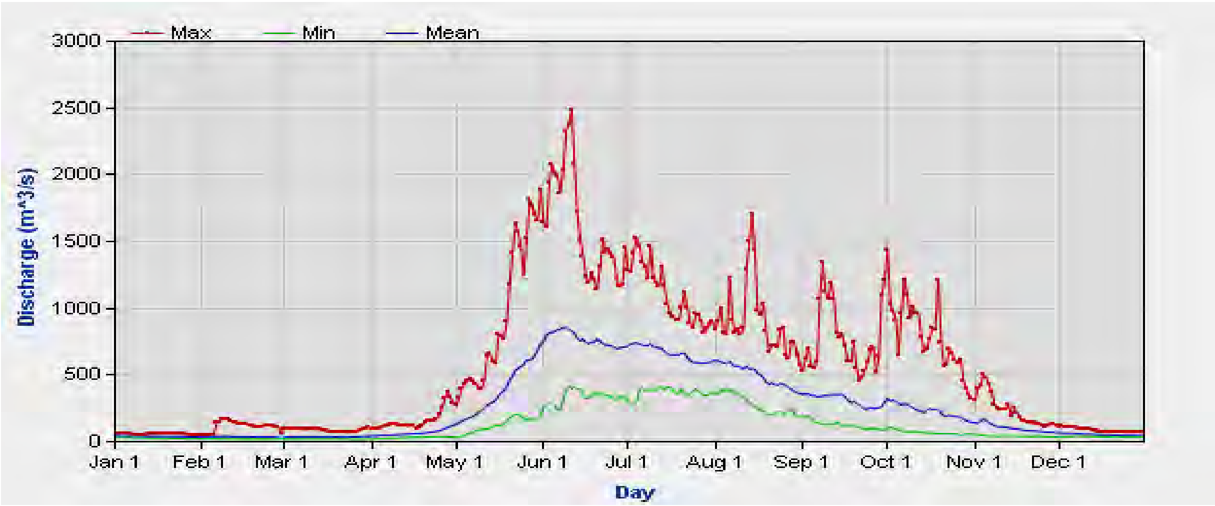
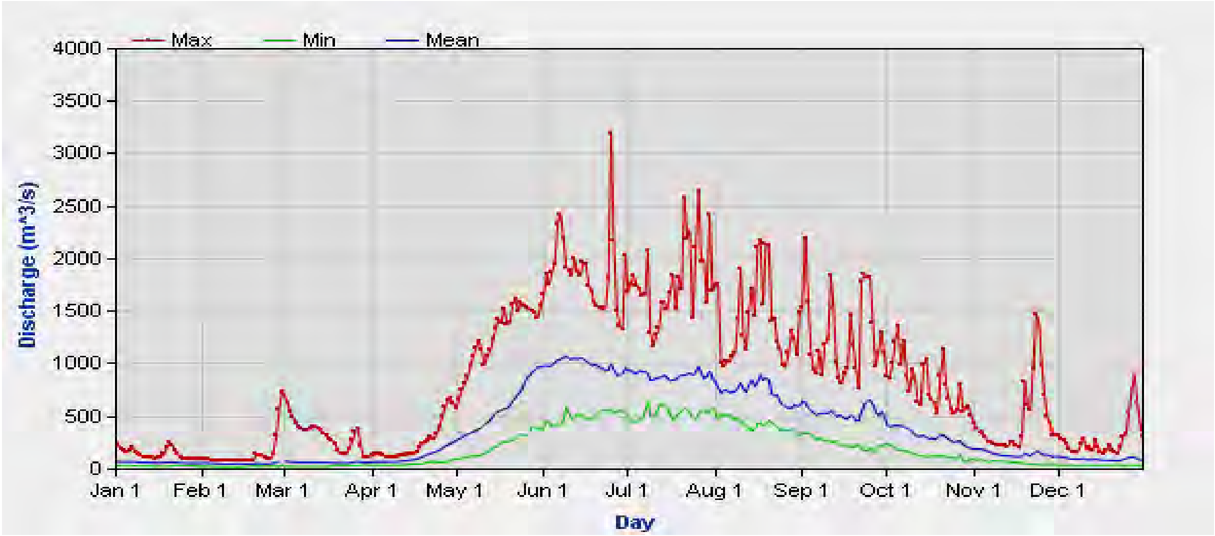


Figure 15. Daily Discharge for Taku River Near Juneau



4.2 Tissue Residue Assessment

Concerns about acid rock drainage (ARD) resulting in cadmium, copper, lead, and zinc leaching from the Tulsequah Chief mine into the Tulsequah River led the Alaska Government to conduct a study of the ARD into the Tulsequah and Taku Rivers and its effects on salmon and salmon habitat. Joseph Hitselbuger (2012) was commissioned to complete heavy metals tissue residue investigation of resident fish in the Tulsequah and Taku Rivers.

The study involved the capture of 41 resident juvenile Dolly Varden char from two sites on the Tulsequah River, upstream of the acid rock discharge site (Upper Tulsequah) and below the acid rock discharge site (below the Tulsequah Mine), and from the Taku River near the US-Canada border (Taku Border). The resident juvenile Dolly Varden char whole body metals concentrations of arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), selenium (Se), silver (Ag), and zinc (Zn) were assessed. The analytical results derived from this investigation were compared to results from above and below the Hecla Greens Creek Mine.

Table 15. Juvenile Dolly Varden Tissue Residue Mean Concentrations for COPCs

COPCs	Units	Sample Sites		
		Upper Tulsequah	Tulsequah Chief Mine	Taku Border
Cadmium	mg/Kg	0.2	0.17	0.23
Copper	mg/Kg	3.65	4.21	3.95
Lead	mg/Kg	0.18	0.11	0.13
Zinc	mg/Kg	150	137	124

The study demonstrates that metal concentrations in the tissue of Dolly Varden char collected in the receiving environment of the Tulsequah mine acidic discharge were lower than 10 year resident juvenile Dolly Varden char whole body metals concentrations dataset for all the metals tested from the Hecla Greens Creek Mine area. As shown in Table 15, fish collected from the Upper Tulsequah site had the highest average concentrations of Zn, Pb and Hg. Fish collected from the Taku Border site had the highest average concentration of Cd. While mean concentrations of As, Se and Cu were highest in fish from below the Tulsequah Mine site, they were lower than samples taken above and below the Greens Creek Mine operations. Statistical analysis of the sample means did not find any statistical significance among the metals tested.

5 EFFECTS ASSESSMENT

The effects assessment provides toxicity profiles for identified COPCs and TRVs for COPCs being carried forward for risk estimation. Although many of these COPCs were not measured in the river at concentrations in excess of screening values, it is likely that they exceed the screening levels in the river at the point of discharge.

5.1 Toxicity Profiles

As referenced above, the preliminary COPCs identified for consideration in the risk assessment included:

- Dissolved sulphate
- Total aluminum
- Total arsenic
- Total cadmium
- Total cobalt
- Total copper
- Total iron
- Total lead
- Total nickel
- Total silver
- Total uranium
- Total zinc

The toxicity profiles refer to bioaccumulation, bioconcentration, and biomagnification as defined below (USEPA, 2012):

Bioaccumulation: an overarching term used to describe the process of chemical uptake by plants or animals either through environmental or dietary exposures.

Bioconcentration: Refers to the situation whereby plants or animals are known to concentrate given chemicals at concentrations greater than their surrounding environment. This is very common in the case of essential nutrients where the plant or animal may regulate their internal stores of given chemicals to optimize their health.

Biomagnification: Refers to the situation in which chemical concentrations in plants or animals increase as a result of transfer through the food web (e.g., predatory species have greater concentrations than their prey), which can increase the potential for adverse effects.

Summary profiles of the toxicity for each of the COPCs specific to receptor fish species are presented in the following subsections:

5.1.1 Sulphate

Sulphate is a salt of sulphuric acid (BCMOE, 2013). In surface water, the primary form of sulphate is divalent anion (SO^{-4}). In aqueous solution, sulphate exists primarily as in salt form with variable water solubility (BCMOE, 2013).

Key environmental factors affecting the form, bioavailability and toxicity of sulphate include pH, hardness, oxidation-reduction potential, and availability of ligands (BCMOE, 2013).

Exposure of fish to sulphate has been shown to elicit the following toxic effects: inhibited growth, impaired reproduction, abnormal development, and lethality (BCMOE, 2013). Early life stages appear to be highly sensitive, particularly embryos and larva (BCMOE, 2013).

Sulphur is an essential element in fish, thus sulphur-bearing chemicals such as sulphate are closely regulated (BCMOE, 2013).

5.1.2 Aluminum

Aluminum is a silver-white, ductile and malleable metal (WHO, 1997). The chemistry of aluminum in surface water is complicated. In aqueous solutions, aluminum does not exist as a simple cation (Al^{3+}), rather it exists as a monomeric (inorganic) hydrated complex ion ($Al(H_2O)_6{}^{3+}$) (BCMOE, 1998). These monomeric species undergo successive hydrolysis reactions, which are highly pH dependent, resulting in a variety of hydroxyl aluminum species and polymeric (inorganic) complex ions (BCMOE, 1998). Aluminum also forms strong bonds with inorganic and organic ligands. The most important of these ligands are fluoride, sulphate and phosphate ions, organic acids, polyphenols, sugars, and suspended solids (BCMOE, 1998). Inorganic forms of aluminum tend to be more toxic than organic forms (BCMOE, 1998). Therefore, the species, concentration and toxicity of aluminum in surface water depend on the pH and types of complexing ligands present (BCMOE, 1998).

Acute toxicity of aluminum in fish can result in lethality, but is not well understood. In below-neutral pH conditions, gill flaring and hyperventilation are an early response to aluminum-induced mucus from damaged gill surfaces (BCMOE, 1998). Other symptoms of acute toxicity from aluminum include skin and gill hyperplasia, and kidney and liver damage. The symptoms are similar in above-neutral pH conditions, except that no aluminum-induced mucus accumulations have been observed (BCMOE, 1998).

Chronic toxicity of aluminum in fish can result in impaired growth and lethality. The sensitive life stage varies amongst fish species; however, the fry stage is generally very sensitive. Chronic toxicity of aluminum in fish has been attributed to osmoregulation failure resulting from aluminum replacing calcium in the gill membranes (BCMOE, 1998; WHO, 1997).

Although aluminum can bioconcentrate in fish gill tissues; however, it is not known to biomagnify in the food chain (BCMOE, 1998).

5.1.3 Arsenic

Arsenic is a silver-gray brittle metalloid (exhibiting both metallic and non-metallic properties) (Eisler 1988, WHO 2001a). In surface water, the two primary forms of arsenic are trivalent (arsenite, As^{+3}) and pentavalent (arsenate, As^{+5}) arsenic. However, the pentavalent form is typically more prevalent given that it is thermodynamically more stable in oxygenated environments (WHO 2001a). The trivalent form on the other hand, tends to be more toxic (WHO 2001a).

Acute exposure effects in fish can result in lethality resulting from increased mucous production causing suffocation or direct adverse effects on the gill epithelium (WHO 2001). Chronic exposures by fish can result in accumulation of the metalloid to toxic levels with the liver playing a key detoxification role. As a result fish livers are particularly susceptible to chronic arsenic exposures. Morphological alternations and early neoplastic liver alterations have also been reported in fish (WHO 2001). Although arsenic can bioconcentrate in fish tissue, typically it is not known to biomagnify in the food-chain and the form concentrated in tissues is most commonly of the less toxic organic form (NAS 1977). The bioaccumulation factor (BAF) for arsenic in salmon is 5.79 (USEPA 2003).

5.1.4 Cadmium

Cadmium is a soft, bluish-white metal (WHO, 1992). In surface water, cadmium is predominantly found as a salt in its divalent oxidation state (Cd^{+2}). Cadmium salts can be highly soluble in water. Cadmium may also be present as hydrated ions or as complexes with inorganic or organic ligands. The fate and bioavailability of cadmium are influenced by pH, hardness, redox potential, and the presence of ligands (CCME, 1999a).

Cadmium exerts acute and chronic toxicity, including lethality, at very low concentrations in fish. The primary target organ for acute and chronic toxicity appears to be the kidneys, where tissue damage can result in kidney failure (Kumar and Singh, 2010). Other target organs include the gills, liver, intestine, and gonads. Salmonids have been shown to be highly sensitive to cadmium toxicity. The most susceptible life-stages are the embryo and early larva (CCME, 1999a).

Although cadmium bioconcentrates in fish tissue, biomagnification seems to be negligible in fish (CCME, 1999a). There is conflicting evidence as to whether cadmium biomagnifies in aquatic food chains (CCME, 1999a).

5.1.5 Cobalt

Cobalt is a hard silvery-grey metal (BCMOE, 2004). In surface water, the primary forms of cobalt are divalent (Co+2) and divalent (Co+3) cobalt. In solution, cobalt exists predominantly as divalent cobalt (Co+2) because it is the most thermodynamically stable under the redox and pH conditions that occur in natural waters (BCMOE, 2004). Cobalt commonly forms salts with variable water solubility (BCMOE, 2004).

Key environmental factors affecting the form, bioavailability and toxicity of cobalt include pH, suspended solids, and the presence of ligands (BCMOE, 2004).

Cobalt exposure can result in a variety of toxic effects, including lethality, impaired reproduction, and impaired development (BCMOE, 2004). Salmonid larvae appear to be highly sensitive to cobalt toxicity (BCMOE, 2004).

As an essential micronutrient, fish bioconcentrate cobalt, where bioconcentration factors (BCF) range from 10 to 10,000 in freshwater fish (BCMOE, 2004). Fish can regulate cobalt within their system and therefore it does not bioaccumulate to levels that are harmful (OECD, 2011).

5.1.6 Copper

Copper is a reddish-brown, ductile and malleable metal (WHO, 1998). In surface water, the primary form of copper is divalent (Cu^{+2}) copper. In solution, copper may exist as hydrated free cupric ion (Cu^{+2}), as complexed cupric ion, or as complexed cupric compounds (BCMOE, 1987a). Copper may also adsorb to suspended particulates.

Key environmental factors affecting the form, bioavailability and toxicity of copper include pH, hardness, alkalinity, and the presence of ligands (BCMOE, 1987a).

Copper exposure can result in a variety of toxic effects, including lethality, impaired reproduction, inhibited growth, and osmoregulation imbalance (BCMOE, 1987a; WHO, 1998). Salmonid fry appear to be highly sensitive to copper toxicity (BCMOE, 1987a).

As an essential nutrient, fish bioconcentrate copper, where copper BCFs vary from 40 to 2900 in freshwater fish (BCMOE, 1987a). While fish may bioconcentrate copper, they do regulate it and copper is not known to biomagnify in food chains (US EPA, 2013).

5.1.7 Iron

Iron is a lustrous grey metal (HSBD, 2013). In surface water, the primary forms of iron are divalent (ferrous, Fe^{+2}) and trivalent (ferric, Fe^{+3}) iron. Ferric iron is almost insoluble in water whereas, ferrous iron is soluble in water and readily bioavailable (BCMOE, 2008).

Key environmental factors affecting the form, bioavailability and toxicity of iron include pH, oxidation-reduction potential, hardness, dissolved oxygen, dissolved and total organic carbon (DOC/TOC) ratio, colour, humic and other organic acids, exposure to sunlight and chloride concentration (BCMOE, 2008).

Exposure to iron has been shown to elicit a variety of effects, including lethality, in fish (BCMOE, 2008). A possible mechanism of action for dissolved iron may be the disruption of sodium balance (BCMOE, 2008). Another possible mechanism of action is suffocation resulting from the precipitation of ferric hydroxide ($Fe(OH)_3$) directly onto the gills (or eggs) of fish (BCMOE, 2008).

As an essential nutrient, fish bioconcentrate iron and incorporate it in their tissues (BCMOE, 2008). Within fish and other vertebrates, iron is regulated and can be rapidly eliminated (BCMOE, 2008).

5.1.8 Lead

Lead is a soft, silvery grey metal (WHO, 1995). In surface water, the primary form of lead is divalent (Pb^{+2}). In aqueous solution, lead exists in the form of inorganic and organic salts with variable water solubility (WHO, 1995). Organolead compounds are generally more toxic than inorganic lead (BCMOE, 1987b; WHO, 1995).

Key environmental factors affecting the form, bioavailability and toxicity of lead include pH, hardness, oxidation-reduction potential, temperature, and availability of ligands (BCMOE, 1987b).

Fish exposure to lead may result in a variety of toxic effects, including lethality, growth inhibition, and larval spine deformities (BCMOE, 1987b). The mechanism of action is not well understood though it may interfere with calcium regulation. The larval and juvenile life stages appear to be more susceptible to lead toxicity than eggs and adult life stages (BCMOE, 1987b).

Inorganic lead uptake by fish is very slow and may take weeks to reach equilibrium; whereas, organolead is rapidly absorbed and eliminated by fish (WHO, 1995).

5.1.9 Nickel

Nickel is a silvery white metal with typical metallic properties (CEPA, 1994b; WHO, 1991b). In surface water, the primary form of nickel is divalent (Ni^{+2}) nickel (CEPA, 1994b). In aqueous solution, nickel exists primarily as a salt with inorganic or organic ligands with variable water solubility (CEPA, 1994b).

Key environmental factors affecting the form, bioavailability and toxicity of nickel include pH, hardness, oxidation-reduction potential, ionic strength, and availability of ligands (CEPA, 1994b).

Sensitivity to nickel varies among fish species (WHO, 1991b). Toxic effects resulting from nickel exposure include lethality, gill membrane damage, depletion of energy stores (stress), decreased hatchability of eggs, and abnormal development of larva (CEPA, 1994b; WHO, 1991b).

Fish have been shown to bioconcentrate nickel (BCFs ranging from 1.9 to 4.2); however, fish and higher trophic level organisms appear to regulate nickel, thus biomagnification is not likely to occur in aquatic food chains (CEPA, 1994b; WHO, 1991b).

5.1.10 Silver

Silver is a lustrous white metal (HSBD, 2013). In surface water, the primary form of silver is monovalent (Ag+1) silver. In aqueous solution, silver exists primarily as a salt with inorganic or organic ligands with variable water solubility (BCMOE, 1996). Ionic silver tends to be more toxic than silver compounds (BCMOE, 1996).

Key environmental factors affecting the form, bioavailability and toxicity of silver may include pH, hardness, oxidation-reduction potential, and availability of ligands (BCMOE, 1996).

The primary toxic effects in fish resulting from exposure to silver include lethality (BCMOE, 1996). Embryos of fish are generally more sensitive than juvenile and adult fish (BCMOE, 1996). Silver binds with enzymes and other molecules on the surface of cells resulting in membrane disruption, enzyme inhibition and disabling of proteins (BCMOE, 1996).

Studies have shown that fish bioconcentrate (mainly in their gills), but do not biomagnify silver (BCMOE, 1996). Vertebrate animals are capable of regulating and rapidly eliminating silver, thus biomagnification in aquatic food chains is not likely to occur (BCMOE, 1996).

5.1.11 Uranium

Uranium is a silvery-white, lustrous, radioactive metal (HSDB 2013). In surface water, the primary forms of uranium are quadrivalent (V^{+4}), pentavalent (V^{+5}) and hexavalent (V^{+6}) uranium. Hexavalent uranium is the most common in surface water, since it is the most stable form in oxygenated aqueous solutions (CCME, 2011). In aqueous solution, uranium exists primarily as the uranyl ion (UO_2^{+2}), as opposed the simple uranium ion (U^{+6}) (CCME, 2011). The uranyl ion is considered to be the most toxic species of uranium to aquatic organisms (CCME, 2011). Uranium commonly forms salts with inorganic and organic ligands (CCME, 2011).

Key environmental factors affecting the form, bioavailability and toxicity of uranium include pH, temperature, hardness, and availability of ligands (CCME, 2011).

Uranium is both chemically toxic and radiotoxic; however, the radiotoxicity is considered to be minimal due to its low penetrating power and being a weak emitter (CCME, 2011). Therefore, environmental guidelines for the protection of aquatic life have focused on the chemical toxicity of uranium. Toxicological studies investigating uranium exposure to fish have focused on lethality and growth effects (CCME, 2011). Salmonids and early life stages are particularly susceptible to uranium toxicity (CCME, 2011).

Uranium can bioaccumulate in aquatic organisms; however, the uptake rate is low, thus it is not considered likely to biomagnify in food chains (CCME, 2011). It has been shown that lower trophic level organisms have higher concentrations of uranium than higher trophic level organisms (CCME, 2011).

5.1.12 Zinc

Zinc metal does not occur in the natural environment (WHO, 2001b). In surface water, the primary form of zinc is divalent (Zn^{+2}) zinc (WHO, 2001b). In aqueous solution, zinc exists primarily as a salt or in ionic form. Zinc forms salts with inorganic and organic ligands (WHO, 2001b). Only dissolved zinc appears to be bioavailable and toxic (WHO, 2001b).

Key environmental factors affecting the form, bioavailability and toxicity of zinc include pH, temperature, hardness, dissolved organic carbon, competing ions, and availability of ligands (WHO, 2001b).

Toxic effects of zinc in fish include lethality, growth inhibition, impaired hatchability, developmental deformities, and reduced feeding behaviour (WHO, 2001b).

As an essential nutrient, fish bioconcentrate zinc and incorporate it in their tissues (WHO, 2001b). Within fish, zinc is regulated and can be rapidly eliminated. Zinc is not known to biomagnify in food chains (WHO, 2001b).

5.2 Toxicity Reference Values

Toxicity reference values (TRVs) for fish exposures to cadmium, copper, lead and zinc in surface water are identified in this section. As the focus of this risk assessment is on salmonid receptors, TRVs for salmon species were preferentially selected over TRVs for other species. Note that the TRVs used in this risk assessment have been selected to represent the most sensitive life-stage of receptor salmonids and thus are more likely to overestimate the risk to fish exposed to mine discharge.

The effects of a chemical contaminant on an ecological receptor are characterized by an exposure-response curve. The shape and location of the exposure response curve generally depends on the chemical, the receptor, the toxicological response, the exposure route, and the exposure duration. Key points on an exposure response curve that are often used to characterize the effects of a chemical may include the no-observed adverse effect level (NOAEL) or concentration (NOEC), the lowest observed adverse effect level (LOAEL) or concentration (LOEC), or the exposure level that causes a response in some specified fraction of the test animals (e.g., LD50, LC50, EC20, etc). These key points on an exposure response curve are usually referred to as TRVs. A number of studies were identified for consideration and a subset of them are documented in Appendix D. The toxicity reference values (TRVs) selected for the salmonids were considered threshold concentrations or doses/intakes of the COPCs that can cause harm if exceeded. The TRVs considered for use in this risk assessment were based on chronic toxicity tests carried out under standardized conditions in the laboratory. For the purpose of this risk assessment, the following principles were applied in selection of TRVs from the literature:

- Endpoints involving growth, reproduction and survival were considered to be relevant to the persistence of aquatic populations.
- Only freshwater toxicity studies were considered.
- Studies not providing test duration, endpoint or exposure concentrations information were eliminated.
- Chronic EC20 concentrations were preferred. If not reported, other endpoints were considered and adjusted to an estimated EC20 value. For adjustment from chronic LC50 to chronic EC20, a factor was used based on an assumed linear chronic dose-response with zero response at EC0 and 50% response at the EC50 concentration.

Acute and chronic TRVs identified for use in this risk assessment are shown in Table 16 below.

Table 16. **Acute and Chronic TRVs and Acute to Chronic Ratio**

Chemical	TRV Chronic (ug/L)	TRV Acute (ug/L)	Acute to Chronic Ratio
Cadmium	1.3	1.3	1
Zinc	187	460	2.5
Lead	15	1170	78.0
Copper	13	19	1.5

The acute TRV divided by the chronic TRV for a given species or genus is the acute to chronic ratio (ACR). The acute to chronic ratio informs us how quickly changes in the exposure concentration for a chemical can result in changes in environmental effect. Small ACRs indicate that small changes in the EEC can result in large increases in environmental effect, whereas for large ACRs small increases in the EEC likely result in little or no increase in the environmental effect. It was found that the difference between the acute and the chronic TRV varied significantly. This is related to the slope of the dose response curve.

Cadmium, zinc, lead, and copper TRVs are dependent on water hardness. As such, TRVs were based on the average hardness (57 mg/L $CaCO_3$) measured over the sampling events at the four sampling stations. In addition to the intrinsic toxicity of the metal, metal toxicity to aquatic receptors is related to the bioavailable fraction of metals in the water column. The bioavailable fraction varies between the dissolved and total metals concentrations and in this assessment, exposure and risk estimates for receptor fish species were provided for both dissolved metals and total metals.

6 RISK CHARACTERIZATION

Potential risks to receptor fish species exposed to the COPCs in the surface waters of the Tulsequah River were evaluated through comparison of dissolved and total concentrations with each COPC and their respective chronic TRVs. As discussed in the problem formulation, COPCs were identified based on their concentration in the Site Exfiltration pond water (SE-2). COPCs from SE-2 discharges and at the point of discharge into the Tulsequah River, were expected to exceed screening levels. However, at the sampling stations in the Tulsequah River, several COPCs identified in SE-2 did not exceed screening values or background concentration. As such, those COPCs (aluminum, arsenic, cobalt, iron, nickel, silver, sulphate and uranium) were not quantified because of their low concentration in the Tulsequah River mainstem.

Four COPCs (cadmium, copper, lead and zinc) were measured in the Tulsequah River at concentrations in excess of their screening levels and background concentrations, and are carried forward in the risk assessment. The following section will characterize the risk to fish in the Tulsequah River associated with exposure to these metals.

6.1 Hazard Quotient Methodology

The risk evaluation for fish for exposure to the COPCs cadmium, copper lead, and zinc in surface water was based on the Hazard Quotient (HQ) approach.

Hazard quotients (HQs) are widely used in ecological risk assessments. The hazard quotient for each combination of contaminant and receptor (plant or animal) of concern is calculated by dividing the estimated environmental concentration (EEC) by a single point toxicity reference value (TRV). However, HQs measure hazard (as the name implies) rather than simply the classical definition of "risk" (Risk incorporates the likelihood of an adverse event occurring). In other words, HQs do not contain information about the probability that an adverse effect will occur) (SABCS 2008). Although this document uses the term risk when discussing HQs one should keep this in mind.

Example HQ Calculation

The average cadmium concentration at station W51 was 4.04 ug/L. The chronic TRV for cadmium in this risk assessment is 1.3 ug/L. Therefore the hazard quotient was calculated as

$$HQ = EEC / TRV$$

If the HQ is less than or equal to one (1), it is believed that no unacceptable risks will occur in the exposed aquatic population. If the value of HQ exceeds one, then unacceptable risks may occur, with the probability and/or severity of the adverse effect tending to increase as the value of HQ increases.

The HQ was calculated for dissolved and total metals for each COPC at each station for every sampling event while the IWTP was not operating (June 2012 through to July 2013) and for while the IWTP was operating (April 2012 through to June 2012). The HQs are graphed as box plots for the chronic or long-term exposure condition. Division of the chemical-specific chronic HQs by its acute to chronic ratio will provide an estimate of the acute HQ. The acute to chronic ratio is provided in the toxicity assessment section of this report (Section 5.2).

Note that some of the results in these graphs are plotted on a log-scale, so large differences between HQ values are somewhat compressed. Each graph provides a visual representation of the risks of chronic effects on growth or reproduction due to longer-term exposure. The box plots not only reflect the minimum, maximum, 25th percentile, 75th percentile, median and mean HQ at each station, but also the variability in HQ, and hence variability in risk.

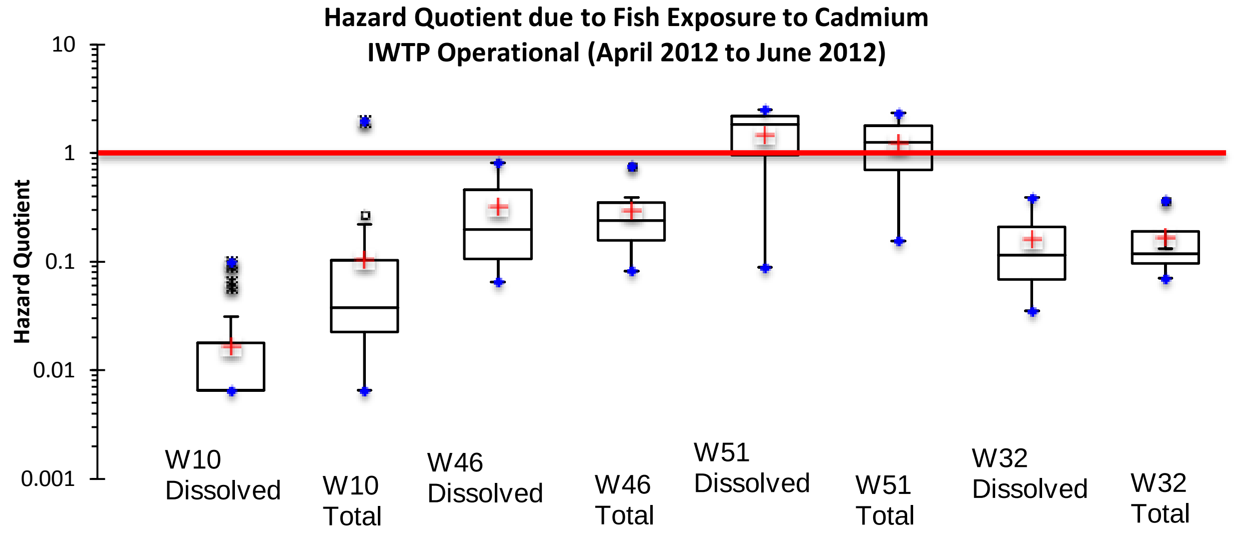
In the following box and whisker plots:

- the ends of the box are the upper (75th percentile) and lower (25th percentile) quartiles, so the box spans the interquartile range (IQR);
- the median is marked by a vertical line inside the box;
- the red plus sign in the box represent the mean concentration;
- the whiskers are the two lines outside the box that extend to the highest and lowest observations, unless there are outliers in which case the whiskers extend 1.5 IQRs beyond the upper and/ or lower end of the box;
- when the box is not centered between the whiskers, the sample may be positively (lower) or negatively (higher) skewed;
- the size of the box can provide an estimate of the kurtosis; a very thin box relative to the whiskers indicates that a very high number of cases are contained within a very small segment of the sample;
- open circles beyond the whiskers represent suspected outliers and they are 1.5 to 3 IQR beyond the interquartile range upper or lower edge;
- values more than 3 IQRs from the edges of the IQR are considered to be outliers and are represented by a stared circle;
- the blue starred circle represents the minimum and maximum value; and
- the red horizontal line represents an HQ of 1.

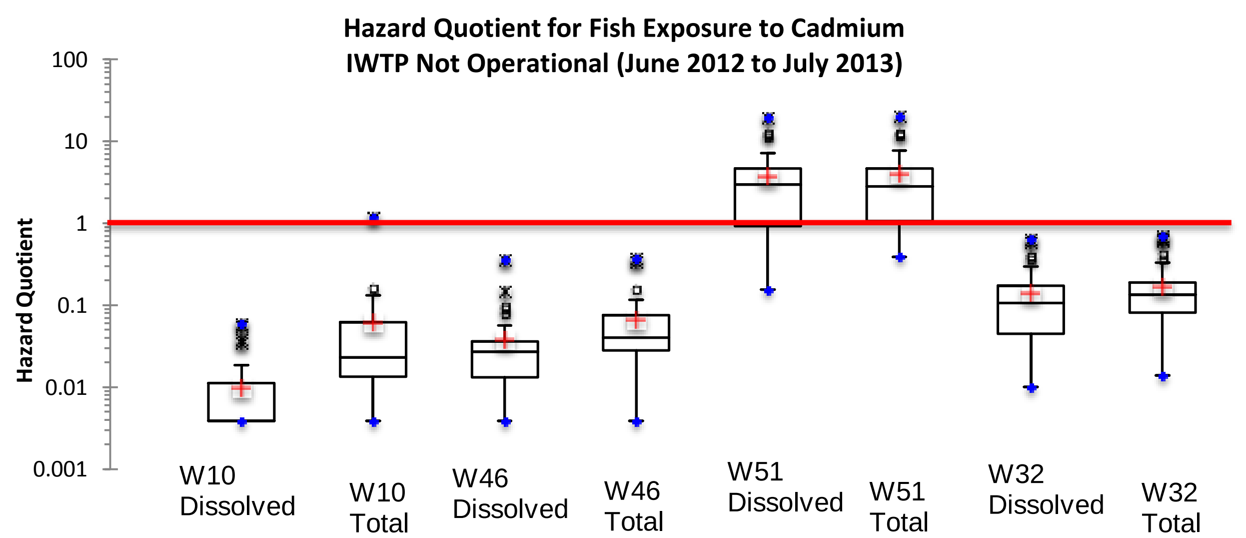
6.2 Hazard Quotient Estimates

HQ box plot graphs were generated for each of the four COPCs at stations W46, W51, and W32, for IWTP operational and non-operational scenarios. For comparative purposes, each graph also contains an HQ boxplot for the background station W32. HQs of greater than one (unity) represent risk levels that indicate a potential for unacceptable adverse effects to fish resulting from exposure to potentially affected surface water. The red line in the following boxplots represents the HQ = 1 threshold. Hazard quotient descriptive statistics are presented in Appendix E.

6.2.1 Cadmium HQs Boxplots – Surface Water Exposures to Fish

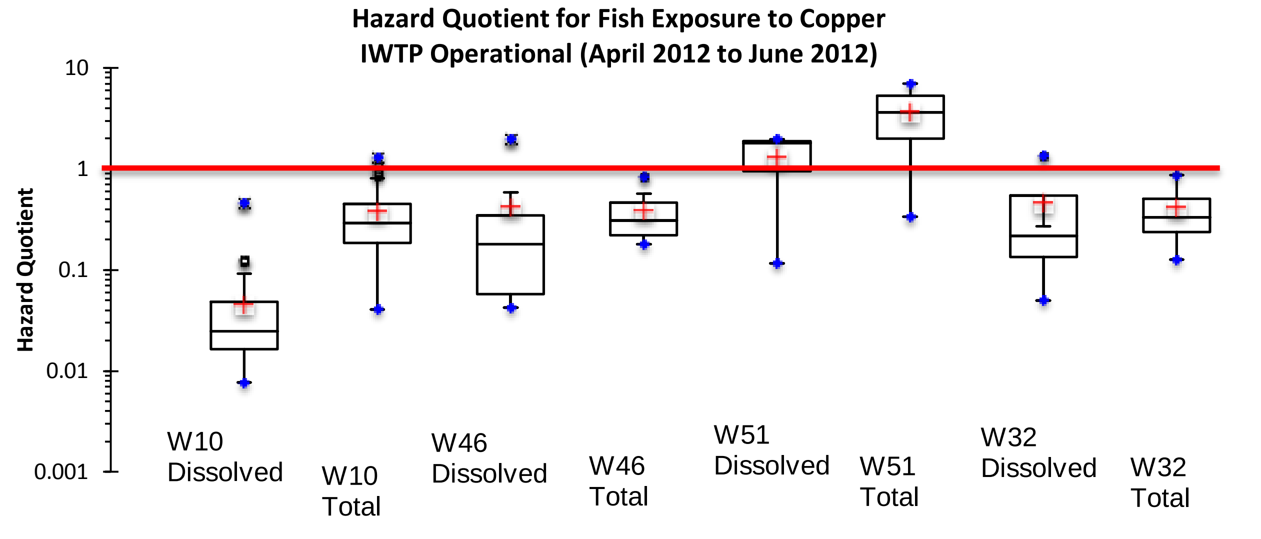


Plots indicate potential unacceptable hazard to fish in the Tulsequah River at station W51 even when the IWTP was operational. Total cadmium HQ also exceeded one (HQ>1) in one sample at sample station W10, suggesting that total cadmium may be naturally elevated in the Tulsequah River.

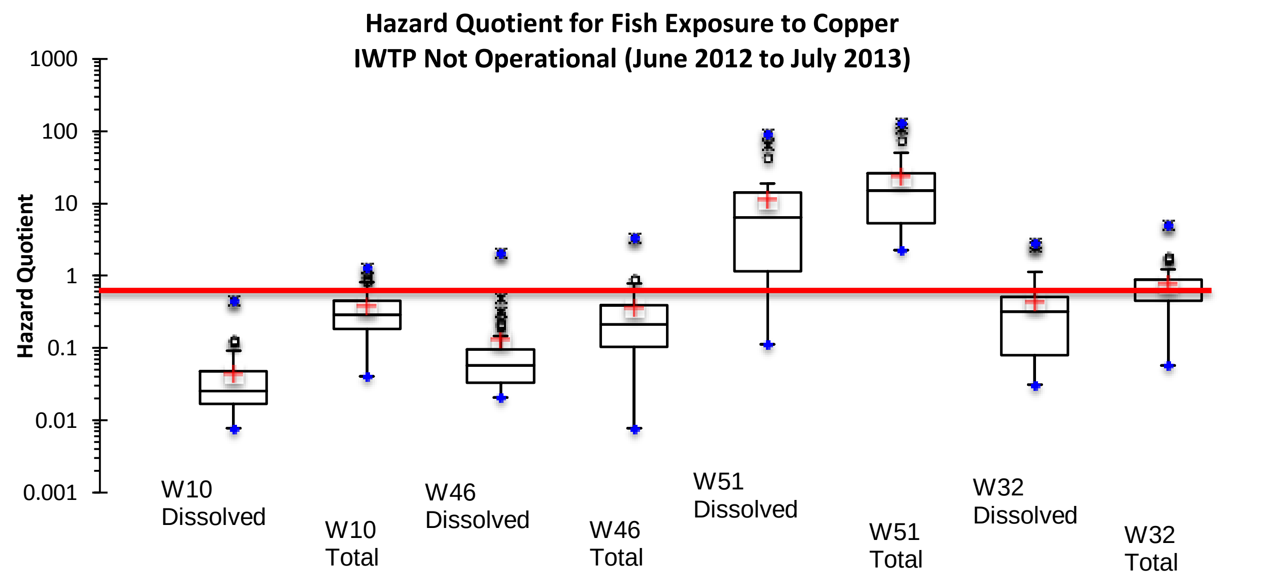


Plots indicate potential unacceptable risk to fish in the Tulsequah River at station W51 when the IWTP was not operational. The maximum HQ when the IWTP was not operational was approximately 8 times higher for cadmium than the maximum HQ when the IWTP was operational. The 75th percentile HQ was 2 to 3 times higher for cadmium when the IWTP was not operational.

6.2.1 Copper HQs Boxplots – Surface Water Exposures to Fish

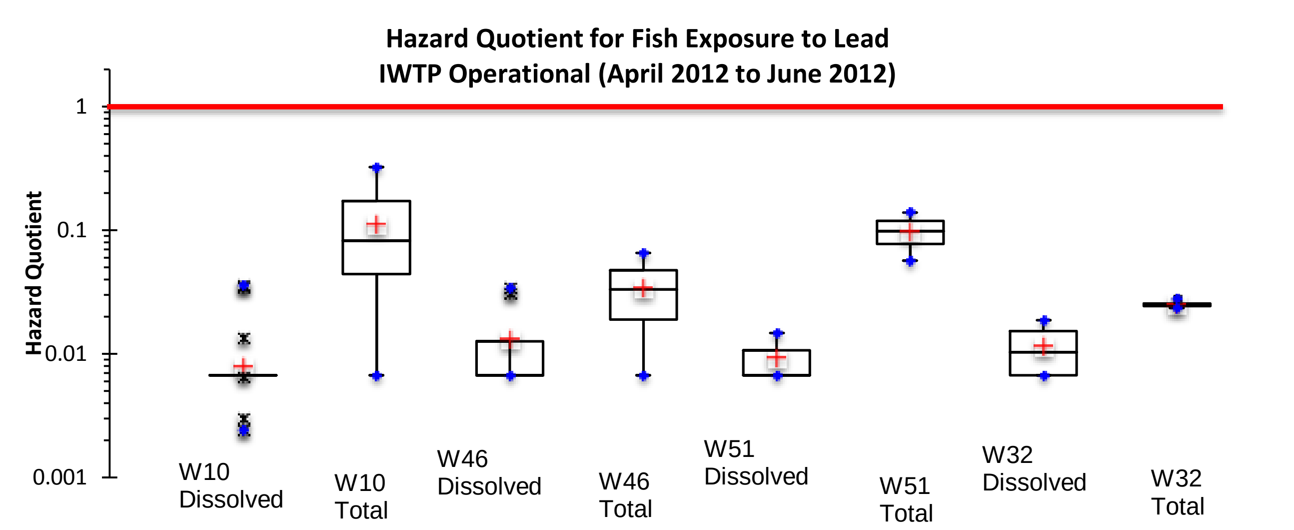


Copper HQs indicate potential unacceptable hazard to fish at station W51 when the IWTP was operational. Dissolved copper also marginally exceeded the HQ of 1 at sample station W46 and W32, however total copper HQs were less than one. Total copper exceeded the HQ of 1 in one sample at station W10 suggesting that copper may be naturally elevated in the Tulsequah River.

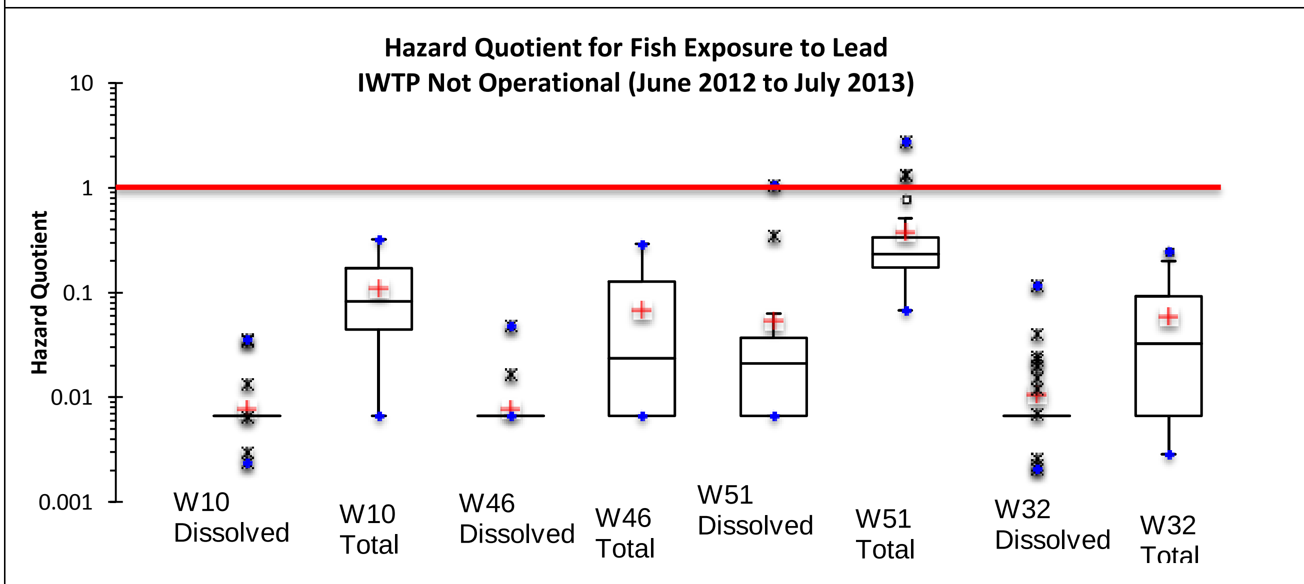


Dissolved and total copper HQs when the IWTP was not operational indicate potential unacceptable hazard to fish in the Tulsequah River at stations W5, and W32. Almost all fish HQs based on dissolved and total copper at site W51 were greater than 1. Two fish HQ for total copper at station W10 and W46 marginally exceeded the HQ of 1, indicating the copper levels are naturally elevated in the river. The selected TRV was equivalent to the P95 value for copper at W10.

6.2.2 Lead HQs Boxplots – Surface Water Exposures to Fish

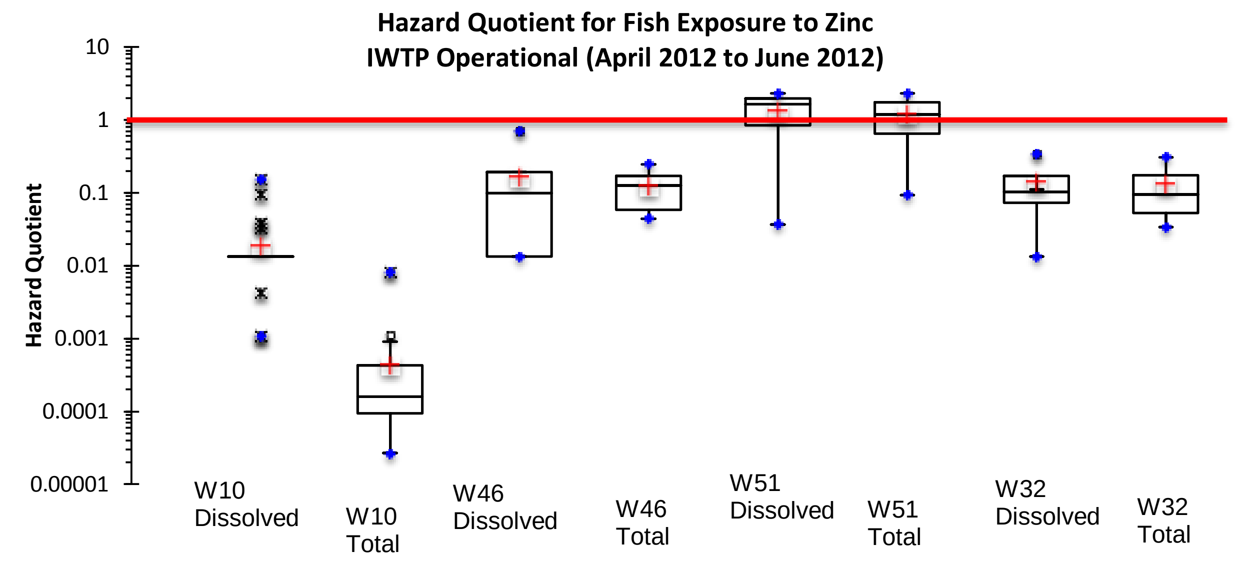


Dissolved and total lead HQs for surface water exposures to fish indicate negligible risk at stations W46, W51, and W46 when the IWTP was operational.

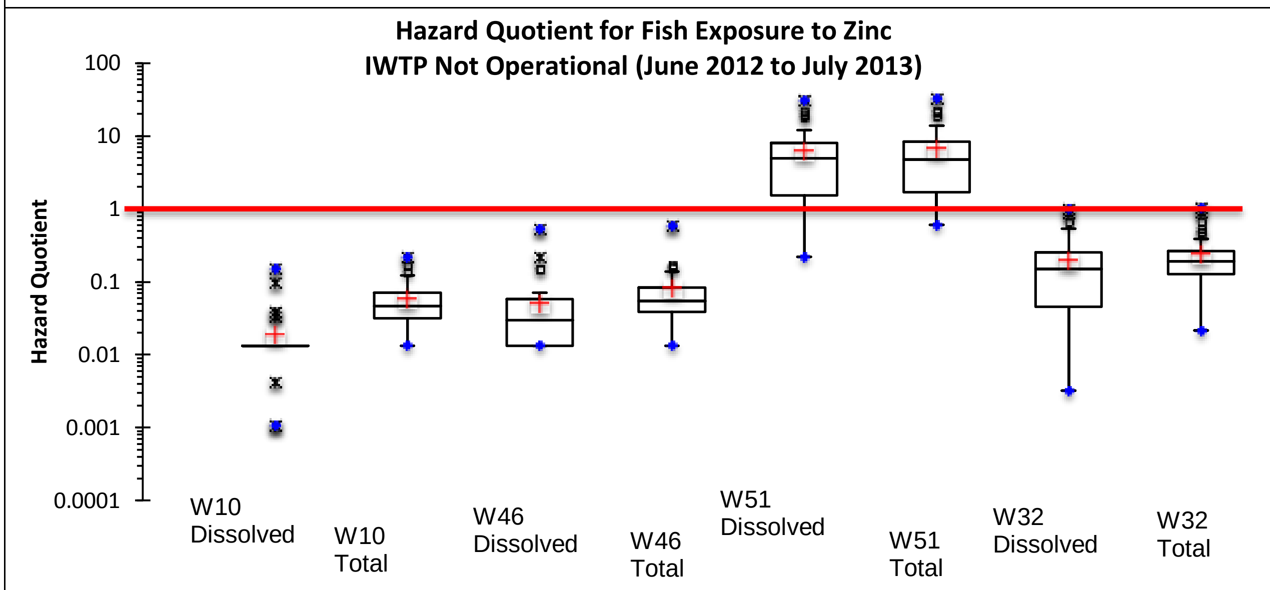


Dissolved and total lead HQs indicate occasional potential unacceptable hazard at station W51 when the IWTP was not operational. One fish HQ based on dissolved lead in surface water and two fish HQs based on total lead in surface exceeded the HQ of 1 at station W51. All other fish HQ for lead in water were less than one.

6.2.3 *Zinc HQs Boxplots – Surface Water Exposures to Fish*



Dissolved and total zinc HQs indicate potential unacceptable hazard at station W51 when the IWTP was operational. All other fish HQ for zinc in water were less than one.



Dissolved and total HQs for zinc indicate potential unacceptable risk at station W51 when the IWTP was not operational. Almost all fish HQs based on dissolved and total zinc at W51 were greater than 1. All other fish HQ for zinc in water were less than one.

6.3 Uncertainty Analysis

Risks to fish from COPCs in the Tulsequah River were evaluated for direct contact exposure pathways (surface water), but not for dietary uptake (see Section 2.2). This may lead to an underestimation of risk. While the magnitude of this underestimation is not known, it is not considered to be substantial as it is likely that the direct contact pathway (see Section 2.2) is more important than the ingestion pathway and that the magnitude of the error is relatively small. Furthermore there is a high level of uncertainty associated with literature based bioaccumulation factors (BAF) and bioconcentration factors (BCF) for metals that would have been required for use if dietary exposure was assessed. The variability in the BAF and BCF can be 50 fold or higher with a given metal (USEPA 2007).

Analyzed samples of surface water may not fully characterize the spatial and temporal variability in actual levels of COPCs at the site. For example, short-term peaks (i.e. less than seven days in duration) in surface water concentrations might occur in the river during times of surface water runoff, or higher-than-average recharge from groundwater. If these peaks are not well represented in the set of surface water samples, risks of acute toxicity may be higher (either more severe and/or more frequent) than estimated. Conversely, some water samples were collected from sites suspected of increased (maximum) contamination (e.g. station W51, which becomes isolated from the Tulsequah River except for mostly hyporheic flow, leaving it inaccessible to fish for part of the year. Therefore, some of the data used to characterize risk may tend to be biased high even though the measured chemical results used in the risk assessment only reflects one year of in-stream sampling.

Discharge waters from portals 5200 and 5400 are the primary source of much of the metals contamination in the Tulsequah River. Multi-year chemical analyses of portal waters indicate consistent concentrations of dissolved and total metals over time (Figure 4 to Figure 11). Based on this, it is considered unlikely that the surface water chemistry used in the risk assessment significantly over- or under-estimates the actual concentrations over time. Overall, the uncertainty associated with measured surface water chemistry used in this risk assessment is considered low.

It is important to recognize that the toxicity of COPCs in surface water to aquatic receptors depends on the duration of exposure time, and that available TRVs are based on exposures of 48-96 hours (acute) or for 60-90 days or longer (chronic). Thus, concentration values used to calculate the HQ values would ideally reflect the average concentration over the time interval appropriate for the TRV. However, the available data on the concentration of metals in surface water samples are all "grab" samples that represent instantaneous measures of concentration. Hence, these values do not reflect either short-term or long-term variability in concentration over time. Thus, use of grab sample data to calculate accurate and chronic HQ values is a source of uncertainty, and might either underestimate or overestimate actual risks depending on the ability of the sample results to represent actual conditions. It should be noted that the sampling frequency (weekly for a year) was consistent with permit requirements, and that continuous monitoring of surface water COPC chemistry is outside the realm of current best practices, available technology and scope of this assessment. Moreover, it is possible that actual average concentrations of COPCs in surface water are lower than that estimated using the grab samples. As such, the uncertainty may represent a more conservative result. The term uncertainty does not imply direction.

7 DISCUSSION AND CONCLUSION

The Hazard Quotients (HQs) calculated for each chemical were compared by station. This is illustrated graphically in Section 6.2. The HQs were the highest at station W51, followed by W32. With a few exceptions the next highest HQs were at station W46 and the lowest HQs were at station W10 (the background/upstream station). The HQ results at stations W10 and W46 rarely exceeded 1 for any sampling event. When discussing the influence of the interim water treatment plant's (IWTP's) influence on HQ results, whether from an operational/non-operational or seasonal perspective, station W10 was not a factor as it represents background and is upstream of the mine's influence.

7.1 Receptor Exposure when the IWTP was Operational and was Not Operational

Hazard quotients for all chemicals were consistently highest at station W51, which appears to be the station most affected by discharge from the mine site. At this location the HQs for all COPCs were greater than one (HQ > 1) under both IWTP operational and non-operational conditions, with the exception of lead, which had an HQ consistently less than one under the IWTP operational period.

Of the downstream stations, HQs were generally lowest at station W32, 2.7 km downstream from the mine site. Under IWTP operational conditions, only copper and zinc had HQs for fish greater than or equal to 1 at station W32; the HQ results for all other COPCs was less than 1 at station W32.

At each station, HQs were considerably lower during IWTP operational conditions compared to when the IWTP was not operating. Based on the above, the operation of the IWTP clearly showed a positive influence on water quality at the stations monitored.

7.2 Seasonal Trend in Surface Water COPC Concentrations

Trends in COPCs concentrations at stations W51 and W32 appear to follow seasonal discharges and climatic conditions in the Tulsequah River watershed. When the Tulsequah River stream flow was high, COPC surface water concentrations were lower. When the stream flow was low COPC surface water concentrations were higher. Station W46 is located within the discharge zone of the IWTP; however, given that it only operated for 4 months it was not possible to discern seasonal trends relative to its operation. Once the IWTP was closed, the site water that was previously directed to the IWTP was re-directed to the Site Exfiltration pond. Water from the Site Exfiltration pond discharges closer to station W51 and therefore further discussion of COPC (and HQ) trends in the receiving environment are therefore in the context of stations W51 and W32.

The lowest HQs at station W51 and W32 occurred between mid-May to December, as shown in Figure 14. The period between January and early April had HQs that were on average, three to four times higher than during the high flow period. These winter months represent the period of lowest flows in the Tulsequah River and therefore the least amount of dilution

The highest HQs at stations W51 and W32 occurred during late April and early May for all COPCs. This is the result of snow melt and precipitation at this time of year and the subsequent annual flush of the historic waste dumps into the river. As water from the historic waste dumps is not directed to the IWTP, this peak in COPC surface water concentrations and subsequent peak in HQs occurred whether or not the IWTP was operational. When the IWTP was operational the HQs were 2 to 4 times lower during the 2012 snow melt period. This is illustrated in Table 17 below which presents HQs at station W32 for cadmium, copper, and zinc during the 2012 snow melt when the IWTP was operational and during the 2013 snow melt when the IWTP was not operational. The copper HQ at W32 is a high of 1.4 during the 2012 snow melt and is a high of 2.8 during the 2013 snow melt.

Table 17. HQs during 2012 and 2013 Snowmelt period for Copper, Cadmium and Zinc

Date	Copper Dissolved (ug/L)	Cadmium Dissolved (ug/L)	Zinc Dissolved (ug/L)	Copper HQ	Cadmium HQ	Zinc HQ
23-Apr-12	17.6	0.298	64.6	**1.4**	0.2	0.3
23-May-12	3.52	0.061	17.4	0.3	0.047	0.1
06-Apr-13	6.26	0.196	41.8	0.5	0.2	0.2
13-Apr-13	6.02	0.196	40.7	0.5	0.2	0.2
20-Apr-13	11.8	0.385	80.0	0.9	0.3	0.4
27-Apr-13	37	0.827	185	**2.8**	0.6	1.0
04-May-13	33.0	0.759	164	**2.5**	0.6	0.9
11-May-13	8.44	0.220	48.9	0.6	0.2	0.3
18-May-13	5.02	0.153	30.8	0.4	0.1	0.2
25-May-13	4.31	0.134	28.2	0.3	0.1	0.2

Until such time that the historical waste rock is capped to reduce infiltration, it does not appear possible to prevent occurrences of HQs exceeding the threshold of 1. However, and perhaps most importantly, is that whether or not the IWTP was operating, the HQ was less than 1 for the majority of the year including the critical time periods when Chinook Salmon, Sockeye Salmon and Coho Salmon are migrating to spawn and the eggs are incubating and hatching.

7.3 Risk Mitigation as a Result of Timing of Receptor Presence by life-stage in the Tulsequah River

To convey a meaningful picture of risk from the Tulsequah Chief mine discharge, HQs must be viewed in the context of the exposure of a COPC to the receptors of concern: Chinook Salmon, Coho Salmon, Sockeye Salmon and Dolly Varden/Bull Trout. In particular, the most sensitive life stage of the most sensitive receptor should be explored. Chapman (1978) describes the most sensitive life stage of Chinook Salmon and Steelhead Trout for acute toxicity with Cd, Cu and Zn as being the juvenile form. As described in Section 3.2, juveniles from all three salmon species spend at least 18 months in freshwater before migration to the ocean. Dolly Varden/Bull trout comprise both anadromous and resident forms. Juvenile salmonids in the Tulsequah River watershed are less likely to rear extensively in the fast-flowing, turbid water of the mainstem as they typically rear and overwinter in beaver ponds, side channels, sloughs, channel edges, and tributaries. As such, juvenile forms of the receptors of concern are less likely to be exposed to the episodic loadings of COPCs from mine discharge. It is therefore reasonable to assume that the sensitive life stage of the juvenile form is unlikely to be exposed to high exposure of mine effluent discharge in the Tulsequah River.

Potential impacts to salmon spawning are one of the key issues to evaluate in this risk assessment. As stated previously, the period of highest concentrations of the COPCs coincides with the period of the annual snowmelt and rainfall in late April to early May when the flushing of the waste rock dumps discharge into the Tulsequah River via the Site Exfiltration Pond. Following this period of high snowmelt and loadings into the Tulsequah River, the Taku River flows begin to increase, prior to peaking in late May. As discussed in 3.2.2, Coho enter the Taku River between mid-July and November and spawn in the watershed between August and December (DFO 2001). Similarly, Sockeye return to the Taku River to spawn between mid-June and August (DFO 2001). Both of these spawning periods are during a time of low HQs for COPCs and therefore result in relatively lower exposure levels. Moreover, when they do enter the Tulsequah River, they are more likely to be found in the clear water side channels, accessible wetlands and lower tributary reaches than in the mainstem. These high quality habitats are known to support rearing, overwintering and spawning for salmonids.

Chinook Salmon enter the Taku River between May and early June with known spawning areas in the Nakina, Nahlin, Tatsatua and Kowatua Rivers. It remains uncertain whether adult Taku River Chinook migrate into or spawn in the Tulsequah River watershed (Boyce and Gagnon, DFO pers. comm., 2013). Previous studies (e.g., Rescan 1997), determined negligible juvenile chinook use in the Tulsequah River mainstem, tributaries or clear water side channels which could suggest low/negligible adult Chinook utilization of this watershed altogether. Spawning chinook salmon were also not observed in the Tulsequah River during the July-August periods in 1994 and 1995 (M. Whelen, Triton Environmental Consultants Ltd., pers. comm., 2013), despite their high abundance in the Nakina River at that time. Chinook migration into the lower Taku River occurs prior to the period of highest COPC loadings from the Tulsequah mine (Figure 16).

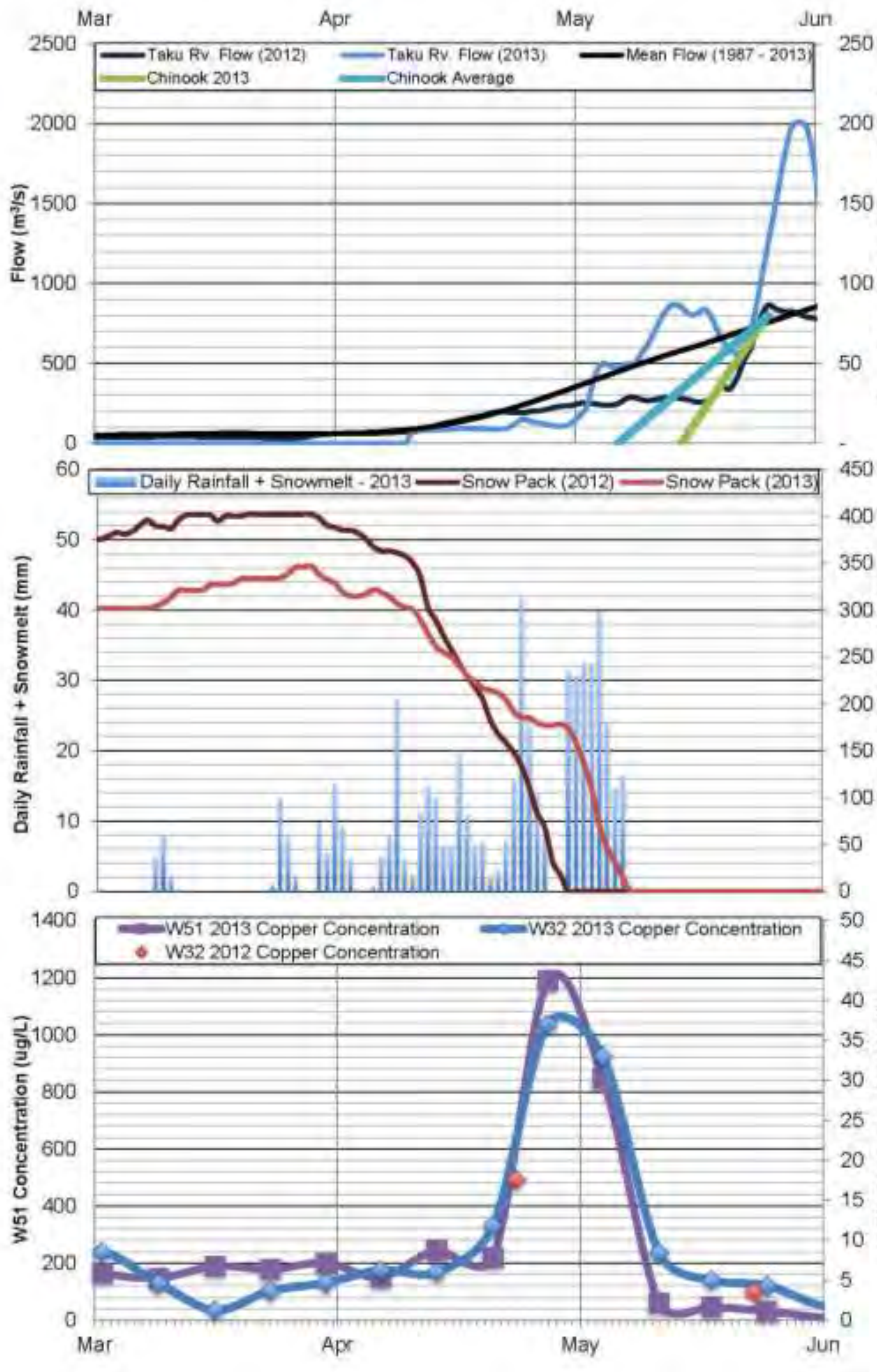


Figure 16. Timing of the Taku River Flows with Peak Tulsequah River Copper Loadings and Chinook Salmon Migration in the Taku River

Based on the seasonal trends of metal concentrations in the Tulsequah River and the lifecycles and habitat preferences of the receptors of concern, the risk is considered low for anadromous species. The risk to resident receptors of concern is greater (i.e. moderate) due to increased potential for exposure to COPCs. However, the metals tissue residue study completed by Hitselberger (2012) of juvenile Dolly Varden char from the Tulsequah River found that the discharges from the mine site were not causing elevated metals in juvenile Dolly Varden char suggesting that either the exposures were not significant or that the exposure levels were within a range that the fish could readily bioregulate.

7.4 Zone of Influence

The zone of influence for mine discharge includes the area where HQ results for receptors of concern were greater than a threshold of 1. As the maximum HQ for dissolved copper (HQ=2.8) was greater than 1 at station W32, the zone of influence extends downstream within the braided mainstem beyond station W32. It was estimated in section 4.1.4 that based on annual river flow data, the Tulsequah River would be diluted six times when mixed with Taku River at their confluence. By the time Tulsequah River water reaches the Canada-US border it would be diluted by eight times. The six times dilution of the Tulsequah River water provided by the waters from the Taku River, would be more than required to reduce the maximum HQ to less than 1. Therefore, the zone of influence would not extend into the Taku River. It is recognized that the flows fluctuate with seasons and that in the summer the incremental dilution provided by the Taku River is reduced to about 2 times at the confluence. However, during these times the HQ is already less than the threshold of 1 for copper at station W32. Based on the above, it is unlikely that the zone of influence of mine discharge extends beyond the confluence of the Taku and Tulsequah Rivers.

7.5 Tissue Residue Assessment

Hitselberger (2012), conducted tissue residue analysis of juvenile Dolly Varden char collected from the Tulsequah River upstream and downstream from the mine discharge and from the Taku River near the US-Canada border. The results found no significant differences in Dolly Varden tissue metal concentrations between sample site locations. These results further suggest that either:

- Dolly Varden do not occur in areas with increased metal levels;
- Metals are not bioavailable to Dolly Varden/Bull Trout; or
- Dolly Varden/Bull Trout are able to bio-regulate metals

7.6 Summary

The objective of the study was to determine the potential for risk to aquatic species in the Tulsequah River resulting from exposure to metals contamination from the Tulsequah Chief Mine. A second objective was to attempt to assess the effectiveness of the IWTP that was operated briefly in 2012.

Fish were chosen as the main receptor of concern due to their ubiquitous distribution and relative abundance, throughout the Tulsequah River watershed, and, sensitivity to metals during the juvenile life stages. Specifically, the three most common and abundant species in the Tulsequah drainage were the focus of the study: Coho Salmon, Sockeye Salmon, and Dolly Varden/Bull Trout. Chinook Salmon was chosen as the fourth receptor as they occur in the Taku /Tulsequah River confluence and therefore potentially occur within the zone of influence.

A systematic screening of all measured surface water quality parameters resulted in the identification of four contaminants of potential concern (COPCs): total concentrations of cadmium, copper, lead and zinc. Using the hazard quotient (HQ) methodology, evaluation of the mine effluent showed that the highest HQs in the Tulsequah River coincided with the period of snowmelt and is believed to be the result of the annual flushing of the historic waste rock during the spring thaw. During the annual flushing period, most juvenile salmonids will be overwintering in the preferred habitats of the clear water side channels, prior to seaward emigration.

With respect to the effectiveness of the IWTP, it was evident from surface water quality monitoring that during its operation it did lower the HQs at sites downstream from the point of discharge. However, during the annual flush period select HQs (Cu and Zn) were still greater than 1. Until such time that the historic waste rock is capped to reduce infiltration, it does not appear that the IWTP is capable of reducing mine discharge to levels where resulting HQs do not exceed the threshold of 1. Regardless of whether the IWTP was operating or not, the HQs at all sites except W51 were less than 1 for the majority of the year. Resident fish such as Dolly Varden/Bull Trout can be present all year round, but as the fish tissue studies show, they were not affected by the mine discharge (Hitselberger, 2012). Migratory salmonids also occur year round in the Tulsequah River as adults or juveniles, but are most often associated with clear water side channel or tributary habitat, removed from the direct influences of the mine discharge.

Overall, the potential risk to aquatic receptors as a result of mine discharge is considered low. As HQs at some sites were greater than 1 (e.g., W51), the risk to mainstem aquatic receptors would be considered moderate during those times. However, as most migratory species are known to utilize clear water side channels, removed from direct influences of the mine discharge, and resident species

(Dolly Varden/Bull Trout) are shown to bioregulate COPCs, the moderate risk designation for the selected aquatic receptors is considered conservative.

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APPENDIX A

Letter Update on Activities (October 24, 2012) and
Tulsequah Chief Interim Water Treatment Plant Mitigation and Re-Start
Report (July 27, 2012)

Ian Sharpe
BC Ministry of Environment
Skeena Region
Bag 5000
Smithers BC V0J 2N0

24 October 2012

Dear Mr. Sharpe,

RE: Tulsequah Chief Mine Interim Water Treatment Plant Authorization # 105719

Chieftain Metals is pleased to provide an update on activities at the Tulsequah Chief Mine, in particular with regard to activities controlled by Authorization # 105719. We wish to advise you of the activities and steps undertaken since our last correspondence to you and to provide an update on the actions proposed in the *Chieftain Metals Inc. Tulsequah Chief Interim Water Treatment Plant Mitigation and Re-Start Report*, dated July 2012.

Early results indicate that mitigation measures at site have been successful in reducing contaminant loadings into the Tulsequah River and that Chieftain is meeting surface water quality objectives downstream of the mine site. The Company has successfully reduced costs across all business units and anticipates receipt of its Environmental Assessment Certificate and Special Use Permits in early course. Furthermore, Chieftain has signed a Memorandum of Understanding with Procon Holdings (Alberta) Inc., a subsidiary of China CAMC Engineering Co., to pursue a partnership for construction of the Tulsequah Chief Project. A private placement by Procon into Chieftain has provided the needed funding to complete the feasibility optimization and related project financing.

This letter provides:

- An update on activities undertaken since curtailment of plant activities in June 2012;
- A discussion of the effectiveness of mitigation measures and early monitoring results; and
- Notification of Chieftain's intention to undertake a process optimisation trial at the Tulsequah Chief Interim Water Treatment Plant in early November 2012.

Interim Water Treatment Plant Activity Summary

The Historic mining activities at the Tulsequah Chief Mine have left a legacy of acid mine drainage issues. Chieftain Metals Inc. (Chieftain) agreed to address these issues as part of the acquisition of the Tulsequah Project. An Interim Water Treatment Plant (IWTP) was constructed in Fall 2011 and commissioned in early 2012 to treat poor quality water prior to its discharge from site.

The IWTP has been operating since March 2012 and discharging treated effluent to the Tulsequah River. All plant discharges have met permit water quality conditions. However, reagent consumption rates, sludge production volumes and plant operating costs have far exceeded the engineered design parameters. The total cost of operation and support for the IWTP is in the order of $4.0M/year vs. an original estimate of $1.2M/year. The IWTP was designed as an interim measure to address the environmental legacy of historic mining activities, with the long-term acid mine drainage (AMD) solution being to develop, operate and ultimately close the mine in an environmentally responsible manner that addresses all AMD issues.

On 22 June 2012, Chieftain Metals curtailed operations at the Tulsequah Chief Interim Water Treatment Plan and entered into a period of non-compliance with the conditions of Waste Water Discharge Permit #105719.

Summary of Actions Undertaken To Date

Reduction of site workforce

The site workforce was reduced to immediately reduce operating costs. The site is currently in Care and Maintenance mode and is operating with a 4-strong workforce on a 2 in/2 out rotation.

Staged shutdown of plant operations

Plant operations ceased on 22 June 2012. Since this time, numerous activities have been undertaken, including a comprehensive flushing of the IWTP, removal of sludge from the IWTP Storage Pond, site-wide winterization programs and preparations for the eventual re-start of the plant.

Review of IWTP Operating Plan

The IWTP Operating Plan has been reviewed and a comprehensive process review, involving a plant restart and testing program, will be undertaken in early November. Chieftain expects the outcomes of this investigation to result in further changes to the plant process and anticipates the potential additional planning and works prior to plant re-commissioning.

Catchment assessment

A catchment assessment was completed to identify potential sources of buffering and dilution for mine-impacted water on site. The findings of this assessment informed surface hydrology works at the site.

Surface hydrology works

Surface water diversions were implemented to provide some buffering and dilution on site, and to increase the residence time of impacted water on site prior to diffusion into the Tulsequah River. These works were undertaken with a view to reducing total metals loading.

IWTP Sludge Storage Pond cleanout

The IWTP Temporary Sludge Storage Pond has been emptied and all sludge has been deposited at the Airstrip Sludge Storage Pit.

Increased monitoring and surveillance

An intensive monitoring and surveillance program has been developed in consultation with the BC Ministry of Environment Environmental Protection Unit to collect data monitor the effects of the IWTP shutdown on the receiving environment. Monthly letter reports are provided to BC Ministry of Environment, along with the updated CMI Water Quality Database.

Investigation of sludge thickening options

Sohan Basra of SGS, an experienced high-density sludge plant designer and operator, has been engaged to conduct a review of the IWTP and will be directly involved in the re-start and testing to be undertaken in early November. Several Chieftain employees have visited the Britannia Mine Water Treatment Plant to review sludge thickening options which may be applicable to the Tulsequah Chief IWTP.

Cost reduction in other areas of Chieftain's business

A comprehensive cost review has been taken across all of Chieftain's business units. Cost saving and austerity measures have been implemented across the Company's business units to ensure that the Company remains viable while project financing is secured. Furthermore, extensive efforts have been made to reduce energy consumption at the site and to ensure that environmental effects of site activities are kept to a minimum. This campaign has resulted in a 90% reduction in fuel consumption rates and cost since plant activities were curtailed. Plant re-start will see an increase in fuel consumption, but Chieftain is confident that efficiency measures will realize continued savings over the coming months.

Discussion of monitoring results and outcomes

Three months of intensive monitoring is complete and a full quarterly suite of samples will be collected in November, to meet permit requirements.

Prior to the full data set becoming available, Chieftain has undertaken an internal review of the outcomes of activities undertaken since curtailment of operations at the IWTP. The following questions were posed to assess the success of mitigation activities:

Is dilution in the Exfiltration Pond by the Neutral Mine Water reducing metals concentrations in the discharge to the river?

CMI did not have a database of Exfiltration Pond (SE-2) water quality prior to adding the NMW flow to the 5400 portal discharge. However, there is a record of water treatment plant feed water (SE-3) data, which during plant operations, was the combination of 5200 and 5400 portal discharges. Table 1 presents dissolved zinc concentrations in mg/L for samples collected from May to September 2012.

Table 1 - Dissolved Zn Concentrations, Exfiltration Pond

Location	May 2012	June 2012	August 2012	September 2012
SE-2/SE-3	67 mg/L	76 mg/L	47 mg/L	40 mg/L

There have been two SE-2 samples since the NMW was re-introduced to the portal discharge and diverted to the Exfiltration Pond. Dissolved zinc concentrations in both the August and September samples are significantly lower than the May and June samples, which demonstrates that the mixing of Neutral Mine Water with impacted mine water discharging from the 5200 and 5400 portals is reducing metals concentrations in the Exfiltration Pond.

How much dilution is occurring by the time the water gets to W51 (~300 m downstream of the Exfiltration pond)?

For this assessment, data for W46, upstream of the Exfiltration Pond, were compared with W51 data. In June, even with the plant discharge potentially affecting river water quality at W46, the D-Zn concentration was at or below 0.032 mg/L. Background Zn concentration was measured at or below the laboratory detection limit of 0.005mg, so a conservative value of 0.0025mg/L has been adopted for the purposes of this review. Table 2 presents dissolved zinc concentrations for W46 and W51 during plant operations and after shutdown.

Table 2 - Dissolved Zinc Concentrations (mg /L) W51 vs. W46

Sample Location	June 2012	September 2012
W46	0.032 mg/L	0.0025 mg/L
W51	0.0069 mg/L	0.289 mg/L

Sampling at W51 commenced in June 2012, so there are no pre-IWTP results available for comparison. For the purposes of this calculation, the background Zn concentration is assumed to be 2.5 ug/L (conservatively assumed to be only half the detection limit). With the discharge assumed to be at the SE-2 concentration of 40 mg/L D-Zn, the dilution is: (40-0.289)/(0.0069-0.0025) = 137. This suggests the flow in the Tulsequah river braid adjacent to the mine is 137 times greater than the discharge (e.g., ~19 L/s vs 2.5 m3/s). So, dilution in the Tulsequah River within 300m downstream of the Exfiltration Pond is 137:1.

How much dilution is occurring 3 km downstream, at W32? Do any parameters continue to exceed the Site Surface Water Quality Objectives?

W32 was measured to be near background (W46) at 0.0134 mg/L in Sept vs. 0.0174 mg/L in May and non-detectable (<0.005 mg/L) in June. Table 3 presents dissolved metals concentrations for W46 (upstream of Exfiltration Pond), W51 (<300m downstream of Exfiltration Pond) and W32 (3km downstream of Exfiltration Pond).

Table 3 - Dissolved Zinc Concentrations, Tulsequah River June & September 2012

Sample Location	June 2012	September 2012
W46	0.032 mg/L	0.0025 mg/L
W51	0.0069 mg/L	0.289 mg/L
W32	<0.005 mg/L	0.0134 mg/L

Dilution in September 2012 at W32 is calculated to be: (40-0.0134)/(0.0134-0.0025) = 3623, or 3623:1.

Table 4 presents water quality data for Tulsequah River monitoring locations before, during and after IWTP operations.

Table 4 - Water Quality Monitoring Data Review

Location	Range	Average	September 2008	September 2010	June 2012 (During IWTP operations)	September 2012
W10*	0.0002-0.0285	0.0061	0.0008	0.0072	0.0025	0.0062
W46	0.0025-0.558	0.115	0.0016	0.0008	0.0025	0.0025
W51	0.0069-0.289	0.148	*NEW LOCATION in 2012*		0.0069	0.289

W32	0.0025-0.101	0.0206	0.004	0.016	0.0025	0.0134

(*W10 is located upstream of the Tulsequah Chief site.)

Current water quality monitoring results fall within expected ranges, and results demonstrate that there has been no major change in water quality at W32 before, during or after IWTP operations. Furthermore, no parameters measured at W32 were found to exceed BC FWAL guidelines or the Site Surface Water Quality Objectives for aluminium, cadmium, copper, selenium or zinc.

Weekly monitoring activities are ongoing and further discussion on dilution and water quality monitoring results was provided in the IWTP September Monthly Report, submitted on 22 October 2012. An updated version of the Tulsequah Chief Water Quality Database was also provided with this report.

IWTP Optimization Trial

As previously discussed, Chieftain will be briefly restarting the IWTP for a process optimization trial in early November 2012. Preparatory activities have commenced at site, with the plant being prepared to come online for approximately ten days from late October into November. The test program is being undertaken to:

- Respond to regulator concerns and prepare for long-term plant recommissioning;
- Optimize plant operations to minimize costs, improve plant performance, ensure a safe system of work for operators and return to compliance with permit conditions; and
- Improve instrumentation and control system for the plant.

The anticipated outcomes of the trial are:

- That Chieftain will have a better understanding of plant operating parameters and capabilities;
- Identification of potential plant improvements including any engineering design drawings and recommendations for process optimization;
- A Chieftain-generated report on findings for internal use and to inform decision-making with regard to the IWTP;

Chieftain invites your comments and suggestions regarding this trial. A report detailing the outcomes of the plant optimization trial will be provided to BC Ministry of Environment following the conclusion of the trial.

Conclusion

Chieftain remains committed to delivering a revised feasibility study in Q4 2012, and maintains its commitment to recommissioning the Tulsequah Chief Interim Water Treatment Plant upon completion of financing.

We trust that this letter provides you with sufficient information to meet your purposes. Please do not to hesitate the undersigned at our offices on (604) 671 1154 or by email at joanne.thompson@chieftainmetals.com should you have any further questions or concerns.

Yours Sincerely,

Joanne Thompson,
Sustainability Manager
Chieftain Metals, Inc.

CC: Mark Love, BC MoE
Jeanien Carmody-Fallows, BC MoE
Lisa Torunski, BC MoE
James Cuell, BC MFLNRO
Wade Comin, Environment Canada
Jeska Gagnon, DFO
Nicole Gordon, TRTFN
John Ward, TRTFN
Tina Brooks, TRTFN
Doug Flynn, BC MEMNG
Kim Bellefontaine, BC MEMNG
Diane Howe, BC MEMNG
Victor Wyprysky, CEO, Chieftain Metals
Keith Boyle, COO, Chieftain Metals

CHIEFTAIN METALS INC.
TULSEQUAH CHIEF PROJECT INTERIM WATER TREATMENT PLANT
MITIGATION AND RE-START REPORT

JULY 2012

CONTENTS

EXECUTIVE SUMMARY

Historic mining activities at the Tulsequah Chief Mine have left a legacy of acid mine drainage issues. Chieftain Metals Inc. (Chieftain) agreed to address these issues as part of the acquisition of the Tulsequah Project. An Interim Water Treatment Plant (IWTP) was constructed in Fall 2011 and commissioned in early 2012 to treat poor quality water prior to its discharge from site.

The IWTP has been operating since March 2012 and discharging treated effluent to the Tulsequah River. All plant discharges have met permit water quality conditions. However, reagent consumption rates, sludge production volumes and plant operating costs have far exceeded the engineered design parameters. The total cost of operation and support for the IWTP is in the order of $4.0M/year vs. an original estimate of $1.0M/year. The IWTP was designed as an interim measure to address the environmental legacy of historic mining activities, with the long-term acid mine drainage (AMD) solution being to develop, operate and ultimately close the mine in an environmentally responsible manner that addresses all AMD issues.

On 22 June 2012, Chieftain Metals curtailed operations at the Tulsequah Chief Interim Water Treatment Plan and entered into a period of non-compliance with the conditions of Waste Water Discharge Permit #105719.

Actions undertaken to date include:

- Immediate reduction of site workforce to meet revised operating expectations;
- Plant optimization studies and trial changes to the site operating system;
- Staged shut-down of plant operations;
- Surface Water Diversions; and
- Investigation of dilution and dispersion of AMD and an assessment of river impacts.

It is anticipated that Chieftain will issue a revised feasibility study in Q4 2012 and that financing will be dependent upon the findings of this study. As such, Chieftain expects to secure full project financing in the six to nine months following the issue of the updated Feasibility Study. Chieftain will re-start the water treatment plant upon securing project financing.

Chieftain proposes to continue environmental monitoring activities at the site on a monthly basis. This sampling regime will commence on 6 August 2012 and continue until such time as the IWTP resumes operations.

Chieftain wishes to maintain an open dialogue with regulators over the coming months as monitoring activities are undertaken and the plant returns to full operations.

1. INTRODUCTION

Historic mining activities at the Tulsequah Chief Mine have left a legacy of acid mine drainage issues. Chieftain Metals Inc. (Chieftain) agreed to address these issues as part of the acquisition of the Tulsequah Project. An Interim Water Treatment Plant (IWTP) was constructed in Fall 2011 and commissioned in early 2012 to treat poor quality water prior to its discharge from site.

Chieftain Metals Inc. has demonstrated its commitment to managing the environmental legacy of historical activities at the Tulsequah Chief Mine. Since purchasing the water treatment plant from Redfern's receivers in 2010, Chieftain has spent approximately $9 million to construct and operate the plant. During this time, Chieftain commissioned and operated the plant pursuant to its water quality discharge permit conditions, and discharged water quality results have met all permit requirements. However, the plant operation has not met expectations when compared to design, and Chieftain is currently reviewing all plant and site activities with a view to identifying and resolving the root causes of these issues. The mining industry as a whole is exposed to cost escalation elements and Chieftain is currently reviewing project economics to determine optimal design, construction and operating processes.

On 22 June 2012, Chieftain Metals curtailed operations at the Tulsequah Chief Interim Water Treatment Plan and entered into a period of non-compliance with the conditions of Waste Water Discharge Permit #105719. Chieftain will resume water treatment activities upon completion of project financing.

This report provides a description of activities undertaken to date with regard to water treatment at the Tulsequah Chief Mine and describes the project timeline going forward.

2. PROJECT DESCRIPTION

The Tulsequah Chief Project covers two previously producing underground mines, the Tulsequah Chief and Big Bull deposits, and is currently in an advanced stage of development. Chieftain's principal focus is to develop an underground mine at the Tulsequah Chief Deposit. Mine construction is slated to commence in 2013, following the issue of an updated economic feasibility study review.

The Interim Water Treatment Plant is located proximate to the Tulsequah Chief 5200 Portal and adjacent to the Tulsequah River. Figure 1 provides the project location and a site plan for the Tulsequah Chief Mine and Interim Water Treatment Plant.

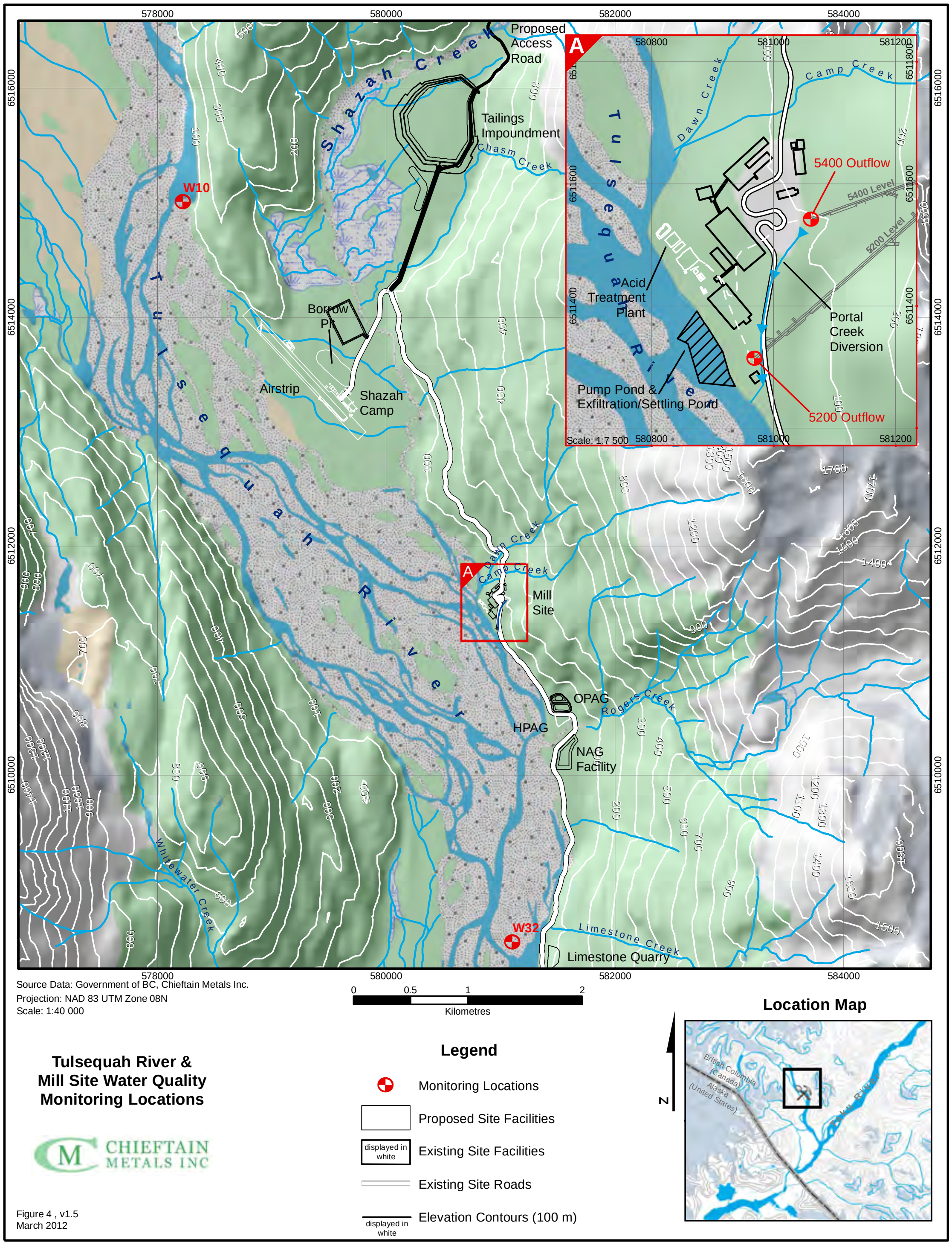

Figure 1 - Tulsequah Chief Site Plan

3. PERMIT SUMMARY

Historic mining activities at the Tulsequah Chief Mine have caused significant acid mine drainage legacy issues, and it was a condition of Chieftain's acquisition of the Tulsequah Chief that these issues be managed and that AMD flows into the Tulsequah River be contained and treated before release into the receiving environment. To meet this requirement, the Tulsequah Chief Interim Water Treatment Plant (IWTP) was constructed in Fall 2011 and commissioned from November 2011 to February 2012. The British Columbia Ministry of Environment issued Waste Water Discharge Permit #105719 under the provisions of the *Environmental Management Act* on 4 April 2012. This permit authorised Chieftain Metals Inc. (Chieftain) to discharge treated water to the Tulsequah River, subject to conditions described in the permit. Table 1 provides the water quality limits for authorised discharges from the Tulsequah Chief Mine.

Table 1. Water Quality Limits for Authorized Discharges

Parameter	Limit
Dissolved Aluminum (D-Al)	0.5 mg/L
Dissolved Arsenic (D-As)	0.05 mg/L
Dissolved Copper (D-Cu)	0.05 mg/L
Dissolved Lead (D-Pb)	0.05 mg/L
Dissolved Zinc (D-Zn)	0.2 mg/L
Total Suspended Solids (TSS)	30.0 mg/L
pH	6.0 to 9.5 pH units

4. INTERIM WATER TREATMENT PLANT OPERATIONS REVIEW

The IWTP has been operating since March 2012 and discharging treated effluent to the Tulsequah River. All plant discharges have met permit water quality conditions. However, reagent consumption rates, sludge production volumes and plant operating costs have far exceeded the engineered design parameters. The total cost of operation and support for the IWTP is in the order of $4.0M/year vs. an original estimate of $1.0M/year. It is in light of these issues that Chieftain has by necessity conducted a comprehensive review of the operation and management of the IWTP. The IWTP was designed as an interim measure to address the environmental legacy of historic mining activities, with the long-term acid mine drainage (AMD) solution being to develop, operate and ultimately close the mine in an environmentally responsible manner that addresses all AMD issues.

Reagent Consumption

Actual reagent consumption rates of 0.2kg of ferric chloride and 0.07 kg of lime per cubic metre of effluent have significantly exceeded design, which forecast reagent consumption rates of 0.03 and 0.016 kg/m^3 respectively. Alterations made to the water treatment process significantly improved reagent consumption rates over the last month of operation, but these changes still yielded results far in excess of forecast.

Effluent Volumes

The 2012 Permit Application submitted by Chieftain to the Ministry of Environment contemplated an average treatment volume of $40m^3$/hr, or $960m^3$/day. Daily treatment volumes averaged $53m^3$/hr or $1,270m^3$/day, 35% greater than anticipated. This is primarily due to the timing of the permitted operations, during the spring snowmelt period.

Sludge Production

Sludge production rates at the water treatment plant outstripped capacity to manage and transport the sludge. Plant operating parameters produced a fluffy, low-density, low percentage solids content sludge. The original design contemplated sludge production at a rate of $1m^3$ sludge per $720m^3$ treated water. In the time period from 1 March 2012 to 31 May 2012, sludge was being produced at an average rate of $1m^3$ sludge per $52.8m^3$ treated water, or 1,200% of design output. Sludge management issues were driving all activities on site and additional personnel were required to manage the sludge output. This placed unsustainable pressure on site resources, and operating costs exceeded design by in excess of 300%. The bulk of these costs were for IWTP support, including the requirement for additional manpower to remove sludge from the plant and the camp and logistical crew required to support a larger than anticipated workforce. This by extension is placed untenable pressure on operation and corporate finances, and overstretched the site workforce.

Continued sludge production at this rate cannot be sustained, in particular through the winter months where constant road maintenance will be required to facilitate hauling sludge 6km from the IWTP to the Airstrip Sludge Storage Pit. There have been no safety incidents to date, but the combination of sub-optimal plant operation, the condition of the site fleet and the relative inexperience of operators provide significant cause for concern. Employee safety is of primary concern at this time and the current state of plant operations necessitates a substantive change in site activities to address these issues.

5. COST REVIEW

Chieftain's corporate cashflow has been severely stressed by excessive costs incurred in addition to delays in permitting, updating of the project feasibility study and, as a result, project financing. Chieftain is a single asset company and project viability is dependent upon careful fiscal management. To this end, planned activities will specifically include a first-principles review of the plant engineering and process, a comprehensive safety audit and development and implementation of safe and efficient practices for management of Interim Water Treatment Plant. Table 1 provides a comparison between forecast, actual and projected operating costs.

Table 2 - IWTP Operating Cost Comparison Table

Area	Item	2009 Forecast		2012 Forecast		CMI Proposal	
		Daily	Monthly	Daily	Monthly	Daily	Monthly
Staffing	**On site**	2	2	8	8	4	4
Sludge Produced	**(av. Daily volume m^3)**	1	31	15	450	2-6	60-180
		Monthly	**Annual**	**Monthly**	**Annual**	**Monthly**	**Annual**
	TOTAL	$89,756	$1,077,069	$362,734	$4,352,808	$185,000	$2,220,000

6. ACTIONS UNDERTAKEN TO DATE

Actions undertaken to date include:

- A comprehensive review of IWTP process inputs and outputs;
- A sludge removal campaign;
- Options assessment and internal consultation program;
- Revision of site operating plans and forecasts; and
- Commencement of a mitigation and site optimization program.

These activities have been completed and, while insufficient data is available at this time to draw conclusions, revisions to the plant process have yielded promising improvements to the process. It is anticipated that these improvements will continue to be seen through testing and refining the process during re-commissioning.

7. OPTIONS ASSESSMENT

Prior to any decision being made with regard to IWTP operations, four options were evaluated. These were:

1. Status Quo (Unchanged operations and practises);
2. Operation with a reduced workforce;
3. Treatment of only the most impacted water (i.e., 5200 outflows); and
4. Curtailment of operations for plant optimization.

For all options, the objective was to be able to operate the IWTP and manage the greater than planned volume of sludge in a safe and effective manner year round with the current equipment fleet, provided funding for such operations has been secured. The intention of any change in site practices will be to protect employee safety, increase plant efficiency, manage overheads and reduce costs to meet revised expectations while all permit conditions are met. In all cases, the curtailment of activities would be on a temporary basis while project financing was secured. Chieftain has pursued Option 4 – Curtailment of operations, and the plant will be restarted as soon as process optimisation is complete and project funding is secured.

8. MITIGATION ACTIVITIES

Chieftain has undertaken a number of options to mitigate environmental effects of the temporary curtailment of activities at the IWTP. This section discusses the mitigation options that were outlined in a letter sent 6 June 2012 to Wade Comin of Environment Canada and provides a progress update on each.

1. Immediate reduction of site workforce to meet revised operating expectations

Chieftain has retrenched the majority of its workforce and has transitioned to a site operating model of 2 employees on site at any time. This is in line with design expectations and is anticipated to continue after full-time water treatment activities resume. The workforce will comprise one manager or his delegate and one water treatment plant operator/general maintenance hand.

2. Staged shut-down of plant operations

A planned and orderly shutdown of plant activities has occurred and the plant has now been placed in care and maintenance until such time as project funding is secured. Two employees are on site at all times to undertake routine maintenance of site water diversion works and the project site.

3. Undertake plant optimization studies and trial changes to the site operating system

These activities have commenced, and early results are promising. Chieftain has undertaken a comprehensive process review and has identified those parts of the water treatment process requiring further investigation and testing. Optimization studies will be actively pursued over the coming months, and an intensive testing process will be undertaken when the plant is re-commissioned.

4. Apply for a permit amendment to allow deposition of sludge into the proposed Pyrite Pond area at Paddy's Flat

An integral part of the IWTP re-start strategy is permitting an alternative sludge disposal site closer to the Plant. A suitable facility was constructed in 2011 at Paddy's Flats, 1km from the IWTP, and Chieftain intends to apply for a permit to re-designate this facility for sludge deposition. This will reduce haul times during periods of high sludge production, remove the need for road maintenance between the IWTP and the Airstrip Sludge Storage Pit and relieve the pressure placed on employees and equipment by hauling from the IWTP to the Airstrip Sludge Pit. Monitoring wells are already present at this location and baseline data are available. It is anticipated that the Airstrip Sludge Pond will continue to be used during summer, when sludge hauling capacity is available. Chieftain will commence this permitting process in Q4 2012.

5. Surface Water Diversions

A meeting was held between Chieftain and Jeanien Carmody-Fallows of the BC Ministry of Environment on 11 June 2012. During this meeting, Ms Carmody-Fallows stated that she wished to see surface water diversions facilitating a longer residence time for impacted water on site prior to discharge to the Tulsequah River. Based on historical monitoring data and on verbal advice received from BC Ministry of Environment, removal of suspended sediments from site water will significantly reduce the total metals load to the Tulsequah River. These works have been undertaken, and all mine water has been diverted to the Exfiltration Pond to allow settling and filtration of solids prior to release to the receiving environment. In short, the diversions undertaken to date are:

- Diversion of 5200 Portal drainage to the Exfiltration Pond;
- Diversion of 5400 Portal drainage to the Exfiltration Pond;
- Re-routing of Neutral Mine Water (previously discharged directly to the receiving environment) to the Exfiltration Pond to provide dilution of impacted water prior to discharge.

Figure 2 illustrates the current surface water diversion configuration.

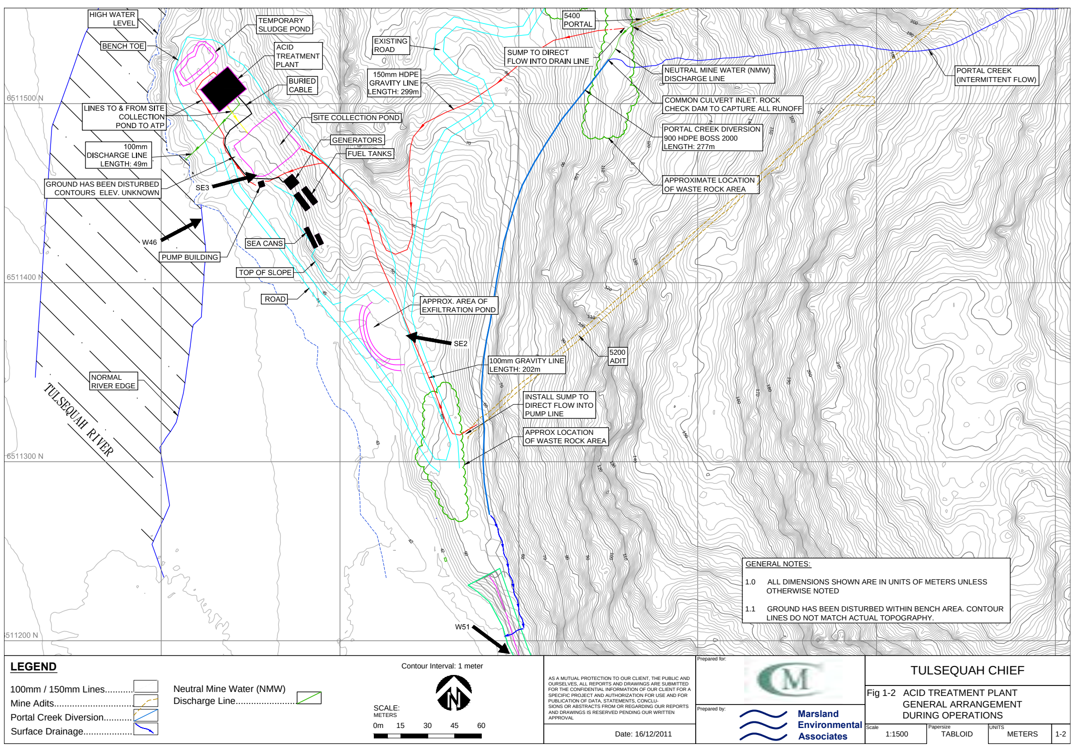

Figure 2 - Tulsequah Chief IWTP Plan

6. Dilution and Dispersion

In 1994, a study of the dilution effects of the Tulsequah River on acid water from the Tulsequah Chief was undertaken by Rescan in support of the original Tulsequah Chief Environmental Assessment. Scientists measured dilution downstream of the mine site at a point 500 m downstream of the Mine (upstream of Rogers Creek) and found open water dilution to be 78-fold in Sept 1994 and as much as 370-fold for sulphate during higher flows. Dissolved copper and zinc were somewhat non-conservative and exhibited higher dilution ratios. Conversely, in the winter when there was no river flow with only limited groundwater inflow, dilution was as low as 2.7. However, this period of limited dilution coincides with periods of no fish access, due to the absence of any surface water flows.

Two subsequent studies, published in 2001 and 2003, by the BC Environmental Assessment Office and BC Ministry of Environment, both found that mass loadings were non-conservative in the Tulsequah River, i.e., that both concentration and mass loading decreased going downstream. The 2003 study reported on sampling conducted during a jokulhaup and found anomalously increased total metal concentrations relative to dissolved concentrations and proposed that colloidal metal particles were flushing out of the river sediments during the flood event. All research was undertaken when impacted water was discharging directly to the Tulsequah River and, although both studies were more focused on cumulative loadings and potential effects on the Taku River as it enters Alaska and so do not provide much information on "near-field" dilution, the findings suggest that any effects caused by impacted water discharging from the Tulsequah Chief Mine are temporary and extremely localised.

In 2011, Alaska Fish and Game undertook a study on resident Dolly Varden collected 1 km downstream of the mine and found no significant effects on fish tissue metal content. Some parameters were higher upstream of the mine, others were lower and Cd was highest in fish collected in the Taku River at the Alaskan border. Those parameters which were higher downstream of the Tulsequah mine were lower than the concentrations measured in Dolly Varden collected above the Greens Creek Mine in Alaska.

In June 2012, Chieftain collected samples of untreated site runoff and the treatment plant discharge as part of its monthly monitoring program. Samples were also collected upstream of the mine (W10), immediately below the treatment plant discharge (W46), 150m downstream of the mine site (W51) and at a location further downstream (below Rogers Creek) (W32). Inspection of the Zn and sulphate data shows that there was almost no measurable effect on the Tulsequah within 150m of the mine site. Table 3 summarizes the analytical results. Where multiple samples were collected, the range of values is reported.

Table 3 - Tulsequah Chief Monitoring Results, June 2012

Sample Location	Zn (µg/L)	SO_4 (mg/L)
Permit Limit	200	
W10 – Tulsequah River – upstream of Airstrip	<5	15
IWTP Discharge	44-100	444-484
W46 – Initial mixing zone of IWTP discharge in Tulsequah River	<5-32	15-23
SE2 – Surface runoff in Exfiltration Pond	19,100	279
W51 – Tulsequah River 150m below Mine	6.9	15
W32 – Far-field location 4km downstream in Tulsequah River	<5	7.8-12

If on-site dilution was the required course of action, to ensure compliance with the SSWQO of 32 ug/L for Zn in the river by diluting the portal discharge (ATP Feed or SE3) at 40-80 mg/L Zn (average 50 mg/L) and a flow of 12 L/s, by using river water at 5 ug/L, the dilution would require 22.2 m3/s of flow. If we wanted to use Camp Creek or NMW flow, we'd need even more water, since the background concentration in those is higher than 5 ug/L. This calculation suggests that as long as the site drainage is mixing with the river (i.e., during the open water season), there would be adequate dilution (May-October). During the winter, site drainage is isolated from the river flow and hence there will be no effect on river water quality.

The modelling for the proposed buried diffuser indicated that groundwater dilution alone provides a 10-fold dilution within 600m of the discharge. One might hypothesize then, that an incremental dilution of 2.2 m3/s would be required to achieve the SSWQO if mixing with surface water were to begin at that point. The 7Q2 flow in the Tulsequah is estimated to be 3.1 m3/s, so in an average year, there would be no adverse effect even if all the discharge were to mix with the river after mixing with groundwater. However, the diffuser groundwater model also indicated that it would take upwards of 100 days to reach steady-state conditions in the groundwater, 600 m downstream. In this case, only a portion of the winter discharge would reach the river surface flow before spring thaw.

9. PROJECT SCHEDULE

It is anticipated that Chieftain will issue a revised feasibility study in Q4 2012 and that financing will be dependent upon the findings of this study. As such, Chieftain expects to secure full project financing in 6-9 months following the issue of the updated Feasibility Study. Table 4 provides the anticipated schedule for Chieftain's activities.

Table 4 - Anticipated Project Schedule

	2012			2013	
Activity	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**
Reduce Workforce	■				
Plant Shutdown	■				
Plant Optimization Study	■			■	■
Permit Application		■	■		
Feasibility Study Issued			■		
Project Financing Secured					■
Resume full IWTP operation					■

10. MONITORING & SURVEILLANCE

Chieftain proposes to continue environmental monitoring activities at the site on a monthly basis. This sampling regime will commence on 6 August 2012 and continue until such time as the IWTP resumes operations.

11. FOLLOW-UP ACTIONS

Chieftain wishes to maintain an open dialogue with regulators over the coming months as IWTP optimization activities are undertaken and the plant returns to full operations.

12. REFERENCES

Rescan Environmental Services Ltd. (1994) *Tulsequah Chief Project Report*

Mehling Environmental Management Inc. (2001*) Tulsequah Chief Project Updated Cumulative Water Quality Effects Assessment* for the Environmental Assessment Office

Lough, J. and Sharpe, I. (2003) *Tulsequah and Taku Rivers Mass Balance Water Quality Report* for the BC Ministry of Water Land and Air Protection – Environmental Protection Division

Hitselberger, J.P. (2012) *Tulsequah Chief Acid Mine Drainage: Whole Body Metals Concentrations in Dolly Varden Char* for the Alaskan Department of Fish and Game, Habitat Division

AECOM (2008) *Preliminary Diffuser Plume Assessment for Redfern Resources Ltd.*

APPENDIX B

Terms of Reference for Risk Assessment For the Tulsequah Chief Mine

(Letter from MOE)

BRITISH
COLUMBIA

FILE NUMBER: 105719

August 12, 2013

Victor Wyprysky, CEO & President
Chieftain Metals Inc.
2 Bloor Street West Suite 2000
Toronto, Ontario, M4W 3E2

Dear Mr. Wyprysky:

RE: Tulsequah Chief Mine, Authorization # 105719, Risk Assessment of Current Mine Effluent Discharge into the Tulsequah River

On Aril 3, 2012 the Ministry of Environment issued *Environmental Management Act* (EMA) authorization #105719 that requires the interim collection and treatment of acid waters coming from the excavation/removal of historical waste rock, portals 5200, 5400 and 5900 at the Tulsequah Chief Mine site. The intent was that the plant would serve as an interim solution to the treatment of acid waters originating from the construction phase of the project. The operational phase of the mine was to have addressed the long term collection and treatment of acid mine water. The water treatment plant (WTP) was commissioned and operated for a 3 month period (April to June 2012) prior to Chieftain Metals Inc. (Chieftain) shutting the plant down due to design problems and the inability to pay for necessary improvements and continued operation.

As a result, Chieftain has been out of compliance with the EMA authorization #105719 since shutting down the WTP at the Tulsequah Chief Mine site in June of 2012. In an official warning letter issued July 24, 2012, the Ministry of Environment required Chieftain to implement onsite water management strategies to minimize potential impacts and to conduct water quality sampling to assess the effectiveness of the mitigation measures.

Since then, the Ministry has been receiving regular water quality submissions, and communicating with Chieftain to review the status of the project and obtain updates on their action plan to come into compliance with the EMA authorization.

The February 2013 updates identified that the feasibility of optimization, re-commissioning and operating the WTP was contingent on the project receiving financing

Ministry of Environment Environmental Protection Division Skeena

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and proceeding to production. Recent updates from Chieftain are that flow through funding is in place for the project's 2013 exploration campaign and that a new timeline has been set for construction (2014 - Q1 2016), commissioning and production (Q1/Q2 of 2016).

Considering all available information regarding the status of the project, Chieftain Metals Inc., under Section 16 of the EMA is being directed to hire a qualified professional, with experience in aquatic impact assessment and in particular, fisheries impact assessment, to provide the Ministry with a risk assessment of the current mine effluent discharge into the Tulsequah River from the Tulsequah Chief mine site. The study terms of reference is attached, as agreed to by the Ministry, Chieftain and their qualified professional on August 8, 2013. A draft of the assessment report shall be submitted to the Director for review and comment by September 30, 2013 and the final assessment report shall be submitted to the Director by October 31, 2013.

The goal of the risk assessment is to provide the Ministry with an evaluation of the success of the current onsite water management strategies implemented by Chieftain to minimize potential impacts and to gather information regarding the extent of aquatic environmental risk to the Tulsequah River as a result of not operating the interim acid water treatment plant.

Please contact Lisa Torunski at (250) 847-7455 should you have any questions or concerns. We look forward to the update call, to be scheduled for September 9, 2013.

Yours truly,

Ian D Sharpe

Ian Sharpe
For Director, *Environmental Management Act*
Environmental Protection Division
Ministry of the Environment
Ministry of Environmental, EPP

ec: Doug Flynn, Senior Inspector of Mines, Ministry of Energy & Mines, Smithers, BC
Jennifer Stalker, Project Manager, FLNRO, Smithers, BC
Wade Comin, Enforcement Officer, Environment Canada, Whitehorse, Yukon
Deb Portman, Enforcement Officer, Environment Canada, Smithers, BC
Kyle Moselle, Large Project Coordinator, Alaska Dept. of Natural Resources, Juneau
John Ward, Spokesperson, Taku River Tlingit First Nation, Atlin, BC
Eric Morrison, Environmental Manager, Douglas Indian Association, Juneau Alaska

LT ML/lt

Terms of Reference for Risk Assessment
For the Tulsequah Chief Mine

- Provide the details on Chieftain's attempts to mitigate impacts associated with the shutdown of the WTP.

- Provide a summary of mine effluent quality that was discharged to the WTP and is now being discharged to the exfiltration pond, including statistical interpretation of any seasonal or annual trends.

- Describe the Environmental Setting:
  - Map and document all known aquatic resources in the Tulsequah River (in the vicinity of the mine and a reasonable distance downstream – i.e. to the confluence with the Taku).
  - Map and document all potential sensitive habitats in that area – i.e. clear water channels, spawning and rearing areas, and wetlands.

- Identify the zone of influence from the discharge of untreated mine effluent (recognizing that this will include non point source loadings from historical waste rock and tailings disposal). Incorporate the seasonal variability of the zone of influence. Complete the same exercise for when the WTP was operating and compare the results of the two.

- Identify the contaminants of concern and their fate and transport mechanisms at site.
  - Describe the mechanisms of ecotoxicity associated with the contaminants of concern and likely categories of receptors that could be affected. This should include both primary and secondary impact pathways (water column and deposition / remobilization).
  - Using all assessment work completed to date (water quality, sediment, benthics, fish) provide an assessment of the potential for impact on those resources at risk.

- The ecotoxicity interpretations should be based on both lethal and non lethal endpoints.

- Given what is known about the sources, pathways and receptors give an assessment of the possible impacts to aquatic resources on the zone of influence and in the Tulsequah River as a whole.

APPENDIX C

Source Analytical Laboratory Results

PARAMETERS	Unit	28-Jun-08	27-Jul-08	25-Aug-08	21-Sep-08	18-Oct-08	02-Aug-11	04-Sep-11	03-Oct-11	06-Dec-11	23-Apr-12	23-May-12	03-Jun-12	05-Aug-12	12-Sep-12	29-Sep-12	13-Oct-12	28-Oct-12	10-Nov-12	25-Nov-12	09-Dec-12	25-Dec-12	05-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13
Misc. Inorganics																										
Acidity (pH 4.5)	mg/L		0.25	0.25	ND	0.25	0.25							0.25												
Acidity (pH 8.3)	mg/L		3.3	2.0	0.70	1.1	0.25							0.25												
Fluoride (F)	mg/L		0.06	0.06	0.05	0.04																				
Preparation																										
Filter and HNO3 Preservation	N/A		LAB	LAB	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD		FIELD		FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																										
Nitrite (N)	mg/L	0.00050	0.0025	0.042	ND	0.0025																				
Calculated Parameters																										
Nitrate (N)	mg/L	0.0629	0.060	0.010	ND	0.040																				
Misc. Inorganics																										
Alkalinity (Total as CaCO3)	mg/L	17	13	25	23	22	17	22	21	24.4	25.6	22.8	23	17.7	21.1	20.4	20.9	21.3	23.4	22	20	23	18	21.9		25.6
Total Organic Carbon (C)	mg/L	0.25	0.25	0.25	2.1	0.60																				
Alkalinity (PP as CaCO3)	mg/L		0.25	0.25	ND	0.25	0.25	22	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25
Bicarbonate (HCO3)	mg/L		15	31	28	27	21	0.25	26	29.8	31.3	27.8	28	21.6	25.8	24.9	25.5	26.0	28.5	27	25	28	21	26.8		31.2
Carbonate (CO3)	mg/L		0.25	0.25	ND	0.25	0.25	27	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25
Hydroxide (OH)	mg/L		0.25	0.25	ND	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25
Anions								0.25																		
Dissolved Sulphate (SO4)	mg/L	14	13	17	11	10	12	5	9	14	12.1	13.5	15	10.1	9.63	9.71	8.30	9.50	9.78	9.3	9.6	10	9.9	10.9		11.2
Dissolved Chloride (Cl)	mg/L	0.25	0.70	0.50	ND	0.25					0.67	1.7	1.5	0.25	1.4	2.2	0.25	0.25	0.25	0.25	1.5	1.3	4.6	1.9		0.96
Nutrients																										
Ammonia (N)	mg/L		0.0025	0.0050	ND	0.0050	0.67																			
Orthophosphate (P)	mg/L	0.0017	0.0025	0.096	ND	0.078																				
Nitrate plus Nitrite (N)	mg/L		0.060	0.060	ND	0.040																				
Physical Properties																										
Conductivity	uS/cm	71.2	59	80	72	69	64	59	64	76.7	86.0	83.3	85	70.1	60.9	62.6	60.7	66.4	67.2	67	67	69	65	70.3		77.1
pH	pH Units	7.59	7.3	7.6	7.6	7.7	7.6	7.6	7.1	7.45	7.67	7.58	7.7	7.51	7.39	7.47	7.16	7.52	7.49	7.5	7.6	7.4	7.26	7.51		7.81
Physical Properties																										
Total Suspended Solids	mg/L	21.5	120	120	77	100	120		110	13.8	2	15.3	9.0	44.5	53.0	40.0	34.7	15.8	24.8	15	10	4.5	4.0	5.0		2
Total Dissolved Solids	mg/L	64	58	78	70	66																				
Turbidity	NTU	88.1	63	192	109	105					20.2	33.2	35	129												
Calculated Parameters																										
Dissolved Hardness (CaCO3)	mg/L		24	35	31	31	24	27	27	33	36.8	37.4	37		26.7	26.9	26.7	28.7	27.4	29	28	29	28	29.2	30.2	30.2
Total Hardness (CaCO3)	mg/L	33.7	36	40	40	35	41	39	37	39	37.0	37.0	36	44.3	30.4	29.8	33.2	36.1	38.4	35	33	33	32	33.6		32.9
Dissolved Metals by ICPMS																										
Dissolved Aluminum (Al)	ug/L	379	71	90	118	99	59	212	58	68.6	55.3	121	54		59.7	53.5	36.0	30.9	41.0	43	53	57	55	47.2	22.0	20.0
Dissolved Antimony (Sb)	ug/L	0.25	0.070	0.11	0.090	0.17	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.65	0.36	0.44	0.52	0.60	0.60	0.50	0.50	0.63	0.62	0.81	0.66		0.40	0.34	0.37	0.32	0.36	0.39	0.46	0.46	0.50	0.52	0.69	0.64
Dissolved Barium (Ba)	ug/L	25	14	19	16	18	12	18	15	17.4	18.0	23.6	16		13.8	13.5	14.7	16.3	15.1	15	14	16	14	14.4	15.0	15.3
Dissolved Beryllium (Be)	ug/L	0.50	0.0050	0.0050	ND	0.0050	0.050	0.050	0.050	0.050	0.05	0.05	0.050		0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Dissolved Bismuth (Bi)	ug/L	0	0.0025	0.0025	ND	0.0025	0.50	0.50	0.50	0.50	0.5	0.5	0.50		0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Boron (B)	ug/L	50	25	25	ND	25	25	25	25	25	25	25	25		25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.050	0.0080	0.0070	ND	0.071	0.020	0.010	0.020	0.017	0.021	0.045	0.0050		0.005	0.005	0.005	0.005	0.005	0.0050	0.0050	0.024	0.0050	0.0050	0.0050	0.0050
Dissolved Chromium (Cr)	ug/L	0.50	0.050	0.20	0.10	0.30	0.50	0.50	0.50	0.50	0.5	0.5	0.50		0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Cobalt (Co)	ug/L	0.38	0.035	0.034	0.064	0.051	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	1.6	0.17	0.17	0.44	1.6	1.2	0.70	1.2	1.00	1.10	5.95	0.22		1.65	0.64	0.39	0.53	0.25	0.22	0.10	0.62	0.10	0.69	0.10	0.10
Dissolved Iron (Fe)	ug/L	473	19	37	92	59	16	178	26	30.3	27.8	104	7.0		29.4	20.6	18.4	12.0	14.0	12	12	42	13	13.6	2.5	5.2
Dissolved Lead (Pb)	ug/L	0.52	0.045	0.036	0.097	0.20	0.10	0.10	0.10	0.10	0.1	0.54	0.10		0.1	0.1	0.1	0.1	0.1	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Dissolved Lithium (Li)	ug/L	2.5	0.25	0.25	ND	0.80	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	17	1.4	2.7	2.0	4.7	1.0	5.0	1.0	0.50	0.5	3.4	1.4		0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Mercury (Hg)	ug/L	0.010	0.0050	0.0050	ND	0.0050	0.025	0.025	0.025	0.025	0.005	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	2.1	2.4	1.4	1.43 (1)	1.7	2.0	1.0	2.0	2.1	2.2	2.5	2.6		1.4	1.6	1.6	1.6	1.6	1.7	1.8	1.7	1.7	1.7	2.0	2.1
Dissolved Nickel (Ni)	ug/L	1.7	0.26	0.32	0.39	0.68	0.50	0.50	0.50	0.50	0.5	1.4	0.50		1.7	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Selenium (Se)	ug/L	0.50	0.060	0.17	0.15	0.090	0.10	0.10	0.10	0.21	0.20	0.16	0.15		0.14	0.14	0.10	0.14	0.13	0.14	0.12	0.12	0.050	0.14	0.22	0.27
Dissolved Silicon (Si)	ug/L	0	782	640	698	727	700	948	699	919	1080	1120	970		596	628	526	693	693	689	671	793	706	765	803	791
Dissolved Silver (Ag)	ug/L	0.010	0.0025	0.0025	ND	0.0025	0.010	0.010	0.010	0.010	0.01	0.481	0.010		0.01	0.01	0.01	0.01	0.01	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Dissolved Strontium (Sr)	ug/L	0	38	51	44	45	40	42	43	50.1	55.7	54.2	54		41.3	41.2	43.0	45.0	43.7	46	44	46	43	43.2	45.9	46.6
Dissolved Thallium (Tl)	ug/L	0.10	0.0030	0.0060	0.0040	0.0040	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	0.25	0.0050	0.0050	ND	0.040	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Titanium (Ti)	ug/L	24	1.3	2.0	4.1	2.0	2.5	9.0	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.56	0.26	0.41	0.41	0.41	0.40	0.30	0.30	0.39	0.44	0.46	0.46		0.30	0.29	0.28	0.26	0.28	0.33	0.34	0.31	0.33	0.32	0.34	0.33
Dissolved Vanadium (V)	ug/L	1.2	0.10	0.40	ND	0.10	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Project: Tulsequah Chief
Station Name: W10 TULSEQUAH RIVER MAINSTEM U/S OF PROJECT

PARAMETERS	Unit	28-Jun-08	27-Jul-08	25-Aug-08	21-Sep-08	18-Oct-08	02-Aug-11	04-Sep-11	03-Oct-11	06-Dec-11	23-Apr-12	23-May-12	03-Jun-12	05-Aug-12	12-Sep-12	29-Sep-12	13-Oct-12	28-Oct-12	10-Nov-12	25-Nov-12	09-Dec-12	25-Dec-12	05-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13
Dissolved Zinc (Zn)	ug/L	7.2	0.20	0.20	0.80	7.2	2.5	2.5	2.5	2.5	18.1	28.5	2.5		6.2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zirconium (Zr)	ug/L	0	0.050	0.050	ND	0.050	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	11.2	8.4	11	10	9.9	8.0	8.9	9.2	10.9	12.1	12.3	12		8.75	8.95	8.86	9.54	9.04	9.5	9.2	9.8	9.1	9.71	10.0	10.1
Dissolved Magnesium (Mg)	mg/L	1.37	0.79	1.7	1.5	1.4	0.89	1.2	1.1	1.32	1.59	1.63	1.5		1.19	1.11	1.12	1.17	1.18	1.2	1.2	1.2	1.2	1.21	1.26	1.25
Dissolved Potassium (K)	mg/L	1.0	0.85	1.0	0.92	1.0	1.2	0.81	0.90	1.07	1.11	4.13	1.2		0.755	0.725	0.794	0.821	0.813	0.82	0.83	0.85	0.82	0.823	0.999	0.978
Dissolved Sodium (Na)	mg/L	1.0	0.83	0.52	0.47	0.78	0.88	0.50	0.50	0.668	1.04	1.26	1.1		0.514	0.476	0.485	0.526	0.506	0.54	0.52	0.56	0.54	0.582	0.580	0.576
Dissolved Sulphur (S)	mg/L		1.5	4.0	4.0	4.0	4.0	1.5	3.0	4.5	4.9	5.0	5.0		3.1	3.3	3.4	3.5	3.2	3.7	3.1	3.7	3.9	1.5	3.4	3.6
Total Metals by ICPMS																										
Total Aluminum (Al)	ug/L	4,010	3,500	1,480	2,010	1,240	5,320	4,390	2,380	2980	1590	1890	1,490		1190	1210	1380	2500	3350	3,390	2,920	2,160	2,300	2000		161
Total Antimony (Sb)	ug/L	0.25	0.090	0.11	0.11	0.10	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25
Total Arsenic (As)	ug/L	2.0	1.6	1.5	1.4	1.3	3.0	2.5	2.2	1.8	1.04	1.43	0.95		0.97	1.00	1.25	1.37	1.64	1.3	1.3	1.1	1.02	1.11		0.72
Total Barium (Ba)	ug/L	101	75	59	65	54	87	80	88	68	44.3	53.9	37		45.2	47.7	52.8	52.5	67.6	69	59	46	50	46.2		18.6
Total Beryllium (Be)	ug/L	0.50	0.10	0.060	0.070	0.060	0.10	0.10	0.050	0.050	0.05	0.05	0.050		0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.050	0.050		0.050
Total Bismuth (Bi)	ug/L	0	0.11	0.058	0.073	0.037	0.50	0.50	0.50	0.50	0.5	0.5	0.50		0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50		0.50
Total Boron (B)	ug/L	50	25	25	ND	25	25	25	25	25	25	25	25		25	25	25	25	25	25	25	25	25	25		25
Total Cadmium (Cd)	ug/L	0.11	0.10	0.087	0.077	0.083	0.17	0.080	0.21	0.04	0.030	0.053	0.022		0.059	0.064	0.081	0.045	0.023	0.039	0.011	0.028	0.0050	0.027		0.0050
Total Chromium (Cr)	ug/L	6.3	4.7	1.8	3.0	1.4	10	7.0	3.0	5	2.4	2.8	2.5		1.7	1.7	1.7	4.2	5.1	4.9	4.3	2.9	3.1	2.9		0.5
Total Cobalt (Co)	ug/L	2.4	2.5	1.5	1.6	1.2	3.4	2.4	2.5	1.4	0.60	0.76	0.72		1.17	1.09	1.29	1.27	1.63	1.3	1.1	0.82	1.0	0.91		0.25
Total Copper (Cu)	ug/L	4.0	8.0	6.3	6.1	5.6	11	12	17	5.3	2.44	3.39	2.3		5.28	5.04	5.04	4.37	5.58	4.5	4.7	3.2	3.64	3.16		0.53
Total Iron (Fe)	ug/L	4,430	4,610	1,800	2,420	1,390	6,580	5,470	3,290	3100	1330	1620	1,300		1550	1560	1520	2750	3410	2,820	2,540	1,850	1,920	1990		146
Total Lead (Pb)	ug/L	2.7	3.4	2.8	2.6	2.5	3.5	3.1	4.6	1.8	0.69	1.23	0.89		1.91	1.99	4.85	1.41	1.74	1.5	1.3	0.96	1.11	1.14		0.1
Total Lithium (Li)	ug/L	2.5	3.2	1.7	2.0	1.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5
Total Manganese (Mn)	ug/L	102	121	71	70	58	150	108	113	61	25.3	31.8	27		54.8	61.3	56.2	55.6	70.9	58	51	36	42	38.4		3.2
Total Mercury (Hg)	ug/L	0.010	0.0050	0.0050	0.010	0.0050	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025
Total Molybdenum (Mo)	ug/L	2.7	2.6	0.57	0.84	0.97	3.0	2.0	0.50	2	2.2	2.4	2.5		0.5	0.5	1.1	1.8	2.0	2.0	1.8	1.8	1.6	1.5		2.0
Total Nickel (Ni)	ug/L	8.5	7.4	4.7	5.5	4.1	13	9.0	7.0	6	2.6	3.2	3.0		4.4	4.1	4.6	5.0	6.0	5.4	5.4	3.9	4.1	3.5		0.5
Total Selenium (Se)	ug/L	0.50	0.10	0.14	0.12	0.12	0.20	0.10	0.050	0.2	0.20	0.19	0.16		0.05	0.05	0.10	0.16	0.05	0.14	0.11	0.050	0.26	0.22		0.22
Total Silicon (Si)	ug/L	0	7,960	2,540	3,450	2,080	10,300	8,610	3,960	7020	4150	4820	3,680		2080	2300	2450	5130	7100	7,160	6,510	4,950	5,000	4210		1150
Total Silver (Ag)	ug/L	0.030	0.040	0.025	0.031	0.0025	0.040	0.030	0.060	0.010	0.01	0.01	0.010		0.01	0.01	0.030	0.01	0.020	0.010	0.010	0.010	0.027	0.010		0.010
Total Strontium (Sr)	ug/L	0	49	56	54	49	59	52	54	61	58.1	54.0	53		44.9	43.4	50.0	50.7	55.5	55	47	48	48	54.1		49.0
Total Thallium (Tl)	ug/L	0.10	0.047	0.024	0.032	0.022	0.060	0.050	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025
Total Tin (Sn)	ug/L	0.25	0.060	0.010	0.030	0.0050	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5
Total Titanium (Ti)	ug/L	283	209	61	102	47	324	207	120	149	70.5	76.3	55		56.2	53.1	70.8	119	149	156	123	86	90	80.4		6.1
Total Uranium (U)	ug/L	0.91	0.90	0.68	0.70	0.63	0.90	0.50	0.80	0.6	0.50	0.56	0.52		0.44	0.46	0.52	0.42	0.50	0.49	0.43	0.40	0.43	0.50		0.34
Total Vanadium (V)	ug/L	11	9.1	3.3	5.1	2.4	15	11	7.0	7	2.5	5.1	2.5		2.5	2.5	2.5	6.2	8.0	7.7	6.6	5.1	5.4	2.5		2.5
Total Zinc (Zn)	ug/L	18	20	12	13	11	23	18	41	10	5.2	7.7	5.1		9.5	9.6	9.6	12.1	12.9	12	14	7.3	7.4	8.2		2.5
Total Zirconium (Zr)	ug/L		0.050	0.050	0.20	0.050	0.25	0.25	0.25	0.7	0.25	0.25	0.25		0.25	0.25	0.25	0.25	1.02	0.89	1.6	0.25	0.92	0.25		0.25
Total Calcium (Ca)	mg/L	12.1	9.5	12	12	11	10	9.8	11	11.3	11.4	11.3	11	11.1	9.23	9.26	9.88	10.2	10.7	9.9	9.4	9.7	9.3	9.55		10.8
Total Magnesium (Mg)	mg/L	3.13	2.9	2.5	2.5	2.0	3.9	3.5	2.5	2.69	2.05	2.13	2.0	4.04	1.77	1.62	2.08	2.56	2.82	2.6	2.3	2.0	2.1	2.37		1.42
Total Potassium (K)	mg/L	2.5	1.6	1.4	1.6	1.2	2.2	1.8	1.7	1.84	1.44	1.59	1.5		1.01	1.03	1.24	1.46	1.73	1.8	1.5	1.4	1.5	1.56		1.08
Total Sodium (Na)	mg/L	1.0	0.93	0.60	0.65	0.58	1.4	1.1	0.75	0.931	1.09	1.30	1.2		0.546	0.546	0.663	0.859	0.964	0.96	0.89	0.78	0.83	0.877		0.641
Total Sulphur (S)	mg/L		1.5	4.0	5.0	4.0	3.0	1.5	3.0	3.5	4.1	1.5	4.8		1.5	1.5	5.3	1.5	1.5	3.2	1.5	3.4	1.5	3.3		4.5

Values in red were reported as ND (Not Detected) and shown here at 1/2 the method detection limit

PARAMETERS	Unit	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Misc. Inorganics																									
Acidity (pH 4.5)	mg/L																								
Acidity (pH 8.3)	mg/L																								
Fluoride (F)	mg/L																								
Preparation																									
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS								34.7	34.8																
Nitrite (N)	mg/L																								
Calculated Parameters																									
Nitrate (N)	mg/L																								
Misc. Inorganics																									
Alkalinity (Total as CaCO3)	mg/L		24.2		23.4		23.4		23.1		26.0		23.5		22.0		21.4		22.9		22.7		14.5		23.4
Total Organic Carbon (C)	mg/L																								
Alkalinity (PP as CaCO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L		29.6		28.6		28.6		28.1		31.7		28.7		26.9		26.1		27.9		27.7		17.7		28.6
Carbonate (CO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																									
Dissolved Sulphate (SO4)	mg/L		11.8		13.8		14.3		11.8		12.4		12.8		11.5		12.6		13.8		12.8		12.7		11.3
Dissolved Chloride (Cl)	mg/L		1.4		1.2		0.96		0.98		0.58		1.3		1.8		0.96		1.7		0.89		0.5		
Nutrients																									
Ammonia (N)	mg/L																								
Orthophosphate (P)	mg/L																								
Nitrate plus Nitrite (N)	mg/L																								
Physical Properties																									
Conductivity	uS/cm		80.2		78.6		76.3		77.8		79.2		77.3		73.7		74.0		77.9		75.9		59.2		70.7
pH	pH Units		7.63		7.33		7.43		7.48		7.64		7.34		7.58		7.46		7.47		7.43		7.17		7.44
Physical Properties																									
Total Suspended Solids	mg/L		2		2		2		30.0		5.5		10.3		10.3		5.7		12.8		26.8		98		77
Total Dissolved Solids	mg/L																								
Turbidity	NTU																								
Calculated Parameters																									
Dissolved Hardness (CaCO3)	mg/L	31.8	33.4	39.1	34.9	33.7	32.6	33.3	33.2	35.8	34.3	31.7	33.2	33.0	32.0	31.1	29.7	31.4	31.5	31.4	30.8	26.1	24.3	28	28.9
Total Hardness (CaCO3)	mg/L	33.3	35.7	36.9	35.4	35.9	35.5			33.9	36.1	36.8	37.8	38.0	36.0	37.6	36.5	35.5	37.3	41.0	41.2	40.5	46	57.2	52.8
Dissolved Metals by ICPMS																									
Dissolved Aluminum (Al)	ug/L	35.8	31.2	23.9	27.2	31.5	32.4	25.6	42.0	38.5	43.4	49.5	43.6	50.9	51.9	52.6	49.2	43.8	46.7	56.1	61.6	65.4	72.7	53.8	51.8
Dissolved Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.44	0.49	0.49	0.46	0.48	0.43	0.47	0.55	0.52	0.52	0.51	0.56	0.53	0.50	0.52	0.48	0.52	0.48	0.49	0.51	0.57	0.57	0.48	0.46
Dissolved Barium (Ba)	ug/L	16.8	17.1	18.9	18.6	17.7	17.4	17.9	16.4	17.7	17.4	14.8	16.0	15.8	15.3	14.4	15.4	13.9	14.8	15.2	15.2	12	10.6	13.2	14.2
Dissolved Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.014	0.005	0.005	0.011	0.005	0.013	0.015	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.077	0.005	0.005	0.005	0.022	0.017
Dissolved Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	7.8	1.7
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	0.27	0.37	0.1	0.68	0.1	0.45	0.35	0.21	0.1	0.22	0.29	0.34	0.51	0.37	0.23	0.22	0.1	0.1	0.60	0.30	0.27	0.32	0.4	0.28
Dissolved Iron (Fe)	ug/L	12.9	10.9	6.1	8.3	5.8	7.4	6.0	11.1	11.5	9.9	25.3	14.8	12.5	12.7	15.2	11.6	15.3	13.0	14.6	18.7	17.4	22.8	17.4	15.9
Dissolved Lead (Pb)	ug/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.1	1.1	0.5	0.5	0.5	0.5
Dissolved Mercury (Hg)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.005	0.005	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	1.9	2.0	2.1	2.1	2.0	2.2	2.1	2.2	2.3	2.3	2.2	2.1	1.9	2.1	2.3	2.2	2.3	2.4	2.3	2.5	2.4	2.3	14.4	4.3
Dissolved Nickel (Ni)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	48.8	11.1
Dissolved Selenium (Se)	ug/L	0.21	0.19	0.15	0.21	0.22	0.10	0.18	0.17	0.19	0.18	0.19	0.17	0.17	0.14	0.18	0.15	0.20	0.20	0.17	0.15	0.14	0.15	0.15	0.13
Dissolved Silicon (Si)	ug/L	860	867	973	874	902	831	817	828	869	863	866	927	985	970	871	796	795	831	939	966	955	785	746	668
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.032	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Strontium (Sr)	ug/L	48.4	50.0	52.5	52.6	50.5	50.2	51.2	49.4	55.0	54.4	49.9	53.1	52.2	50.4	49.6	51.7	52.5	53.6	48.0	45.9	41.5	35.6	45.4	44.7
Dissolved Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.32	0.35	0.37	0.37	0.41	0.39	0.35	0.40	0.38	0.39	0.39	0.38	0.35	0.35	0.37	0.37	0.39	0.41	0.41	0.44	0.4	0.38	0.35	0.35
Dissolved Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Project: Tulsequah Chief
Station Name: W10 TULSEQUAH RIVER MAINSTEM U/S OF PROJECT

PARAMETERS	Unit	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Dissolved Zinc (Zn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	10.5	11.0	13.2	11.5	11.0	10.6	10.9	11.0	11.9	11.3	10.5	11.0	10.8	10.6	10.1	9.57	10.5	10.6	10.3	10.3	8.84	8.4	9.27	9.46
Dissolved Magnesium (Mg)	mg/L	1.37	1.44	1.51	1.49	1.51	1.51	1.46	1.40	1.50	1.49	1.32	1.39	1.48	1.35	1.41	1.40	1.26	1.24	1.36	1.24	0.98	0.796	1.16	1.28
Dissolved Potassium (K)	mg/L	0.932	0.948	1.01	1.01	1.06	1.08	1.01	0.994	0.973	0.937	0.951	0.945	0.955	0.976	0.995	1.00	1.02	1.02	1.16	1.08	0.893	0.853	0.955	0.93
Dissolved Sodium (Na)	mg/L	0.641	0.681	0.703	0.716	0.746	0.821	0.779	0.826	0.905	0.918	0.910	0.919	0.969	1.04	1.13	1.13	1.10	1.10	1.16	1.07	0.969	0.761	0.661	0.564
Dissolved Sulphur (S)	mg/L	3.8	4.4	4.0	4.4	4.2	4.2	4.1	3.8	4.7	4.3	4.4	4.4	4.2	4.3	3.9	4.0	5.1	4.5	4.6	4.1	4.1	1.5	3.2	4
Total Metals by ICPMS																									
Total Aluminum (Al)	ug/L	889	934	831	712	976	874	1580	562	1320	1560	2170	1730	1880	2190	1810	1840	1440	1670	3200	4140	4760	6660	7850	6530
Total Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Arsenic (As)	ug/L	0.90	0.90	0.75	0.62	0.72	0.68	0.88	0.72	0.90	0.94	1.15	0.96	1.04	1.01	1.02	1.00	1.10	1.16	1.62	1.95	2.52	3.92	3.79	3.19
Total Barium (Ba)	ug/L	30.4	32.5	32.3	29.4	33.0	30.8	38.1	27.0	36.6	40.3	45.7	40.8	42.7	46.7	45.0	43.7	36.0	41.2	60.5	74.3	91	116	129	115
Total Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.2	0.15
Total Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Total Cadmium (Cd)	ug/L	0.005	0.019	0.012	0.017	0.005	0.017	0.022	0.016	0.015	0.014	0.018	0.015	0.033	0.034	0.020	0.026	0.026	0.025	1.52	0.041	0.104	0.127	0.113	0.097
Total Chromium (Cr)	ug/L	1.4	1.6	1.3	1.2	1.5	1.4	2.4	0.5	1.9	2.1	3.1	2.6	2.9	3.1	2.9	2.9	3.2	3.3	4.9	6.1	7.3	10.9	14.3	11.2
Total Cobalt (Co)	ug/L	0.25	0.55	0.25	0.25	0.25	0.25	0.55	0.25	0.54	0.65	0.87	0.69	0.81	0.90	0.83	0.76	0.93	0.96	1.43	1.89	2.5	3.84	3.85	3.24
Total Copper (Cu)	ug/L	1.71	1.90	1.45	1.22	1.63	2.12	2.36	1.63	1.94	2.09	3.00	2.46	10.5	3.77	2.86	3.34	2.97	2.93	4.76	6.08	7.87	14	12.1	10.4
Total Iron (Fe)	ug/L	936	1020	740	674	937	909	1280	671	1180	1320	1760	1430	1830	1920	1680	1600	1880	2250	2980	3870	5400	8270	9380	7700
Total Lead (Pb)	ug/L	0.47	0.52	0.54	0.37	0.47	0.51	0.59	0.47	0.52	0.60	0.80	0.64	1.94	0.84	0.74	0.70	0.82	0.93	1.30	1.81	2.79	4.69	4.12	3.38
Total Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Manganese (Mn)	ug/L	18.3	19.2	13.3	11.9	17.2	16.5	23.2	14.6	21.1	24.2	34.0	27.2	30.9	34.8	31.7	29.2	35.2	39.1	57.2	81.0	113	177	171	140
Total Mercury (Hg)	ug/L	0.025	0.025			0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total Molybdenum (Mo)	ug/L	1.9	2.0	2.1	2.1	2.0	2.1	2.2	1.7	2.1	2.3	2.2	2.2	2.1	2.2	2.4	2.4	2.3	2.5	2.6	2.7	2.5	2.7	5.9	2.3
Total Nickel (Ni)	ug/L	2.0	2.3	1.4	1.3	2.2	2.1	2.3	1.8	2.7	2.7	4.0	3.0	4.0	4.1	3.9	4.0	4.0	4.3	6.4	7.5	9.4	13.2	29.5	13.7
Total Selenium (Se)	ug/L	0.20	0.16	0.17	0.25	0.32	0.20	0.26	0.22	0.16	0.16	0.19	0.19	0.27	0.14	0.13	0.35	0.11	0.22	0.05	0.10	0.16	0.16	0.21	0.19
Total Silicon (Si)	ug/L	2390	2450	2480	2160	2850	2620	4280	1530	3400	4070	5290	4390	5040	5950	4700	5020	3350	3980	8710	9650	9360	12900	14100	13500
Total Silver (Ag)	ug/L	0.01	0.01	0.060	0.039	0.01	0.01	0.029	0.01	0.01	0.01	0.01	0.01	0.248	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.034	0.039	0.043	0.029
Total Strontium (Sr)	ug/L	48.9	53.2	56.9	54.5	55.1	53.5	51.4	51.3	49.6	52.8	54.8	54.8	57.7	53.5	55.6	53.9	56.6	55.6	58.1	58.0	57.5	61.7	71.5	68.2
Total Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.051	0.025	0.077	0.087	0.075
Total Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	8.5	2.5	2.5
Total Titanium (Ti)	ug/L	36.2	43.1	33.2	28.5	39.4	36.5	68.9	24.6	63.7	61.6	95.1	63.5	73.3	104	93.8	93.5	71.5	86.1	149	220	252	389	432	313
Total Uranium (U)	ug/L	0.38	0.39	0.43	0.41	0.41	0.39	0.41	0.44	0.40	0.46	0.53	0.45	0.49	0.45	0.46	0.41	0.49	0.50	0.55	0.58	0.72	0.91	0.84	0.75
Total Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	5.3	2.5	2.5	2.5	2.5	7.9	10.4	12.6	16.1	18.7	16.3
Total Zinc (Zn)	ug/L	7.1	5.5	2.5	2.5	2.5	6.5	7.5	2.5	2.5	2.5	6.3	2.5	10.8	8.0	5.5	7.9	8.6	7.8	14.0	13.8	17.4	31.2	25.5	22.2
Total Zirconium (Zr)	ug/L	0.25	0.25	0.90	0.25	0.25	1.08	0.25	0.25	0.25	0.25	0.82	0.53	0.83	0.25	0.54	0.25	0.25	0.25	1.21	2.07	1.11	0.99	1.28	0.92
Total Calcium (Ca)	mg/L	10.4	11.2	11.6	11.2	11.1	11.1	10.8	10.9	10.6	11.2	10.9	11.4	11.6	10.9	11.3	11.1	10.8	11.4	12.0	11.6	10.4	11.1	13.5	13.2
Total Magnesium (Mg)	mg/L	1.76	1.90	1.90	1.79	1.98	1.90	1.86	1.82	1.78	1.97	2.35	2.24	2.21	2.16	2.24	2.15	2.10	2.14	2.68	3.00	3.54	4.42	5.71	4.85
Total Potassium (K)	mg/L	1.15	1.21	1.29	1.21	1.29	1.23	1.36	1.13	1.25	1.34	1.62	1.50	1.42	1.54	1.53	1.53	1.45	1.42	2.11	2.34	2.31	2.63	3.01	2.73
Total Sodium (Na)	mg/L	0.727	0.779	0.808	0.771	1.16	0.955	0.901	0.892	0.901	1.01	1.33	1.22	1.19	1.29	1.36	1.36	1.33	1.32	1.71	1.74	1.57	1.6	1.79	1.33
Total Sulphur (S)	mg/L	4.6	3.8	3.2	1.5	4.3	5.3	1.5	4.2	3.9	4.0	4.0	3.6	1.5	1.5	3.5	4.1	1.5	4.0	4.7	4.6	1.5	1.5	3.2	3.6

Values in red were reported as ND (Not De

PARAMETERS	Unit	22-Jun-12	05-Aug-12	12-Sep-12	23-Sep-12	29-Sep-12	06-Oct-12	13-Oct-12	21-Oct-12	28-Oct-12	03-Nov-12	06-Nov-12	10-Nov-12	18-Nov-12	25-Nov-12	01-Dec-12	09-Dec-12	16-Dec-12	25-Dec-12	29-Dec-12	05-Jan-13	13-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13
Misc. Inorganics																									
Acidity (pH 4.5)	mg/L			33		6.6		23		37		35.2	33.9				24		24		20		47.3		40.0
Acidity (pH 8.3)	mg/L			152		106		149		188		173	162				155		151		145		192		182
Fluoride (F)	mg/L																								
Preparation																									
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD		FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																									
Nitrite (N)	mg/L																								
Calculated Parameters																									
Nitrate (N)	mg/L																								
Misc. Inorganics																									
Alkalinity (Total as CaCO3)	mg/L			0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Total Organic Carbon (C)	mg/L																								
Alkalinity (PP as CaCO3)	mg/L			0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L			0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Carbonate (CO3)	mg/L			0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L			0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																									
Dissolved Sulphate (SO4)	mg/L	279		343		277		307		379		356	341		334		313		332		356		374		415
Dissolved Chloride (Cl)	mg/L	0.51		5.8		4.0		5.5		4.5		4.3	6.0		7.1		8.3		8.4		9.1		7.4		8.0
Nutrients																									
Ammonia (N)	mg/L																								
Orthophosphate (P)	mg/L																								
Nitrate plus Nitrite (N)	mg/L																								
Physical Properties																									
Conductivity	uS/cm	660		782		717		795		951		906	865		851		863		869		865		965		989
pH	pH Units	3.78		3.4		3.7		3.4		3.3		3.33	3.43		3.4		3.6		3.5		3.5		3.32		3.32
Physical Properties																									
Total Suspended Solids	mg/L	2		43		18		31		27		17.3	30.0		37		31		31		32		32.5		34.0
Total Dissolved Solids	mg/L																								
Turbidity	NTU	0.22																							
Calculated Parameters																									
Dissolved Hardness (CaCO3)	mg/L	196	198	199	214	202	201	209	200	221	231	214	212	224	227	216	228	230	236	229	220	251	233	228	235
Total Hardness (CaCO3)	mg/L	202	210	213		198		199		220		231	235		269		215		226		234		231		242
Dissolved Metals by ICPMS																									
Dissolved Aluminum (Al)	ug/L	12600	8330	9,620	9,100	7,480	8,320	8,750	8,850	10,500	13200	9410	9440	9,390	9,220	8,950	9,430	9,630	9,130	9,000	8,470	9710	11700	11500	11400
Dissolved Antimony (Sb)	ug/L	0.25	1.6	2.1	1.8	3.1	1.2	2.0	1.8	0.50	1.1	0.62	1.6	2.0	2.2	2.2	1.8	0.50	1.0	2.1	2.0	1.9	1.66	1.7	1.4
Dissolved Arsenic (As)	ug/L	0.51	1.52	2.4	1.7	0.95	1.3	3.0	2.2	5.3		1.13	3.62	3.7	3.3	4.6	3.9	0.94	3.0	4.2	3.5	3.85	3.75	3.50	3.63
Dissolved Barium (Ba)	ug/L	18.2	26.0	25	27	25	24	24	26	26	18.4	27.0	23.0	24	24	24	27	24	23	23	23	22.6	21.1	21.2	20.6
Dissolved Beryllium (Be)	ug/L	0.50	0.21	0.41	0.35	0.32	0.27	0.38	0.24	0.33	0.46	0.31	0.30	0.28	0.28	0.30	0.27	0.24	0.20	0.10	0.10	0.29	0.39	0.34	0.34
Dissolved Bismuth (Bi)	ug/L	0.5	1	0.50	1.0	0.50	1.0	1.0	1.0	1.0	1	0.5	1	0.50	0.50	0.50	0.50	1.0	2.0	1.0	1.0	1.0	0.5	1.0	1.0
Dissolved Boron (B)	ug/L	25	50	25	50	25	50	50	50	50	50	25	50	25	25	25	25	50	100	50	50	50	25	50	50
Dissolved Cadmium (Cd)	ug/L	78.5	189	162	191	143	192	180	175	213	228	205	174	189	183	186.0	192.0	184	194	191	185	203	193	195	198
Dissolved Chromium (Cr)	ug/L	0.5	1	1.7	1.0	1.1	1.0	1.0	1.0	1.0	1	1.1	1	1.2	1.2	1.2	1.4	1.0	2.0	1.0	1.0	1.0	1.5	1.0	1.0
Dissolved Cobalt (Co)	ug/L	16.7	5.8	8.9	6.7	7.0	6.5	7.9	6.9	8.1	11.5	5.86	7.1	6.7	6.8	6.6	6.7	5.9	6.2	6.2	5.9	6.5	8.45	7.7	8.1
Dissolved Copper (Cu)	ug/L	4470	9810	8,330	10,800	8,180	9,750	9,370	9,850	12,300	12500	10000	10100	9,850	9,250	9,860	10,600	9,190	10,600	11,000	10,700	9500	10600	10800	11300
Dissolved Iron (Fe)	ug/L	1040	5760	6,180	5,740	3,370	5,230	7,270	5,980	11,100	16400	6840	7290	7,460	7,580	7,830	7,470	3,180	6,570	7,280	6,080	8760	10100	8970	9380
Dissolved Lead (Pb)	ug/L	165	129	147	135	108	139	141	125	152	115	163	133	139	134	134	137	130	129	131	122	151	143	139	145
Dissolved Lithium (Li)	ug/L	12.1	10	10	11	8.1	5.0	5.0	5.0	10	12	9.0	5	11	10	12	12	11	10	5.0	5.0	14	12.2	12	11
Dissolved Manganese (Mn)	ug/L	899	299	463	352	349	340	397	349	404	549	308	348	329	336	314	325	301	293	300	280	304	387	359	357
Dissolved Mercury (Hg)	ug/L	0.025		0.025	0.050	0.025	0.050	0.050	0.050	0.050	0.05		0.05	0.025	0.025	0.025	0.025	0.050	0.10	0.050	0.050			0.050	0.050
Dissolved Molybdenum (Mo)	ug/L	0.5	1	0.50	1.0	0.50	1.0	1.0	1.0	1.0	1	0.5	1	0.50	0.50	0.50	0.50	1.0	2.0	1.0	1.0	1.0	0.5	1.0	1.0
Dissolved Nickel (Ni)	ug/L	27.0	7.6	14	12	11	11	12	10	11	18.5	7.4	9.8	8.5	8.9	8.7	9.1	7.7	7.4	8.3	7.2	8.3	10.2	10.8	11.1
Dissolved Selenium (Se)	ug/L	0.05	0.43	0.42	0.27	0.31	0.26	0.24	0.28	0.25	0.1	0.34	0.1	0.36	0.32	0.34	0.32	0.47	0.44	0.21	0.51	0.56	0.34	0.43	0.27
Dissolved Silicon (Si)	ug/L	15000	5810	7,440	6,980	6,690	5,960	5,810	7,460	6,760	9620	5370	6330	6,450	6,970	5,960	6,160	7,830	6,380	6,190	5,860	6600	7410	6590	6300
Dissolved Silver (Ag)	ug/L	0.092	0.042	0.077	0.075	0.069	0.020	0.020	0.047	0.060	0.070	0.054	0.02	0.057	0.057	0.064	0.063	0.060	0.040	0.020	0.020	0.063	0.050	0.088	0.088
Dissolved Strontium (Sr)	ug/L	235	301	289	334	279	321	328	286	357	370	356	335	375	351	376	393	389	379	395	371	426	377	409	415
Dissolved Thallium (Tl)	ug/L	0.357	0.48	0.32	0.35	0.26	0.32	0.35	0.43	0.59	0.33	0.54	0.43	0.30	0.32	0.37	0.36	0.36	0.39	0.40	0.35	0.39	0.412	0.37	0.40
Dissolved Tin (Sn)	ug/L	2.5	5	2.5	5.0	2.5	5.0	5.0	5.0	5.0	5	2.5	5	2.5	2.5	2.5	2.5	5.0	10	5.0	5.0	5.0	2.5	5.0	5.0
Dissolved Titanium (Ti)	ug/L	2.5	5	2.5	5.0	2.5	5.0	5.0	5.0	5.0	5	2.5	5	2.5	2.5	2.5	2.5	5.0	10	5.0	5.0	5.0	5	5.0	5.0
Dissolved Uranium (U)	ug/L	1.19	6.52	4.8	5.8	4.1	6.3	6.2	5.3	7.1	5.44	8.53	7.39	8.0	7.5	7.7	8.0	7.4	7.3	7.4	6.9	10.7	11.5	11.1	10.6

Project: Tulsequah Chief
Station Name: SE-2 (EXFILTRATION POND)

PARAMETERS	Unit	22-Jun-12	05-Aug-12	12-Sep-12	23-Sep-12	29-Sep-12	06-Oct-12	13-Oct-12	21-Oct-12	28-Oct-12	03-Nov-12	06-Nov-12	10-Nov-12	18-Nov-12	25-Nov-12	01-Dec-12	09-Dec-12	16-Dec-12	25-Dec-12	29-Dec-12	05-Jan-13	13-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13
Dissolved Vanadium (V)	ug/L	2.5	5	2.5	5.0	2.5	5.0	5.0	5.0	5.0	5	2.5	5	2.5	2.5	2.5	2.5	5.0	10	5.0	5.0	5.0	2.5	5.0	5.0
Dissolved Zinc (Zn)	ug/L	19100	47300	39,500	52,000	38,400	46,700	44,900	43,800	54,300	58200	48500	44600	47,100	43,600	44,500	47,800	44,200	51,000	52,000	50,100	45400	47800	48600	52100
Dissolved Zirconium (Zr)	ug/L	0.25	0.5	0.25	0.50	0.25	0.50	0.50	0.50	0.50	0.5	0.25	0.5	0.25	0.25	0.25	0.25	0.50	1.0	0.50	0.50	0.50	0.25	0.50	0.50
Dissolved Calcium (Ca)	mg/L	63.3	68.7	68	75	70	69	72	69	76	76.1	74.2	72.9	77	79	74	79	80	82	80	77	85.1	79.0	77.3	79.4
Dissolved Magnesium (Mg)	mg/L	9.34	6.50	7.4	6.7	6.4	6.7	7.2	6.7	7.7	9.95	6.95	7.27	7.5	7.3	7.4	7.5	7.7	7.4	7.3	7.0	9.29	8.55	8.58	8.80
Dissolved Potassium (K)	mg/L	1.66	0.79	0.97	0.86	1.0	0.80	0.99	0.94	0.87	1.16	0.788	0.89	0.94	0.91	0.89	0.97	1.0	0.92	0.93	0.91	1.10	0.958	0.96	1.00
Dissolved Sodium (Na)	mg/L	3.31	5.21	4.9	5.0	3.7	4.7	5.1	4.6	3.7	4.78	2.86	5.11	6.1	5.7	6.3	6.8	7.3	6.6	6.6	6.7	7.08	6.36	6.52	6.53
Dissolved Sulphur (S)	mg/L	106	127	117	114	108	133	126	120	138	157	136	120	134	127	117	130	135	128	127	123	146	144	147	146
Total Metals by ICPMS																									
Total Aluminum (Al)	ug/L	12900	8810	10,500		7,430		9,160		10,400		10200	9530		11,100		8,740		8,910		8,680		11700		11700
Total Antimony (Sb)	ug/L	0.25	7.0	7.0		9.2		1.9		2.4		2.21	6.5		9.2		7.9		8.3		8.3		6.97		7.3
Total Arsenic (As)	ug/L	0.75	39.6	41		29		2.9		48		25.1	62.8		61		54		49		47		47.3		51.1
Total Barium (Ba)	ug/L	27.9	28.5	114		33		23		27		27.7	27.0		30		26		24		23		22.5		21.1
Total Beryllium (Be)	ug/L	0.48	0.29	0.42		0.31		0.32		0.29		0.33	0.26		0.34		0.29		0.30		0.26		0.44		0.39
Total Bismuth (Bi)	ug/L	0.5	1.25	0.50		0.50		0.50		0.50		0.5	1		1.0		1.0		1.0		1.0		0.5		1.25
Total Boron (B)	ug/L	25	65	25		25		25		25		25	50		50		50		50		50		50		65
Total Cadmium (Cd)	ug/L	80.8	192	167		145		172		202		210	194		220		180		189		184		190		204
Total Chromium (Cr)	ug/L	0.5	1.25	2.3		1.3		1.1		1.5		1.8	1		1.0		1.0		1.0		1.0		1.7		1.25
Total Cobalt (Co)	ug/L	16.9	6.0	9.4		6.5		7.4		7.5		6.43	7.8		8.4		6.2		6.1		6.0		8.72		8.5
Total Copper (Cu)	ug/L	4370	10100	8,640		7,910		9,260		11,000		11500	10300		12,500		10,100		10,200		10,100		9020		12000
Total Iron (Fe)	ug/L	1100	13500	13,400		9,220		6,530		16,200		14400	17900		19,600		16,000		15,600		14,900		18600		19000
Total Lead (Pb)	ug/L	170	142	206		116		132		156		169	150		169		131		132		133		169		153
Total Lithium (Li)	ug/L	13.0	6.5	12		8.9		10		11		11.6	10		12		11		11		11		13.8		6.5
Total Manganese (Mn)	ug/L	895	315	502		352		374		381		328	363		407		295		305		297		385		364
Total Mercury (Hg)	ug/L	0.025	0.05	0.025		0.025		0.025		0.025		0.005	0.05		0.050		0.050		0.050		0.050	0.01	0.050		0.065
Total Molybdenum (Mo)	ug/L	0.5	1.25	0.50		1.1		0.50		0.50		0.5	1		1.0		1.0		1.0		1.0		1.1		1.25
Total Nickel (Ni)	ug/L	26.4	8.3	14		11		12		10		9.4	10.3		11		8.8		7.9		7.8		10.7		10.0
Total Selenium (Se)	ug/L	0.05	0.37	0.39		0.28		0.21		0.27		0.05	0.43		0.46		0.25		0.48		0.24		0.41		0.43
Total Silicon (Si)	ug/L	14900	6100	8,250		6,780		6,590		6,800		5780	7060		7,480		5,830		5,910		6,220		6990		6770
Total Silver (Ag)	ug/L	0.126	0.025	0.37		0.10		0.066		0.090		0.088	0.095		0.24		0.10		0.12		0.020		0.155		0.109
Total Strontium (Sr)	ug/L	244	338	314		282		311		353		378	366		444		371		404		395		384		421
Total Thallium (Tl)	ug/L	0.383	0.42	0.38		0.29		0.33		0.53		0.357	0.34		0.45		0.35		0.39		0.35		0.392		0.39
Total Tin (Sn)	ug/L	2.5	6.5	2.5		2.5		2.5		2.5		2.5	5		5.0		5.0		5.0		5.0		2.5		6.5
Total Titanium (Ti)	ug/L	2.5	6.5	8.4		2.5		2.5		2.5		2.5	5		5.0		5.0		5.0		5.0		2.5		6.5
Total Uranium (U)	ug/L	1.18	7.36	5.2		4.2		5.8		7.0		8.47	8.05		9.3		7.3		7.4		7.2		13.8		11.0
Total Vanadium (V)	ug/L	2.5	6.5	2.5		2.5		2.5		2.5		2.5	5		5.0		5.0		5.0		5.0		2.5		6.5
Total Zinc (Zn)	ug/L	19700	49300	39,800		36,400		42,600		47,200		51700	49900		55,900		46,100		48,000		48,500		40000		52500
Total Zirconium (Zr)	ug/L	0.25	0.65	0.25		0.25		0.25		0.25		0.25	0.5		0.50		0.50		0.50		0.50		0.25		0.65
Total Calcium (Ca)	mg/L	64.8	72.4	72		69		68		75		79.9	81.5		93		74		78		81		78.4		82.4
Total Magnesium (Mg)	mg/L	9.84	7.09	7.8		6.4		7.1		8.2		7.71	7.68		9.0		7.1		7.7		7.5		8.50		8.95
Total Potassium (K)	mg/L	1.74	0.79	1.0		1.0		0.89		0.86		0.813	0.90		1.1		0.87		0.94		0.95		1.15		0.92
Total Sodium (Na)	mg/L	3.45	5.72	5.1		3.7		5.0		4.0		3.35	5.33		7.1		6.1		7.0		6.9		6.04		6.52
Total Sulphur (S)	mg/L	110	132	117		107		116		131		142	131		153		131		131		133		144		152

PARAMETERS	Unit	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Misc. Inorganics																									
Acidity (pH 4.5)	mg/L		33.3		68.7		61.5		53.0		42.5		35.0		31.3		45.1		52.3		37.5		43		23.4
Acidity (pH 8.3)	mg/L		160		232		226		211		187		172		142		193		208		184		190		158
Fluoride (F)	mg/L																								
Preparation																									
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS								250	245																
Nitrite (N)	mg/L																								
Calculated Parameters																									
Nitrate (N)	mg/L																								
Misc. Inorganics																									
Alkalinity (Total as CaCO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Total Organic Carbon (C)	mg/L																								
Alkalinity (PP as CaCO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Carbonate (CO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																									
Dissolved Sulphate (SO4)	mg/L		350		448		475		439		401		366		262		380		378		361		335		347
Dissolved Chloride (Cl)	mg/L		5.3		6.4		7.2		7.6		6.8		4.6		3.5		5.5		5.3		5.6		5.3		
Nutrients																									
Ammonia (N)	mg/L																								
Orthophosphate (P)	mg/L																								
Nitrate plus Nitrite (N)	mg/L																								
Physical Properties																									
Conductivity	uS/cm		895		1110		1100		1010		955		839		693		967		978		913		862		849
pH	pH Units		3.41		3.15		3.14		3.27		3.31		3.47		3.37		3.22		3.23		3.33		3.41		3.41
Physical Properties																									
Total Suspended Solids	mg/L		32.0		41.0		2		39.0		28.5		26.3		24.0		40.7		37.3		35.5		28		30.4
Total Dissolved Solids	mg/L																								
Turbidity	NTU																								
Calculated Parameters																									
Dissolved Hardness (CaCO3)	mg/L	167	218	236	246	252	272	237	246	245	230	223	199	140	148	203	202	215	216	215	209	214	221	201	206
Total Hardness (CaCO3)	mg/L	174	223	240	245	255	254			238	234	218	216	147	153	191	211	220	218	231	223	212	223	204	203
Dissolved Metals by ICPMS																									
Dissolved Aluminum (Al)	ug/L	10200	11600	13700	15000	15500	15000	13400	12900	12900	12600	12300	12300	8420	8560	10900	11500	11000	11000	10500	9980	10600	9830	9080	9090
Dissolved Antimony (Sb)	ug/L	1.25	1.3	1.7	1.5	1.7	1.7	1.2	1.7	1.62	1.5	1.2	0.5	1.18	1.09	1.1	1.6	1.4	1.3	1.1	1.1	1.5	6.1	1.2	1.2
Dissolved Arsenic (As)	ug/L	2.39	2.58	4.83	6.47	6.51	6.27	3.30	4.10	3.67	3.05	2.92	1.26	0.78	1.79	2.63	5.03	4.20	3.57	1.67	1.52	2.5	46.2	1.26	1.37
Dissolved Barium (Ba)	ug/L	20.6	18.6	20.2	19.8	20.1	20.4	20.6	19.7	20.2	20.5	20.1	21.1	26.7	24.4	23.0	24.6	25.7	26.0	28.1	27.4	27.3	27.2	28.4	27.2
Dissolved Beryllium (Be)	ug/L	0.36	0.41	0.41	0.47	0.50	0.42	0.37	0.37	0.37	0.42	0.39	0.38	0.29	0.31	0.38	0.36	0.31	0.27	0.36	0.30	0.33	0.31	0.45	0.37
Dissolved Bismuth (Bi)	ug/L	0.5	1	1	1	1	1	1	1	0.5	1	1	1	0.5	0.5	1	1	1	1	1	1	1	1	1	1
Dissolved Boron (B)	ug/L	25	50	50	50	50	50	50	50	25	50	50	50	25	25	50	50	50	50	50	50	50	50	50	50
Dissolved Cadmium (Cd)	ug/L	106	173	215	223	215	217	212	211	212	197	193	188	97.3	153	220	242	256	244	235	216	218	215	200	200
Dissolved Chromium (Cr)	ug/L	2.1	1	1	2.3	2.6	1	1	1	1.6	2.1	2.1	1	1.8	1.2	1	1	1	1	1	1	1	1	5.9	18.4
Dissolved Cobalt (Co)	ug/L	9.48	9.2	9.5	10.2	10.5	10.1	9.1	9.0	9.72	9.4	9.6	9.5	7.55	6.76	8.0	7.7	7.8	7.8	7.6	7.0	7.3	6.9	6.4	6.1
Dissolved Copper (Cu)	ug/L	6220	9910	12100	13000	12000	12000	12400	12200	12700	11600	10800	11000	5860	8930	12700	13300	12600	12100	12100	11500	11400	10800	9910	9630
Dissolved Iron (Fe)	ug/L	7330	8370	13500	16500	16900	15700	12300	12500	12300	10100	8540	5750	4540	6240	8330	10600	13000	12300	7810	7330	8100	16700	5570	5980
Dissolved Lead (Pb)	ug/L	111	144	164	157	161	152	136	134	133	133	135	132	83.2	118	156	155	152	146	142	134	141	139	140	133
Dissolved Lithium (Li)	ug/L	9.6	11	13	14	14	13	13	14	12.9	12	12	11	7.1	7.9	13	13	11	11	13	12	13	11	10	11
Dissolved Manganese (Mn)	ug/L	420	394	394	410	419	414	385	390	429	441	441	422	312	311	379	366	377	368	336	322	347	330	323	311
Dissolved Mercury (Hg)	ug/L	0.025	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.025	0.05	0.005	0.005	0.025	0.025	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Molybdenum (Mo)	ug/L	0.5	1	1	1	1	1	1	1	0.5	1	1	1	0.5	0.5	1	1	1	1	1	1	1	1	8.2	27.9
Dissolved Nickel (Ni)	ug/L	14.8	13.4	12.3	12.5	12.6	11.8	11.5	11.8	12.9	13.9	15.0	15.0	12.6	10.1	10.9	10.5	10.1	9.7	9.6	9.0	10.1	8.9	41.4	127
Dissolved Selenium (Se)	ug/L	0.18	0.27	0.41	0.41	0.43	0.37	0.29	0.41	0.45	0.34	0.35	0.41	0.05	0.15	0.25	0.26	0.23	0.30	0.1	0.29	0.1	0.41	0.1	0.23
Dissolved Silicon (Si)	ug/L	8030	7960	7570	7620	8150	7180	7120	7450	7470	7750	8870	8800	6470	6890	7390	6830	6410	5990	6150	5940	6570	7000	6580	6190
Dissolved Silver (Ag)	ug/L	0.039	0.050	0.064	0.070	0.054	0.051	0.063	0.056	0.040	0.045	0.073	0.02	0.048	0.052	0.108	0.105	0.02	0.067	0.094	0.052	0.02	0.02	0.02	0.02
Dissolved Strontium (Sr)	ug/L	232	342	393	410	413	415	421	416	428	387	339	278	166	221	310	326	355	368	336	327	326	323	317	312
Dissolved Thallium (Tl)	ug/L	0.228	0.35	0.41	0.42	0.34	0.34	0.34	0.28	0.025	0.41	0.33	0.27	0.166	0.269	0.36	0.38	0.30	0.42	0.44	0.41	0.38	0.38	0.4	0.36
Dissolved Tin (Sn)	ug/L	2.5	5	5	5	5	5	5	5	2.5	5	5	5	2.5	2.5	5	5	5	5	5	5	5	5	5	5
Dissolved Titanium (Ti)	ug/L	2.5	5	5	5	5	5	5	5	2.5	5	5	5	2.5	2.5	5	5	5	5	5	5	5	5	5	5
Dissolved Uranium (U)	ug/L	4.61	9.69	15.6	20.6	24.3	22.5	17.5	14.7	12.9	9.82	8.10	6.10	2.74	4.56	7.49	9.33	10.3	10.7	11.0	9.73	8.91	8.27	8.41	8.13

PARAMETERS	Unit	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Dissolved Vanadium (V)	ug/L	2.5	5	5	5	5	5	5	5	2.5	5	5	5	2.5	2.5	5	5	5	5	5	5	5	5	5	5
Dissolved Zinc (Zn)	ug/L	26800	44100	53800	55400	49700	49700	52900	54900	55300	51900	47900	46200	23600	35800	55000	59200	60600	56900	57400	54400	51800	52900	45400	46000
Dissolved Zirconium (Zr)	ug/L	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	0.5	0.5	0.5	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Calcium (Ca)	mg/L	55.4	73.6	79.1	81.9	83.0	91.3	79.1	82.7	83.4	77.8	75.1	66.4	46.5	49.5	68.0	67.1	72.9	73.3	72.2	70.6	72.7	76.4	68.9	70.9
Dissolved Magnesium (Mg)	mg/L	7.00	8.45	9.44	10.0	10.8	10.6	9.67	9.66	9.00	8.67	8.53	8.08	5.74	5.85	7.96	8.25	8.11	7.94	8.35	7.92	7.79	7.25	7.02	7.12
Dissolved Potassium (K)	mg/L	1.03	1.02	1.04	1.05	1.19	1.18	1.06	1.06	0.986	0.99	1.06	1.03	0.875	0.894	0.81	0.77	0.80	0.79	1.00	0.90	0.87	0.9	0.79	0.82
Dissolved Sodium (Na)	mg/L	3.72	5.34	5.92	6.35	6.77	7.00	6.72	6.90	6.76	5.71	5.11	4.51	2.49	3.32	4.43	4.65	4.59	4.74	5.02	4.89	5.28	4.75	4.59	4.71
Dissolved Sulphur (S)	mg/L	109	140	155	166	159	160	156	150	151	136	145	128	88.5	99.2	129	133	152	144	123	120	139	132	130	118
Total Metals by ICPMS																									
Total Aluminum (Al)	ug/L	10400	11800	13500	14700	15600	14600	14500	13100	12300	12200	12200	13200	9080	8680	10200	11200	11200	11200	12300	10900	10000	9700	9910	10000
Total Antimony (Sb)	ug/L	3.12	3.99	4.7	5.5	5.7	5.8	6.15	6.28	5.9	5.1	4.4	5.1	3.60	3.38	5.62	6.78	6.0	6.1	14.3	7.1	6.2	6.5	6.22	6.84
Total Arsenic (As)	ug/L	24.7	31.4	47.9	52.9	47.0	46.5	45.9	41.3	36.1	34.4	31.8	44.7	21.2	35.3	72.3	76.8	64.7	60.0	142	59.1	45.9	46	45.2	49.3
Total Barium (Ba)	ug/L	49.8	20.6	20.9	20.3	20.8	21.0	20.8	20.7	20.4	21.2	22.3	26.7	64.3	31.1	24.6	67.8	26.8	26.1	58.5	30.1	26.6	28.5	26.3	27.8
Total Beryllium (Be)	ug/L	0.37	0.42	0.45	0.48	0.49	0.42	0.39	0.38	0.37	0.42	0.46	0.46	0.30	0.27	0.30	0.37	0.31	0.24	0.43	0.33	0.3	0.36	0.33	0.27
Total Bismuth (Bi)	ug/L	0.5	0.5	1	1	1	1	0.5	0.5	1	1	1	1	0.5	0.5	0.5	0.5	1	1	1.25	1.25	1	1	0.5	0.5
Total Boron (B)	ug/L	25	25	50	50	50	50	25	25	50	50	50	50	25	25	25	25	50	50	65	65	50	50	25	25
Total Cadmium (Cd)	ug/L	108	176	211	218	218	225	224	208	210	194	188	198	100	153	206	233	261	251	252	234	218	222	203	209
Total Chromium (Cr)	ug/L	2.8	1.7	1	2.4	1	1	2.5	1.9	2.1	2.2	2.1	2.5	2.4	1.7	1.7	1.7	1	1	1.25	1.25	1	1	4.4	6.3
Total Cobalt (Co)	ug/L	9.99	9.12	9.7	10.4	10.4	10.3	9.58	9.03	9.2	9.6	9.2	10.6	7.74	6.91	8.01	8.41	8.4	8.2	8.2	7.6	7.4	6.9	7.25	7.54
Total Copper (Cu)	ug/L	6160	9840	12700	12600	13300	13300	13200	12500	12100	11400	10600	12100	6070	9230	12900	14300	13100	12500	13600	12600	11700	11000	11300	11000
Total Iron (Fe)	ug/L	11200	14100	20900	25000	25100	24900	23900	21700	19400	16700	14500	14400	8930	11900	18100	21700	22800	21600	39000	20900	16200	17000	15500	16500
Total Lead (Pb)	ug/L	118	151	159	159	156	154	138	135	131	137	136	145	103	126	148	164	162	154	151	137	139	147	147	148
Total Lithium (Li)	ug/L	9.7	11.6	13	14	14	14	13.4	12.6	13	12	12	14	7.5	8.4	10.4	11.8	10	10	13	6.5	12	13	10.2	11.3
Total Manganese (Mn)	ug/L	422	400	415	407	432	419	403	390	414	437	430	470	325	327	370	385	403	381	375	347	340	335	342	330
Total Mercury (Hg)	ug/L	0.025	0.025		0.005	0.05	0.05	0.025	0.025	0.05	0.05	0.05	0.05	0.025	0.025	0.025	0.025	0.05	0.05	0.065	0.065	0.05	0.05	0.025	0.025
Total Molybdenum (Mo)	ug/L	0.5	0.5	1	1	1	1	1.3	1.4	1	1	1	1	0.5	0.5	0.5	1.0	1	1	1.25	1.25	1	1	5.8	8.5
Total Nickel (Ni)	ug/L	15.2	13.1	12.5	13.2	13.1	12.7	10.9	11.1	12.5	13.8	14.8	16.5	12.2	10.4	11.3	11.1	10.6	10.0	10.3	9.4	9.6	9.1	30.2	42.7
Total Selenium (Se)	ug/L	0.18	0.36	0.27	0.31	0.1	0.50	0.21	0.23	0.1	0.38	0.1	0.36	0.20	0.25	0.27	0.21	0.57	0.32	0.37	0.125	0.41	0.28	0.28	0.37
Total Silicon (Si)	ug/L	8530	7940	8170	7210	7850	7360	7360	6990	7230	7900	8640	8940	7040	6960	6730	6870	6430	6150	6930	6680	6360	6510	6260	6300
Total Silver (Ag)	ug/L	0.095	0.075	0.068	0.02	0.098	0.093	0.058	0.073	0.185	0.131	0.071	0.058	0.162	0.115	0.090	0.138	0.060	0.02	0.127	0.085	0.045	0.057	0.091	0.064
Total Strontium (Sr)	ug/L	239	354	396	408	430	433	413	414	405	376	332	301	178	222	291	325	365	370	388	365	332	338	324	325
Total Thallium (Tl)	ug/L	0.263	0.366	0.46	0.33	0.37	0.41	0.341	0.352	0.43	0.40	0.34	0.27	0.242	0.345	0.392	0.485	0.32	0.34	0.52	0.45	0.42	0.39	0.502	0.52
Total Tin (Sn)	ug/L	2.5	2.5	5	5	5	5	2.5	2.5	5	5	5	5	2.5	2.5	2.5	2.5	5	5	6.5	6.5	5	5	2.5	2.5
Total Titanium (Ti)	ug/L	17.5	2.5	5	5	5	5	2.5	2.5	5	5	5	5	2.5	2.5	2.5	2.5	5	5	6.5	6.5	5	5	2.5	2.5
Total Uranium (U)	ug/L	4.68	9.95	15.1	20.8	22.0	20.9	17.2	14.9	12.7	10.2	8.00	6.52	2.95	4.91	6.98	9.30	10.9	11.1	10.1	8.98	8.71	9.06	8.81	9.3
Total Vanadium (V)	ug/L	2.5	2.5	5	5	5	5	2.5	2.5	5	5	5	5	2.5	2.5	2.5	2.5	5	5	6.5	6.5	5	5	2.5	2.5
Total Zinc (Zn)	ug/L	26700	43300	54200	52400	55500	55800	58000	54500	54000	48600	45900	48900	23100	36000	49200	55900	60700	59200	63200	60000	54600	53400	50500	51200
Total Zirconium (Zr)	ug/L	0.25	0.25	0.5	0.5	0.5	0.5	0.25	0.25	0.5	0.5	0.5	0.5	0.25	0.25	0.25	0.25	0.5	0.5	0.65	0.65	0.5	0.5	0.25	0.25
Total Calcium (Ca)	mg/L	57.5	75.4	80.7	80.9	85.3	84.5	83.8	82.0	80.8	79.6	73.4	70.9	49.6	51.7	63.6	70.5	74.3	73.6	78.1	75.6	72.9	77.3	69.4	67.9
Total Magnesium (Mg)	mg/L	7.33	8.45	9.35	10.4	10.2	10.4	9.98	9.76	8.81	8.52	8.30	9.45	5.63	5.84	7.74	8.53	8.32	8.28	8.78	8.24	7.32	7.27	7.49	8.25
Total Potassium (K)	mg/L	1.23	1.04	1.07	1.15	1.19	1.04	1.05	1.05	1.02	1.02	1.01	1.17	0.938	0.831	0.834	0.847	0.81	0.83	0.93	0.92	0.8	0.82	0.818	0.838
Total Sodium (Na)	mg/L	3.65	5.40	5.86	6.47	6.38	6.74	6.85	6.90	6.13	5.69	4.92	5.34	2.43	3.36	4.45	4.90	4.80	4.89	5.44	5.52	4.7	4.67	5.88	6.53
Total Sulphur (S)	mg/L	105	142	167	162	177	164	166	156	152	146	137	146	87.5	102	126	140	157	155	156	155	123	126	133	139

Project: Tulsequah Chief
Station Name: W46 TULSEQUAH RIVER MAINSTEM D/S OF MINE

PARAMETERS	Unit	19-Jan-12	09-Feb-12	03-Apr-12	09-Apr-12	23-Apr-12	23-May-12	03-Jun-12	19-Jun-12	22-Jun-12	28-Jun-12	05-Aug-12	12-Sep-12	23-Sep-12	29-Sep-12	06-Oct-12	13-Oct-12	21-Oct-12	28-Oct-12	03-Nov-12	06-Nov-12	06-Nov-12
Misc. Inorganics																						
Acidity (pH 4.5)	mg/L											0.25									0.25	
Acidity (pH 8.3)	mg/L											0.25									1.10	
Fluoride (F)	mg/L																					
Preparation																						
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD			FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																						
Nitrite (N)	mg/L										0.00050											
Calculated Parameters																						
Nitrate (N)	mg/L										0.0632											
Misc. Inorganics																						
Alkalinity (Total as CaCO3)	mg/L	55.8	56.0	51.7	56.3	50.6	39.9	39			22.5		25.5		24.3		30.4		38.7		33.1	36.3
Total Organic Carbon (C)	mg/L										0.25	22.6										
Alkalinity (PP as CaCO3)	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25				0.25	0.25		0.25		0.25		0.25		0.25	0.25
Bicarbonate (HCO3)	mg/L	68.0	68.3	63.1	68.7	61.8	48.7	48				27.6	31.1		29.6		37.1		47.2		40.4	44.3
Carbonate (CO3)	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25				0.25	0.25		0.25		0.25		0.25		0.25	0.25
Hydroxide (OH)	mg/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25				0.25	0.25		0.25		0.25		0.25		0.25	0.25
Anions																						
Dissolved Sulphate (SO4)	mg/L	25.2	56.1	51.2	57.6	25.1	18.9	23	18	15	14.5	11.1	12.4		10.1		13.0		18.4		24.0	20.5
Dissolved Chloride (Cl)	mg/L	3.0	6.8	5.5	5.9	1.9	1.2	0.93	0.90	1.1	0.25	0.25	1.4		1.9		0.54		0.97		1.4	1.6
Nutrients																						
Ammonia (N)	mg/L																					
Orthophosphate (P)	mg/L										0.00050											
Nitrate plus Nitrite (N)	mg/L																					
Physical Properties																						
Conductivity	uS/cm	174	247	237	259	172	131	132	112	109	77.9	75.7	76.5		72.3		86.0		119		129	123
pH	pH Units	7.73	7.80	7.74	7.91	7.92	7.67	7.8	7.8	8.0	7.53	7.54	7.61		7.61		7.41		7.58		7.36	7.66
Physical Properties																						
Total Suspended Solids	mg/L	13.0	2	2	2	2	13.8	2.0	22	136	14	38.5	38.5		31.0		20.7		2		6.5	5.0
Total Dissolved Solids	mg/L										72											
Turbidity	NTU		0.39	0.61		0.85	5.87	5.1	16	85	80.3	108										
Calculated Parameters																						
Dissolved Hardness (CaCO3)	mg/L	80.5	109	98.8		77.3	64.0	64	51	48			32.4	30.2	30.8	35.5	38.8	47.6	57.0	56.5	59.8	54.8
Total Hardness (CaCO3)	mg/L		110	103		72.8	61.1	59	51	62	38	46.5	41.4		36.2		44.6		55.2		55.2	55.6
Dissolved Metals by ICPMS																						
Dissolved Aluminum (Al)	ug/L	9.4	14.3	11.5	12.5	30.5	107	86	23	54	96		44.6	49.9	57.6	31.2	25.9	24.1	15.6	12.7	38.9	19.0
Dissolved Antimony (Sb)	ug/L	0.77	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	1.19	0.94	0.83	0.93	0.68	1.34	1.2	0.91	0.83	0.25		0.48	0.44	0.46	0.52	0.47	0.57	0.61	0.58	0.37	0.64
Dissolved Barium (Ba)	ug/L	37.0	37.8	38.4	36.9	34.5	22.8	18	13	12	22		15.2	14.7	15.6	16.1	17.6	22.2	27.3	23.5	26.2	24.8
Dissolved Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.50		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	50		25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.777	0.527	0.269	0.597	0.626	0.159	0.15	0.050	0.16	0.031		0.005	0.103	0.005	0.012	0.013	0.024	0.036	0.085	1.94	0.072
Dissolved Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	3.82	3.60	1.57	3.13	25.9	7.63	3.5	0.75	8.1	0.50		0.54	6.38	0.57	0.34	0.50	1.12	0.74	0.55	25.6	0.75
Dissolved Iron (Fe)	ug/L	7.2	2.5	5.6	10.4	45.2	148	46	12	21	86		21.3	43.4	28.5	13.3	23.4	13.2	5.5	2.5	13.0	13.7
Dissolved Lead (Pb)	ug/L	0.10	0.1	0.1	0.1	0.51	0.46	0.10	0.10	0.30	0.25		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.22	0.1
Dissolved Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	3.1	4.2	2.4	5.7	3.8	14.3	9.8	7.2	8.0	5.8		2.9	2.2	2.5	3.4	4.7	6.4	3.2	6.1	17.7	9.0
Dissolved Mercury (Hg)	ug/L	0.025	0.025	0.025	0.025	0.005	0.025	0.025	0.025	0.025	0.010		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		
Dissolved Molybdenum (Mo)	ug/L	3.1	3.2	3.5	3.3	3.1	2.1	2.3	2.1	2.1	2.2		1.6	1.7	1.6	1.9	2.1	2.1	2.7	2.4	2.4	2.4
Dissolved Nickel (Ni)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50		0.5	0.5	0.5	1.9	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Selenium (Se)	ug/L	0.42	0.39	0.47	0.45	0.42	0.25	0.30	0.20	0.25	0.50		0.14	0.13	0.16	0.17	0.15	0.17	0.29	0.19	0.18	0.20
Dissolved Silicon (Si)	ug/L	1690	1620	1800	1650	1890	1930	1,610	1,200	1,030	0		712	709	779	762	811	1180	1330	1270	1440	1260
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.010	0.010	0.010	0.010		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Strontium (Sr)	ug/L	118	160	140	152	102	103	109	93	87	0		54.7	50.3	52.3	62.6	68.9	79.6	87.4	89.2	91.9	87.3
Dissolved Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.10		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0.25		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

PARAMETERS	Unit	19-Jan-12	09-Feb-12	03-Apr-12	09-Apr-12	23-Apr-12	23-May-12	03-Jun-12	19-Jun-12	22-Jun-12	28-Jun-12	05-Aug-12	12-Sep-12	23-Sep-12	29-Sep-12	06-Oct-12	13-Oct-12	21-Oct-12	28-Oct-12	03-Nov-12	06-Nov-12	06-Nov-12
Dissolved Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	5.0		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.62	0.56	0.61	0.61	0.63	0.78	0.77	0.53	0.45	0.48		0.35	0.32	0.35	0.37	0.38	0.43	0.49	0.46	0.21	0.48
Dissolved Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0.50		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zinc (Zn)	ug/L	77.3	32.3	18.3	36.1	133	35.8	19	2.5	32	2.5		2.5	28.1	2.5	2.5	2.5	2.5	6.8	2.5		2.5
Dissolved Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	27.4	38.7	34.8	40.5	26.7	22.2	22	18	17	12.9		10.8	10.1	10.3	11.9	13.0	16.0	19.4	19.3	20.6	18.8
Dissolved Magnesium (Mg)	mg/L	2.92	3.06	2.87	3.15	2.55	2.04	2.1	1.7	1.5	1.43		1.34	1.19	1.22	1.41	1.52	1.86	2.11	2.01	2.05	1.94
Dissolved Potassium (K)	mg/L	1.62	1.52	1.62	1.55	1.51	0.604	0.51	0.39	0.38	1.0		0.708	0.676	0.685	0.751	0.799	0.888	1.01	0.936	0.970	0.944
Dissolved Sodium (Na)	mg/L	2.42	2.41	2.38	2.50	2.14	0.923	0.87	0.64	0.64	1.0		0.531	0.484	0.496	0.567	0.605	0.893	1.09	0.977	0.930	0.886
Dissolved Sulphur (S)	mg/L	8.9	19.8	15.5	20.4	10.0	7.1	8.1	5.8	4.9			3.7	3.7	3.9	4.6	4.9	5.5	6.2	6.9	8.5	6.2
Total Metals by ICPMS																						
Total Aluminum (Al)	ug/L		26	20	20	195	637	179	629	3,220	3,170		1220		1470		669		512		1110	1170
Total Antimony (Sb)	ug/L		0.25	0.25	0.25	0.25	0.55	0.25	0.25	1.0	0.25		0.25		0.25		0.25		0.25		0.25	0.25
Total Arsenic (As)	ug/L		1.0	0.9	1.0	1.41	2.95	1.3	2.3	9.5	2.4		1.25		1.25		1.03		0.91		1.17	0.98
Total Barium (Ba)	ug/L		37	37	37	40.5	29.1	19	24	85	87		48.7		50.3		39.1		32.0		37.7	41.6
Total Beryllium (Be)	ug/L		0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.50		0.05		0.05		0.05		0.05		0.05	0.05
Total Bismuth (Bi)	ug/L		0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0		0.5		0.5		0.5		0.5		0.5	0.5
Total Boron (B)	ug/L		25	25	25	25	25	25	25	25	50		25		25		25		25		25	25
Total Cadmium (Cd)	ug/L		0.48	0.30	0.59	0.240	0.185	0.14	0.11	0.32	0.097		0.072		0.056		0.047		0.055		1.80	0.063
Total Chromium (Cr)	ug/L		0.5	0.5	0.5	0.5	1.7	0.50	1.4	8.2	6.4		1.9		2.2		0.5		0.5		1.4	1.5
Total Cobalt (Co)	ug/L		0.25	0.25	0.25	0.25	0.58	0.25	0.54	2.7	2.1		1.14		1.07		0.64		0.25		0.58	0.25
Total Copper (Cu)	ug/L		6.1	4.0	4.7	10.9	7.36	3.4	2.4	8.8	3.5		6.13		4.89		3.34		1.92		90.6	2.33
Total Iron (Fe)	ug/L		39	37	38	425	1110	256	999	5,320	3,790		1570		1780		703		519		909	925
Total Lead (Pb)	ug/L		0.2	0.1	0.1	0.72	0.98	0.47	0.71	3.3	2.2		1.90		1.94		1.22		0.32		2.09	0.50
Total Lithium (Li)	ug/L		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5		2.5		2.5		2.5		2.5		2.5	2.5
Total Manganese (Mn)	ug/L		4	3	6	16.2	34.9	14	30	125	91		55.0		62.5		33.5		11.9		33.9	27.4
Total Mercury (Hg)	ug/L			0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.010		0.025		0.025		0.025		0.025			
Total Molybdenum (Mo)	ug/L		3	3	3	3.2	2.3	2.2	2.1	3.4	2.6		1.0		1.2		1.6		2.3		2.3	2.3
Total Nickel (Ni)	ug/L		0.5	0.5	0.5	1.5	3.1	1.1	2.9	14	7.6		4.2		4.3		2.8		1.0		2.5	6.0
Total Selenium (Se)	ug/L		0.5	0.5	0.5	0.34	0.41	0.27	0.30	0.78	0.50		0.17		0.05		0.12		0.26		0.13	0.17
Total Silicon (Si)	ug/L		1680	1650	1790	2100	2600	1,600	2,360	6,990	0		2250		2980		1760		2170		3320	3560
Total Silver (Ag)	ug/L		0.01	0.01	0.01	0.01	0.01	0.010	0.010	0.030	0.020		0.027		0.01		0.01		0.01		0.01	0.01
Total Strontium (Sr)	ug/L		159	138	154	101	98.3	105	88	99	0		69.3		55.9		78.6		83.2		89.7	90.3
Total Thallium (Tl)	ug/L		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.19	0.10		0.025		0.025		0.025		0.025		0.025	0.025
Total Tin (Sn)	ug/L		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0.25		2.5		2.5		2.5		2.5		2.5	2.5
Total Titanium (Ti)	ug/L		2.5	2.5	2.5	2.5	20.0	2.5	21	83	210		59.9		74.8		24.6		25.4		45.0	47.0
Total Uranium (U)	ug/L		0.6	0.6	0.6	0.71	0.86	0.75	0.62	0.77	0.79		0.55		0.52		0.56		0.50		0.54	0.50
Total Vanadium (V)	ug/L		2.5	2.5	2.5	2.5	2.5	2.5	2.5	13	9.9		2.5		2.5		2.5		2.5		2.5	2.5
Total Zinc (Zn)	ug/L		37	26	38	46.4	23.7	14	8.3	31	15		15.3		9.4		6.6		12.6			8.5
Total Zirconium (Zr)	ug/L		0.25	0.25	0.25	0.25	0.25	0.25	0.25	3.0			0.25		0.25		0.25		0.25		0.25	0.25
Total Calcium (Ca)	mg/L		39.2	36.3	39.6	25.0	21.0	20	17	19	13.7	12.4	13.0		11.3		14.3		18.4		18.2	18.3
Total Magnesium (Mg)	mg/L		2.98	2.95	2.96	2.52	2.11	2.0	2.1	3.3	3.15	3.75	2.18		1.93		2.16		2.25		2.35	2.42
Total Potassium (K)	mg/L		1.43	1.53	1.47	1.46	0.616	0.45	0.55	1.3	2.1		1.11		1.12		1.04		1.14		1.18	1.29
Total Sodium (Na)	mg/L		2.35	2.42	2.27	2.06	0.833	0.73	0.61	0.71	1.0		0.683		0.609		0.758		1.08		1.03	1.08
Total Sulphur (S)	mg/L		19.1	15.4	18.3	8.3	4.7	7.3	3.5	4.1			3.4		1.5		8.1		5.0		6.8	7.1

PARAMETERS	Unit	10-Nov-12	18-Nov-12	25-Nov-12	01-Dec-12	09-Dec-12	16-Dec-12	25-Dec-12	29-Dec-12	05-Jan-13	13-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13
Misc. Inorganics																						
Acidity (pH 4.5)	mg/L																					
Acidity (pH 8.3)	mg/L																					
Fluoride (F)	mg/L																					
Preparation																						
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																					79.1	77.3
Nitrite (N)	mg/L																					
Calculated Parameters																						
Nitrate (N)	mg/L																					
Misc. Inorganics																						
Alkalinity (Total as CaCO3)	mg/L	39.7		42		47		55		53		49.1		55.4		56.3		60.5		60.2		59.9
Total Organic Carbon (C)	mg/L																					
Alkalinity (PP as CaCO3)	mg/L	0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L	48.5		51		57		68		65		59.8		67.6		68.6		73.8		73.4		73.0
Carbonate (CO3)	mg/L	0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L	0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																						
Dissolved Sulphate (SO4)	mg/L	17.0		18		20		22		19		20.7		21.9		20.3		22.7		24.3		22.0
Dissolved Chloride (Cl)	mg/L	1.1		0.56		0.55		1.8		1.4		1.4		1.9		1.9		2.1		1.6		1.7
Nutrients																						
Ammonia (N)	mg/L																					
Orthophosphate (P)	mg/L																					
Nitrate plus Nitrite (N)	mg/L																					
Physical Properties																						
Conductivity	uS/cm	123		130		141		164		146		149		163		164		176		180		174
pH	pH Units	7.76		7.6		7.8		7.6		7.77		7.72		7.65		7.81		7.90		7.92		7.90
Physical Properties																						
Total Suspended Solids	mg/L	2		2.0		2.0		2.0		2.0		2.0		2.0		2		2		2		2
Total Dissolved Solids	mg/L																					
Turbidity	NTU																					
Calculated Parameters																						
Dissolved Hardness (CaCO3)	mg/L	54.5	61	55	60	62	47	80	81	68	66.2	66.5	69.3	70.8	69.4	73.1	79.1	78.1	82.6	94.0	78.7	78.5
Total Hardness (CaCO3)	mg/L	58.9		58		62		75		70		65.7		74.3	70.3	73.3	81.0	80.8	81.6	158		
Dissolved Metals by ICPMS																						
Dissolved Aluminum (Al)	ug/L	15.8	12	16	13	11	11	8.7	11	8.6	18.8	10.3	7.8	6.9	9.8	7.6	7.2	7.4	8.1	6.5	6.3	5.2
Dissolved Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.57	0.59	0.60	0.57	0.59	0.43	0.58	0.62	0.56	0.47	0.74	0.68	0.66	0.78	0.79	0.72	0.76	0.76	0.69	0.64	0.67
Dissolved Barium (Ba)	ug/L	25.4	29	27	29	28	23	36	37	34	32.8	31.5	35.3	35.8	33.5	34.2	39.4	39.0	38.4	39.2	38.5	37.7
Dissolved Beryllium (Be)	ug/L	0.05	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Bismuth (Bi)	ug/L	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.024	0.035	0.073	0.026	0.040	0.042	0.12	0.041	0.040	0.043	0.034	0.038	0.026	0.068	0.064	0.054	0.047	0.194	0.067	0.029	0.036
Dissolved Chromium (Cr)	ug/L	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	0.43	1.1	2.9	0.36	1.0	1.1	1.5	1.1	2.7	4.06	0.90	0.48	0.36	2.58	1.40	1.09	1.15	1.68	1.25	0.39	0.45
Dissolved Iron (Fe)	ug/L	12.1	10	16	13	15	7.6	23	20	7.6	25.4	12.9	9.5	7.1	24.1	17.8	13.3	7.5	5.4	6.4	2.5	8.4
Dissolved Lead (Pb)	ug/L	0.1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	5.6	5.3	6.2	11	14	3.7	20	22	5.1	3.3	3.5	4.2	5.5	5.9	3.3	6.9	4.0	3.8	5.7	1.7	1.8
Dissolved Mercury (Hg)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025			0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	2.5	2.9	2.8	2.8	2.9	2.3	3.3	3.3	3.2	3.0	2.9	3.2	3.1	2.7	2.9	3.2	3.4	3.1	3.3	3.5	3.3
Dissolved Nickel (Ni)	ug/L	1.0	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Selenium (Se)	ug/L	0.26	0.31	0.25	0.37	0.32	0.30	0.40	0.43	0.41	0.30	0.43	0.32	0.36	0.37	0.41	0.43	0.42	0.43	0.40	0.44	0.41
Dissolved Silicon (Si)	ug/L	1320	1,380	1,330	1,370	1,400	1,320	1,890	1,870	1,670	1750	1690	1540	1620	1720	1810	1840	1800	1920	2910	1810	1800
Dissolved Silver (Ag)	ug/L	0.01	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Strontium (Sr)	ug/L	84.9	95	88	93	99	72	121	127	103	103	93.1	104	107	98.7	105	113	116	112	116	115	115
Dissolved Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

PARAMETERS	Unit	10-Nov-12	18-Nov-12	25-Nov-12	01-Dec-12	09-Dec-12	16-Dec-12	25-Dec-12	29-Dec-12	05-Jan-13	13-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13
Dissolved Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.48	0.55	0.52	0.53	0.54	0.40	0.63	0.65	0.59	0.60	0.56	0.61	0.64	0.58	0.62	0.69	0.71	0.76	0.74	0.73	0.71
Dissolved Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zinc (Zn)	ug/L	2.5	5.6	13	2.5	2.5	12	12	5.7	9.2	40.6	7.1	6.2	5	12.9	11.5	10.8	8.4	13.2	12.3	2.5	6.4
Dissolved Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	18.5	21	19	21	21	16	27	27	23	22.3	22.8	23.5	24.0	23.6	24.9	27.0	26.5	28.1	32.4	26.8	26.6
Dissolved Magnesium (Mg)	mg/L	2.02	2.2	2.0	2.2	2.3	1.8	2.9	2.9	2.5	2.56	2.33	2.61	2.63	2.51	2.62	2.82	2.89	3.02	3.16	2.88	2.93
Dissolved Potassium (K)	mg/L	0.985	1.1	1.1	1.1	1.0	0.96	1.4	1.2	1.3	1.41	1.18	1.28	1.29	1.21	1.25	1.44	1.39	1.54	1.52	1.39	1.39
Dissolved Sodium (Na)	mg/L	1.05	1.2	1.3	1.0	1.0	1.2	2.0	1.3	1.5	1.74	1.55	1.84	1.84	1.74	1.78	1.93	1.95	1.95	1.87	1.77	1.76
Dissolved Sulphur (S)	mg/L	5.7	6.8	6.4	6.5	6.1	5.2	8.2	8.2	6.4	5.6	6.9	7.0	6.5	7.0	7.3	7.5	7.6	7.9	7.6	7.5	7.5
Total Metals by ICPMS																						
Total Aluminum (Al)	ug/L	674		231		227		52		50		61.9		22.3	32.5	23.2	17.1	15.8	15.2	25.9	16.6	18.3
Total Antimony (Sb)	ug/L	0.25		0.25		0.25		0.25		0.25		0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Arsenic (As)	ug/L	0.84		0.64		0.63		0.75		0.64		0.84		0.74	0.83	0.85	0.80	0.75	0.77	0.56	0.63	0.66
Total Barium (Ba)	ug/L	37.7		33		34		34		35		32.4		37.4	34.1	35.3	38.7	39.2	39.8	44.8	39.3	37.8
Total Beryllium (Be)	ug/L	0.05		0.050		0.050		0.050		0.050		0.050		0.050	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total Bismuth (Bi)	ug/L	0.5		0.50		0.50		0.50		0.50		0.50		0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Boron (B)	ug/L	25		25		25		25		25		25		25	25	25	25	25	25	119	25	25
Total Cadmium (Cd)	ug/L	0.033		0.037		0.050		0.15		0.032		0.044		0.030	0.076	0.057	0.043	0.040	0.202	0.005	0.034	0.034
Total Chromium (Cr)	ug/L	0.5		1.3		0.50		0.50		0.50		0.50		0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Cobalt (Co)	ug/L	0.25		0.25		0.25		0.25		0.25		0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Copper (Cu)	ug/L	1.44		2.0		3.5		4.2		2.3		1.61		0.57	3.26	1.50	0.90	0.69	1.93	0.1	0.57	0.47
Total Iron (Fe)	ug/L	626		259		363		109		92		109		29.7	56.5	34.0	41.6	28.2	25.0	917	28.3	31.2
Total Lead (Pb)	ug/L	0.31		0.10		0.39		0.24		0.10		0.10		0.10	0.1	0.1	0.1	0.1	0.1	2.19	0.1	0.1
Total Lithium (Li)	ug/L	2.5		2.5		2.5		2.5		2.5		2.5		2.5	2.5	2.5	2.5	2.5	2.5	24.5	2.5	2.5
Total Manganese (Mn)	ug/L	17.1		10		18		21		7.2		5.2		5.9	6.7	3.7	6.9	4.6	3.8	591	2.2	2.0
Total Mercury (Hg)	ug/L	0.025		0.025		0.025		0.025		0.025		0.025		0.025	0.025	0.025			0.025	0.025	0.025	0.025
Total Molybdenum (Mo)	ug/L	2.9		2.8		2.7		3.1		3.1		2.9		3.2	2.8	2.9	2.9	3.2	3.2	0.5	3.3	3.2
Total Nickel (Ni)	ug/L	1.6		0.50		1.8		0.50		2.2		0.50		0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Selenium (Se)	ug/L	0.20		0.27		0.33		0.36		0.42		0.25		0.45	0.35	0.40	0.47	0.47	0.46	0.14	0.43	0.39
Total Silicon (Si)	ug/L	2610		1,670		1,740		1,880		1,730		1720		1910	1730	1820	2030	2000	1900	3450	1850	1730
Total Silver (Ag)	ug/L	0.01		0.010		0.010		0.010		0.010		0.030		0.010	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total Strontium (Sr)	ug/L	92.7		98		94		114		102		110		109	101	106	116	119	116	194	113	112
Total Thallium (Tl)	ug/L	0.025		0.025		0.025		0.025		0.025		0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total Tin (Sn)	ug/L	2.5		2.5		2.5		2.5		2.5		2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Titanium (Ti)	ug/L	26.8		9.5		7.9		2.5		2.5		2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Uranium (U)	ug/L	0.57		0.57		0.53		0.60		0.56		0.70		0.61	0.60	0.62	0.67	0.69	0.71	0.05	0.70	0.69
Total Vanadium (V)	ug/L	2.5		2.5		2.5		2.5		2.5		2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Zinc (Zn)	ug/L	9.3		8.5		14		26		8.5		8.8		5.5	14.3	11.8	8.2	7.5	14.2	2.5	5.9	6.2
Total Zirconium (Zr)	ug/L	0.25		0.25		0.25		0.25		0.25		0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Calcium (Ca)	mg/L	19.7		20		21		26		24		21.8		25.1	23.8	25.0	27.7	27.4	28.0	39.9	26.7	26.2
Total Magnesium (Mg)	mg/L	2.34		2.3		2.3		2.8		2.6		2.71		2.81	2.62	2.63	2.91	2.99	2.83	14.1	3.01	2.89
Total Potassium (K)	mg/L	1.23		1.1		1.0		1.4		1.3		1.40		1.30	1.24	1.27	1.34	1.37	1.46	7.74	1.39	1.35
Total Sodium (Na)	mg/L	1.14		1.2		1.1		2.2		1.4		1.79		1.96	1.80	1.75	1.94	2.00	2.00	34.2	1.81	1.75
Total Sulphur (S)	mg/L	6.2		5.8		5.4		7.7		7.4		6.9		7.1	7.3	6.6	8.0	7.8	8.0	11.0	7.6	7.2

PARAMETERS	Unit	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Misc. Inorganics																	
Acidity (pH 4.5)	mg/L																
Acidity (pH 8.3)	mg/L																
Fluoride (F)	mg/L																
Preparation																	
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																	
Nitrite (N)	mg/L																
Calculated Parameters																	
Nitrate (N)	mg/L																
Misc. Inorganics																	
Alkalinity (Total as CaCO3)	mg/L		57.9		48.6		25.9		28.8		25.7		24.8		21.2		25.4
Total Organic Carbon (C)	mg/L																
Alkalinity (PP as CaCO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L		70.7		59.3		31.6		35.1		31.4		30.2		25.8		31
Carbonate (CO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																	
Dissolved Sulphate (SO4)	mg/L		23.6		19.6		14.7		13.8		15.8		12.7		10.2		13
Dissolved Chloride (Cl)	mg/L		1.8		1.3		1.1		1.3		0.87		0.84		0.67		
Nutrients																	
Ammonia (N)	mg/L																
Orthophosphate (P)	mg/L																
Nitrate plus Nitrite (N)	mg/L																
Physical Properties																	
Conductivity	uS/cm		167		146		88.2		88.9		87.4		82.1		65.9		74.1
pH	pH Units		7.92		7.77		7.65		7.66		7.47		7.42		7.34		7.33
Physical Properties																	
Total Suspended Solids	mg/L		2		2		9.7		7.0		10.3		46.5		109		75.5
Total Dissolved Solids	mg/L																
Turbidity	NTU																
Calculated Parameters																	
Dissolved Hardness (CaCO3)	mg/L	78.3	78.9	73.4	68.7	49.8	40.4	36.1	39.5	36.4	36.5	35.3	34.7	31.1	25.4	30.6	31.5
Total Hardness (CaCO3)	mg/L	79.3	76.8	73.9	63.6	50.8	42.6	41.0	40.6	42.5	42.4	44.3	48.9	48	47.4	58.9	53.4
Dissolved Metals by ICPMS																	
Dissolved Aluminum (Al)	ug/L	5.9	6.2	6.5	11.8	58.9	48.9	46.9	42.9	39.2	36.1	42.9	51.3	53.7	60.4	51.1	45.6
Dissolved Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.69	0.72	0.75	0.77	0.54	0.70	0.64	0.65	0.59	0.59	0.60	0.56	0.61	0.57	0.48	0.47
Dissolved Barium (Ba)	ug/L	39.4	38.9	36.3	31.6	21.8	17.1	16.6	15.9	14.2	15.3	14.1	13.6	12.8	12.3	14.8	14.4
Dissolved Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.035	0.039	0.048	0.128	0.469	0.030	0.015	0.015	0.005	0.005	0.017	0.012	0.005	0.014	0.021	0.019
Dissolved Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.2	0.5
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	0.45	0.64	0.69	3.71	27.0	1.91	0.76	0.65	0.27	0.33	0.40	0.33	0.29	0.32	0.96	0.31
Dissolved Iron (Fe)	ug/L	5.8	5.6	6.1	16.9	63.7	26.3	17.1	12.2	17.6	14.8	9.4	13.6	19.5	22.5	16.3	15
Dissolved Lead (Pb)	ug/L	0.1	0.1	0.1	0.1	0.73	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	1.3	2.5	2.8	5.4	11.8	4.7	3.8	3.1	4.3	2.9	2.8	2.9	3	2.2	2.2	1.8
Dissolved Mercury (Hg)	ug/L	0.025	0.025	0.005	0.005	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	3.5	3.4	3.0	2.5	1.7	2.0	2.2	2.3	2.2	2.4	2.4	2.3	2.4	2.7	3.9	2.6
Dissolved Nickel (Ni)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.6	7.7	4
Dissolved Selenium (Se)	ug/L	0.47	0.51	0.41	0.33	0.20	0.21	0.20	0.18	0.17	0.20	0.15	0.15	0.18	0.13	0.13	0.11
Dissolved Silicon (Si)	ug/L	1780	1870	1860	1910	1800	1350	1060	1120	891	916	956	987	886	869	811	722
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Strontium (Sr)	ug/L	119	118	109	95.1	77.5	66.0	63.8	64.7	65.1	67.2	59.8	53.9	55.2	43.1	52.2	50.6
Dissolved Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

PARAMETERS	Unit	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Dissolved Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.67	0.68	0.61	0.53	0.47	0.49	0.50	0.49	0.42	0.45	0.44	0.43	0.4	0.32	0.37	0.35
Dissolved Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zinc (Zn)	ug/L	6.7	6.5	9.1	28.5	99.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	26.5	26.9	25.2	23.8	17.2	13.6	12.0	13.3	12.4	12.4	11.8	11.8	10.6	8.66	10.2	10.4
Dissolved Magnesium (Mg)	mg/L	2.91	2.85	2.55	2.24	1.69	1.55	1.52	1.52	1.32	1.38	1.41	1.26	1.1	0.917	1.23	1.35
Dissolved Potassium (K)	mg/L	1.32	1.33	1.32	1.15	0.757	0.813	0.836	0.829	0.822	0.858	0.917	0.905	0.8	0.79	0.925	0.867
Dissolved Sodium (Na)	mg/L	1.79	1.92	1.67	1.39	0.901	0.935	0.977	0.983	0.914	0.958	0.959	0.900	0.813	0.73	0.649	0.559
Dissolved Sulphur (S)	mg/L	8.3	8.0	7.8	7.0	5.6	5.1	4.3	4.4	4.8	4.8	4.7	4.0	3.9	3.2	4.9	5.4
Total Metals by ICPMS																	
Total Aluminum (Al)	ug/L	15.7	15.6	34.7	89.1	436	1390	1270	1210	1690	1270	2840	4550	3950	6610	6820	6900
Total Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.66	0.25	0.25	0.25	0.25
Total Arsenic (As)	ug/L	0.70	0.74	0.76	0.97	1.27	1.07	1.16	1.20	2.18	1.19	2.67	3.71	3.2	4.24	4.04	3.49
Total Barium (Ba)	ug/L	39.3	38.7	35.9	31.2	27.9	38.1	36.6	35.0	41.2	35.4	58.4	81.7	76.7	115	121	120
Total Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.16	0.17
Total Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Total Cadmium (Cd)	ug/L	0.037	0.041	0.060	0.127	0.440	0.042	0.025	0.024	0.144	0.029	0.483	0.068	0.091	0.112	0.14	0.101
Total Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	1.9	2.0	2.0	3.4	2.4	4.9	7.8	6.7	10.2	14.1	13.8
Total Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.55	0.56	0.58	0.98	0.73	1.40	2.25	2.36	3.63	3.61	3.08
Total Copper (Cu)	ug/L	0.59	0.75	1.01	5.81	43.4	4.13	2.59	2.87	8.33	2.66	4.84	6.97	7.19	11.5	11.7	10.1
Total Iron (Fe)	ug/L	23.0	26.1	47.3	149	617	1200	1170	1140	2140	1650	2980	4680	4640	7840	7940	7650
Total Lead (Pb)	ug/L	0.1	0.1	0.1	0.21	3.48	0.69	0.56	0.55	1.10	0.75	1.36	2.17	2.63	4.35	3.94	3.4
Total Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Manganese (Mn)	ug/L	1.4	2.4	3.3	7.9	19.4	24.5	24.1	24.7	42.7	31.8	61.2	100	105	174	161	138
Total Mercury (Hg)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total Molybdenum (Mo)	ug/L	3.4	3.3	3.0	2.6	1.8	2.1	2.2	2.2	2.5	2.5	2.8	3.0	2.9	2.8	7.4	2.6
Total Nickel (Ni)	ug/L	0.5	0.5	0.5	0.5	1.3	2.6	2.7	2.9	4.3	3.3	6.6	9.2	8.7	12.6	34.3	13.9
Total Selenium (Se)	ug/L	0.38	0.44	0.34	0.44	0.26	0.18	0.20	0.25	0.30	0.22	0.28	0.32	0.32	0.21	0.27	0.27
Total Silicon (Si)	ug/L	1790	1800	1850	1740	2630	4300	3860	3500	3940	3280	7260	10700	8590	12900	13300	13700
Total Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.025	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.043	0.029	0.021
Total Strontium (Sr)	ug/L	117	109	107	92.1	74.4	67.1	63.6	64.3	70.1	71.5	75.3	76.4	69	68.5	81.1	76.5
Total Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.053	0.078	0.061	0.081	0.082	0.09
Total Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	12.7	48.2	49.5	42.8	88.7	58.6	151	251	205	359	338	307
Total Uranium (U)	ug/L	0.68	0.65	0.60	0.54	0.55	0.60	0.53	0.54	0.56	0.55	0.58	0.67	0.75	0.92	0.99	0.77
Total Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	7.7	11.7	10.6	16	17.8	16.2
Total Zinc (Zn)	ug/L	6.5	6.1	10.3	29.0	110	10.0	6.1	6.1	30.7	8.0	14.0	16.8	17.2	25.7	32.2	21.6
Total Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.66	0.25	0.69	0.25	1.18	2.05	0.66	0.86	1.22	1.24
Total Calcium (Ca)	mg/L	27.0	26.3	25.3	21.7	17.5	13.8	13.1	12.9	13.3	13.5	13.2	14.0	13.5	11.7	15.3	14
Total Magnesium (Mg)	mg/L	2.88	2.67	2.57	2.31	1.73	1.99	1.98	2.04	2.23	2.10	2.74	3.35	3.46	4.44	5.01	4.47
Total Potassium (K)	mg/L	1.36	1.30	1.26	1.16	0.810	1.11	1.16	1.13	1.34	1.23	1.78	2.28	1.92	2.54	2.88	2.82
Total Sodium (Na)	mg/L	1.79	1.79	1.63	1.41	0.894	1.05	1.10	1.09	1.17	1.20	1.46	1.67	1.33	1.65	1.6	1.42
Total Sulphur (S)	mg/L	7.4	7.5	6.9	6.5	4.7	1.5	4.4	4.4	4.5	6.2	4.5	4.3	3.5	1.5	3.9	4

Project: Tulsequah Chief
Station Name: W51 TULSEQUAH RIVER NEAR FIELD DOWNSTREAM

PARAMETERS	Unit	19-Jun-12	06-Aug-12	12-Sep-12	23-Sep-12	29-Sep-12	06-Oct-12	13-Oct-12	21-Oct-12	28-Oct-12	03-Nov-12	06-Nov-12	10-Nov-12	18-Nov-12	25-Nov-12	01-Dec-12	09-Dec-12	16-Dec-12	25-Dec-12	29-Dec-12	05-Jan-13	13-Jan-13	19-Jan-13	26-Jan-13	02-Feb-13
Misc. Inorganics																									
Acidity (pH 4.5)	mg/L		0.25									0.25													
Acidity (pH 8.3)	mg/L		0.25									1.10													
Fluoride (F)	mg/L																								
Preparation																									
Filter and HNO3 Preservation	N/A	FIELD		FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																									
Nitrite (N)	mg/L																								
Calculated Parameters																									
Nitrate (N)	mg/L																								
Misc. Inorganics																									
Alkalinity (Total as CaCO3)	mg/L		22.2	23.6		22.9		24.9		38.0		33.1	37.1		39		43		55		51		44.7		54.9
Total Organic Carbon (C)	mg/L																								
Alkalinity (PP as CaCO3)	mg/L		0.25	0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L		27.1	28.7		27.9		30.4		46.3		40.4	45.3		47		52		68		63		54.6		67.0
Carbonate (CO3)	mg/L		0.25	0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L		0.25	0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																									
Dissolved Sulphate (SO4)	mg/L	15	12.7	14.2		14.5		20.3		26.6		24.0	32.8		27		27		23		22.6		33.2		32.2
Dissolved Chloride (Cl)	mg/L	0.65	0.25	1.2		2.0		0.25		1.1		1.4	1.4		0.95		1.1		1.5		1.8		1.6		1.8
Nutrients																									
Ammonia (N)	mg/L																								
Orthophosphate (P)	mg/L																								
Nitrate plus Nitrite (N)	mg/L																								
Physical Properties																									
Conductivity	uS/cm	107	81.1	80.2		79.5		94.7		143		129	156		146		150		166		154		169		178
pH	pH Units	7.7	7.50	7.49		7.56		7.05		7.81		7.36	7.55		7.5		7.5		7.8		7.7		7.36		7.70
Physical Properties																									
Total Suspended Solids	mg/L	23	67.5	44.0		48.3		31.3		7.0		6.5	6.5		4.8		2.0		2.0		2.0		2.0		2.0
Total Dissolved Solids	mg/L																								
Turbidity	NTU	16	109																						
Calculated Parameters																									
Dissolved Hardness (CaCO3)	mg/L	50		33.6	30.6	32.4	34.6	41.6	51.7	61.1	57.6	59.8	62.2	64	73	63	69	68	75	83	71	76.6	72.1	74.1	73.8
Total Hardness (CaCO3)	mg/L	50	48.4	42.4		37.4		45.9		57.5		55.2	63.4		63		63		75		72		74.1		80.1
Dissolved Metals by ICPMS																									
Dissolved Aluminum (Al)	ug/L	27		48.0	64.6	84.1	27.7	21.8	22.5	38.9	36.2	38.9	57.5	46	27	28	23	49	26	20	24	45.6	74.3	56.0	54.0
Dissolved Antimony (Sb)	ug/L	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.83		0.34	0.39	0.22	0.28	0.22	0.17	0.12	0.42	0.37	0.13	0.19	0.12	0.20	0.30	0.13	0.40	0.44	0.33	0.18	0.15	0.18	0.29
Dissolved Barium (Ba)	ug/L	13		17.8	17.2	19.2	16.9	21.0	25.5	27.7	25.0	26.2	26.5	29	31	30	31	31	34	38	34	33.1	31.4	33.8	35.5
Dissolved Beryllium (Be)	ug/L	0.050		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Dissolved Bismuth (Bi)	ug/L	0.50		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Boron (B)	ug/L	25		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.068		1.16	0.589	1.06	1.56	2.27	4.41	5.22	1.41	1.94	7.26	4.0	8.7	3.8	3.5	5.8	1.2	1.4	1.7	6.35	5.94	5.62	3.24
Dissolved Chromium (Cr)	ug/L	0.50		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Cobalt (Co)	ug/L	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	1.5		15.0	10.7	8.07	14.8	20.1	61.5	84.4	23.3	25.6	183	95	217	82	72	149	40	48	54	187	174	165	114
Dissolved Iron (Fe)	ug/L	13		31.1	45.7	81.6	7.5	14.7	6.8	6.8	12.5	13.0	14.6	7.4	6.9	6.8	6.8	7.7	17	13	76	9.0	18.9	13.4	7.3
Dissolved Lead (Pb)	ug/L	0.10		0.1	0.33	0.1	0.1	0.1	0.1	0.39	0.1	0.22	0.92	0.44	0.81	0.25	0.10	0.57	0.10	0.10	0.10	0.68	0.77	0.59	0.50
Dissolved Lithium (Li)	ug/L	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	7.5		7.6	4.7	8.7	8.1	12.2	21.4	18.8	11.8	17.7	26.5	17	25	22	23	19	22	24	10	17.8	21.7	18.9	14.0
Dissolved Mercury (Hg)	ug/L	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025			0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	2.2		1.5	1.8	1.6	1.8	2.0	2.0	2.4	2.4	2.4	2.3	2.7	2.8	2.8	2.9	2.8	3.1	3.2	3.2	3.0	2.5	3.0	3.1
Dissolved Nickel (Ni)	ug/L	0.50		0.5	0.5	0.5	0.5	0.5	1.6	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dissolved Selenium (Se)	ug/L	0.19		0.15	0.13	0.05	0.15	0.13	0.17	0.24	0.22	0.18	0.21	0.31	0.30	0.29	0.29	0.31	0.36	0.44	0.38	0.26	0.37	0.31	0.36
Dissolved Silicon (Si)	ug/L	1,180		757	746	861	807	873	1370	1490	1360	1440	1650	1,570	1,780	1,540	1,550	1,980	1,790	2,000	1,750	1940	2000	1790	1730
Dissolved Silver (Ag)	ug/L	0.010		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Dissolved Strontium (Sr)	ug/L	91		56.2	51.0	53.7	61.4	72.9	84.4	95.0	91.8	91.9	95.2	101	109	101	110	101	117	129	107	114	110	114	112
Dissolved Thallium (Tl)	ug/L	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Titanium (Ti)	ug/L	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.54		0.22	0.25	0.24	0.11	0.05	0.05	0.05	0.23	0.21	0.05	0.15	0.050	0.050	0.24	0.14	0.53	0.57	0.43	0.27	0.23	0.30	0.39
Dissolved Vanadium (V)	ug/L	2.5		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Fluoride (F)	mg/L																								
Dissolved Zinc (Zn)	ug/L	6.9		289	152	241	367	544	1040	1230	310	434	1830	943	2,070	903	791	1,370	283	340	410	1530	1480	1350	800
Dissolved Zirconium (Zr)	ug/L	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	17		11.1	10.2	10.8	11.6	14.0	17.3	20.8	19.6	20.6	21.1	22	24	22	23	23	26	28	24	26.4	24.4	25.0	25.0
Dissolved Magnesium (Mg)	mg/L	1.7		1.40	1.27	1.28	1.35	1.62	2.08	2.21	2.07	2.05	2.33	2.3	2.5	2.4	2.4	2.6	2.7	3.0	2.6	2.60	2.72	2.83	2.77
Dissolved Potassium (K)	mg/L	0.43		0.740	0.714	0.718	0.666	0.819	1.04	0.998	0.932	0.970	0.995	1.1	1.2	1.1	1.1	1.2	1.1	1.1	1.2	1.23	1.25	1.26	1.25
Dissolved Sodium (Na)	mg/L	0.65		0.564	0.587	0.526	0.556	0.672	1.61	1.25	1.04	0.930	1.23	1.4	1.7	1.2	1.2	1.8	1.4	1.4	1.5	1.80	1.76	1.85	1.78
Dissolved Sulphur (S)	mg/L	5.6		5.0	3.7	4.9	6.2	6.5	9.4	9.8	7.4	8.5	11.3	8.5	13	9.2	9.0	11	7.9	9.1	8.7	9.3	10.7	11.5	9.1
Total Metals by ICPMS																									
Total Aluminum (Al)	ug/L	684		1380		1220		755		742		1110	1030		436		458		108		135		503		252
Total Antimony (Sb)	ug/L	0.25		0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Total Arsenic (As)	ug/L	2.8		1.36		1.20		1.08		0.94		1.17	1.19		0.90		0.96		0.86		0.80		0.92		0.83
Total Barium (Ba)	ug/L	26		50.4		44.9		36.0		30.7		37.7	34.8		31		30		34		35		31.7		36.6
Total Beryllium (Be)	ug/L	0.050		0.05		0.05		0.05		0.05		0.05	0.05		0.050		0.050		0.050		0.050		0.050		0.050
Total Bismuth (Bi)	ug/L	0.50		0.5		0.5		0.5		0.5		0.5	0.5		0.50		0.50		0.50		0.50		0.50		0.50
Total Boron (B)	ug/L	25		25		25		25		25		25	25		25		25		25		25		25		25
Total Cadmium (Cd)	ug/L	0.12		1.51		1.38		2.55		4.77		1.80	7.61		3.6		3.1		1.4		1.7		5.81		3.59
Total Chromium (Cr)	ug/L	1.9		2.0		1.7		0.5		0.5		1.4	0.5		0.50		0.50		0.50		0.50		0.50		0.50
Total Cobalt (Co)	ug/L	0.67		1.26		1.05		0.74		0.25		0.58	0.65		0.25		0.25		0.25		0.25		0.25		0.25
Total Copper (Cu)	ug/L	4.4		79.6		73.8		122		220		90.6	378		188		161		64		84		314		182
Total Iron (Fe)	ug/L	1,040		1710		1540		756		612		909	672		289		378		155		123		263		96.2
Total Lead (Pb)	ug/L	0.85		3.28		2.93		3.34		4.22		2.09	7.70		3.1		2.5		1.0		1.3		5.41		2.32
Total Lithium (Li)	ug/L	2.5		2.5		2.5		2.5		2.5		2.5	2.5		2.5		2.5		2.5		2.5		2.5		2.5
Total Manganese (Mn)	ug/L	33		61.4		62.0		38.5		25.9		33.9	36.1		21		25		24		11		23.4		15.3
Total Mercury (Hg)	ug/L	0.025		0.025		0.025		0.025		0.025			0.025		0.025		0.025		0.025		0.025		0.025		0.025
Total Molybdenum (Mo)	ug/L	2.2		1.2		1.1		1.5		2.4		2.3	2.5		2.6		2.6		3.1		3.2		2.9		3.2
Total Nickel (Ni)	ug/L	3.3		5.1		3.8		2.3		1.4		2.5	1.8		1.2		2.2		0.50		0.50		0.50		0.50
Total Selenium (Se)	ug/L	0.32		0.12		0.11		0.05		0.19		0.13	0.16		0.22		0.25		0.33		0.30		0.39		0.49
Total Silicon (Si)	ug/L	2,540		2380		2480		1840		2260		3320	2710		1,890		1,990		1,780		1,810		1970		2080
Total Silver (Ag)	ug/L	0.010		0.020		0.01		0.01		0.01		0.01	0.01		0.010		0.010		0.010		0.010		0.010		0.010
Total Strontium (Sr)	ug/L	88		70.1		56.1		76.1		89.0		89.7	97.2		97		94		116		105		107		117
Total Thallium (Tl)	ug/L	0.025		0.025		0.025		0.025		0.025		0.025	0.025		0.025		0.025		0.025		0.025		0.025		0.025
Total Tin (Sn)	ug/L	2.5		2.5		2.5		2.5		2.5		2.5	2.5		2.5		2.5		2.5		2.5		2.5		2.5
Total Titanium (Ti)	ug/L	20		59.8		50.5		23.6		63.7		45.0	20.1		7.3		11		2.5		2.5		2.5		2.5
Total Uranium (U)	ug/L	0.66		0.59		0.57		0.60		0.60		0.54	0.78		0.63		0.59		0.64		0.61		0.91		0.72
Total Vanadium (V)	ug/L	2.5		2.5		2.5		2.5		2.5		2.5	2.5		2.5		2.5		2.5		2.5		2.5		2.5
Total Zinc (Zn)	ug/L	18		355		320		559		1050		432	1750		888		766		320		422		1430		890
Total Zirconium (Zr)	ug/L	0.25		0.25		0.25		0.25		0.25		0.25	0.25		0.25		0.25		0.25		0.25		0.25		0.25
Total Calcium (Ca)	mg/L	16	13	13.2		12.0		14.9		19.3		18.2	21.2		22		21		26		24		24.6		27.3
Total Magnesium (Mg)	mg/L	2.3	3.9	2.26		1.78		2.11		2.29		2.35	2.51		2.3		2.3		2.8		2.6		3.07		2.93
Total Potassium (K)	mg/L	0.63		1.10		1.03		1.01		1.07		1.18	1.16		1.1		0.98		1.2		1.3		1.45		1.28
Total Sodium (Na)	mg/L	0.69		0.707		0.584		0.784		1.15		1.03	1.27		1.3		1.1		1.4		1.5		1.97		1.88
Total Sulphur (S)	mg/L	4.0		4.2		3.8		9.1		7.5		6.8	10.8		8.1		6.8		8.4		7.9		11.3		9.9

Values in red were reported as ND (Not Detected) and shown here at 1/2 the method detection limit

PARAMETERS	Unit	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Misc. Inorganics																									
Acidity (pH 4.5)	mg/L																								
Acidity (pH 8.3)	mg/L																								
Fluoride (F)	mg/L																								
Preparation																									
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS								85.8	83.9																
Nitrite (N)	mg/L																								
Calculated Parameters																									
Nitrate (N)	mg/L																								
Misc. Inorganics																									
Alkalinity (Total as CaCO3)	mg/L		51.6		56.3		56.5		55.9		50.9		6.36		23.1		25.0		26.0		25.3		20.8		25.7
Total Organic Carbon (C)	mg/L																								
Alkalinity (PP as CaCO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L		63.0		68.7		68.9		68.2		62.1		7.76		28.2		30.5		31.7		30.9		25.4		31.3
Carbonate (CO3)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																									
Dissolved Sulphate (SO4)	mg/L		38.2		33.6		37.7		35.3		41.8		87.2		19.2		18.7		17.6		14.3		11.1		12.4
Dissolved Chloride (Cl)	mg/L		2.0		2.0		1.7		2.0		2.0		1.1		1.3		0.88		1.4		1.1		0.25		
Nutrients																									
Ammonia (N)	mg/L																								
Orthophosphate (P)	mg/L																								
Nitrate plus Nitrite (N)	mg/L																								
Physical Properties																									
Conductivity	uS/cm		186		191		195		192		194		214		101		94.8		92.9		84.7		67.3		76.1
pH	pH Units		7.65		7.72		7.81		7.72		7.77		6.67		7.54		7.45		7.59		7.42		7.32		7.47
Physical Properties																									
Total Suspended Solids	mg/L		2		2		2		2		2		12.5		8.3		7.0		6.8		48.3		92.7		78
Total Dissolved Solids	mg/L																								
Turbidity	NTU																								
Calculated Parameters																									
Dissolved Hardness (CaCO3)	mg/L	89.1	78.5	84.7	82.4	84.5	99.5	84.4	81.5	83.9	83.2	89.1	79.6	68.3	43.2	40.4	39.7	37.1	37.9	36.4	34.0	31.7	25.9	32	31.3
Total Hardness (CaCO3)	mg/L	84.5	80.2	86.5	86.2	85.7	86.0			81.7	83.9	94.7	78.1	65.6	45.1	44.6	48.1	44.5	41.0	46.2	48.8	47.1	48.2	54.2	57.8
Dissolved Metals by ICPMS																									
Dissolved Aluminum (Al)	ug/L	54.1	55.7	69.5	35.0	38.3	57.3	43.6	49.4	32.6	41.1	23.8	154	1550	56.9	46.4	52.8	38.2	32.8	50.0	56.2	53.6	53.3	45.1	46.9
Dissolved Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.05	0.14	0.12	0.15	0.17	0.16	0.16	0.15	0.20	0.14	0.05	0.05	2.04	0.30	0.17	0.31	0.44	0.40	0.46	0.47	0.53	0.45	0.42	0.38
Dissolved Barium (Ba)	ug/L	31.4	33.3	36.1	38.3	39.6	38.5	37.5	37.4	38.7	37.4	35.4	33.5	25.2	18.8	18.4	17.6	15.6	16.6	15.4	15.3	13.5	13.3	15.6	15.9
Dissolved Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	16.4	6.31	9.25	5.33	4.63	5.22	5.38	6.31	4.36	7.78	14.8	25.2	15.8	3.39	3.79	2.39	0.952	1.12	0.623	0.443	0.32	0.2	0.256	0.248
Dissolved Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.6	3.4	10.9
Dissolved Cobalt (Co)	ug/L	1.62	0.25	0.59	0.25	0.25	0.25	0.25	0.25	0.25	0.51	1.02	2.43	1.41	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	565	206	230	166	148	189	178	200	150	246	220	1190	847	60.2	47.4	31.2	8.53	9.66	3.52	2.85	2.49	1.53	2.09	1.46
Dissolved Iron (Fe)	ug/L	34.6	12.6	14.5	6.8	6.6	8.1	6.5	6.5	2.5	7.6	10.2	116	1520	41.4	26.8	27.3	21.0	16.3	8.3	17.0	20.2	16	16.4	17.8
Dissolved Lead (Pb)	ug/L	0.47	0.94	0.58	0.31	0.32	0.67	0.49	0.55	0.34	0.50	0.30	5.30	16.1	0.38	0.31	0.21	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	74.7	22.0	28.8	16.0	16.0	19.0	17.3	18.6	12.7	26.4	50.4	120	68.0	14.4	13.1	8.4	6.7	5.5	4.6	4.8	4.4	3.7	3.5	3.3
Dissolved Mercury (Hg)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.005	0.005	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	1.3	2.7	2.9	3.1	3.2	3.1	3.2	3.3	3.4	3.1	2.7	0.5	1.5	2.0	2.1	2.2	2.1	2.3	2.3	2.3	2.3	6.5	7.8	20.4
Dissolved Nickel (Ni)	ug/L	2.7	0.5	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.8	3.7	2.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	16.9	23	71.5
Dissolved Selenium (Se)	ug/L	0.35	0.35	0.37	0.43	0.46	0.26	0.42	0.46	0.45	0.47	0.32	0.19	0.18	0.12	0.16	0.19	0.15	0.05	0.13	0.14	0.15	0.12	0.12	0.13
Dissolved Silicon (Si)	ug/L	2580	2040	2100	1960	2040	2010	2020	1920	1970	2110	2490	3570	2850	1340	1200	1140	927	971	998	966	990	809	845	746
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Strontium (Sr)	ug/L	120	115	125	123	124	122	123	124	126	128	129	107	94.6	71.2	69.5	69.1	65.7	68.5	60.7	55.4	52.9	44.6	52.9	52.2
Dissolved Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	5.2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.05	0.25	0.22	0.32	0.43	0.40	0.30	0.31	0.34	0.23	0.05	0.25	0.91	0.34	0.23	0.35	0.37	0.35	0.36	0.39	0.38	0.34	0.33	0.29
Dissolved Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Fluoride (F)	mg/L																								
Dissolved Zinc (Zn)	ug/L	4070	1570	2250	1260	1050	1260	1310	1550	1050	2060	3370	5770	3660	799	858	527	196	237	107	74.9	63.6	43.7	42.6	40.9
Dissolved Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	30.1	26.6	28.8	28.0	28.6	34.3	28.8	27.5	28.6	28.2	30.3	26.9	23.2	14.5	13.4	13.2	12.6	12.8	12.2	11.5	10.8	8.77	10.7	10.4
Dissolved Magnesium (Mg)	mg/L	3.39	2.90	3.11	3.05	3.18	3.35	3.04	3.11	3.02	3.14	3.28	2.99	2.53	1.70	1.66	1.62	1.35	1.41	1.43	1.30	1.12	0.97	1.29	1.29
Dissolved Potassium (K)	mg/L	1.16	1.25	1.30	1.38	1.48	1.45	1.38	1.40	1.32	1.32	1.33	0.954	0.804	0.812	0.831	0.817	0.821	0.869	0.902	0.933	0.827	0.84	0.89	0.865
Dissolved Sodium (Na)	mg/L	1.91	1.87	1.93	2.01	2.04	1.91	2.04	1.99	1.91	2.09	1.97	1.55	1.16	1.03	1.05	1.02	0.940	0.975	0.981	0.931	0.785	0.767	0.662	0.553
Dissolved Sulphur (S)	mg/L	25.1	13.0	15.0	11.5	11.2	12.4	11.6	11.9	10.4	13.8	21.3	29.8	19.4	6.5	7.1	5.9	6.0	5.4	4.8	4.6	4.6	3.2	4.1	3.7
Total Metals by ICPMS																									
Total Aluminum (Al)	ug/L	1720	500	1070	388	342	445	433	634	293	572	3610	2550	48.7	1520	1560	1300	2040	1260	3130	4510	4190	6960	6760	6430
Total Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.61	0.61	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Arsenic (As)	ug/L	1.87	0.91	2.63	1.27	1.11	0.94	0.99	1.53	0.92	1.15	4.28	0.81	0.11	1.31	1.36	1.52	2.36	1.36	2.81	3.86	3.18	4.29	3.54	3.69
Total Barium (Ba)	ug/L	33.6	34.8	38.8	38.8	39.7	39.2	39.3	37.8	40.4	37.2	40.9	34.6	22.3	33.8	36.1	32.8	44.4	33.7	56.5	81.2	76.9	116	119	118
Total Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.11	0.18	0.17	0.16
Total Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Total Cadmium (Cd)	ug/L	16.5	6.39	10.1	5.58	4.69	5.54	5.66	6.42	4.42	7.87	16.2	26.1	15.4	3.24	3.99	2.40	1.15	1.20	0.852	0.693	0.577	0.509	0.533	0.562
Total Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.1	0.5	0.5	1.9	2.0	1.9	3.6	2.5	4.8	7.6	7	13.4	10.8	11
Total Cobalt (Co)	ug/L	1.68	0.25	0.63	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.26	2.46	1.39	0.70	0.83	0.68	1.10	0.81	1.43	2.28	2.31	3.83	3.26	3.3
Total Copper (Cu)	ug/L	972	351	657	323	257	311	322	443	256	444	1700	1440	630	198	232	144	56.8	62.5	46.4	40.8	31	29.6	31.2	32.4
Total Iron (Fe)	ug/L	2350	197	731	291	250	168	195	327	181	291	3060	877	59.4	1250	1330	1400	2260	1570	2940	4750	4760	8190	7710	7780
Total Lead (Pb)	ug/L	20.2	5.86	11.8	3.88	3.52	4.08	3.95	6.48	3.05	5.83	41.9	19.8	1.18	3.43	3.55	2.31	1.80	1.51	1.89	2.74	2.9	4.72	3.9	3.89
Total Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	6.2	2.5	2.5
Total Manganese (Mn)	ug/L	77.3	22.6	30.8	16.9	16.4	19.1	17.5	19.7	13.1	25.0	60.2	121	66.1	34.1	34.5	28.8	45.4	35.1	62.2	102	106	177	143	144
Total Mercury (Hg)	ug/L	0.025	0.025			0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total Molybdenum (Mo)	ug/L	2.3	2.7	2.7	3.0	3.2	3.2	3.3	3.2	3.3	3.2	3.7	1.3	1.0	2.2	2.3	2.3	2.6	2.4	2.8	2.9	2.9	7.2	2.8	3.3
Total Nickel (Ni)	ug/L	2.8	0.5	1.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.3	3.9	2.3	2.9	3.2	3.1	4.7	3.7	6.5	9.2	9	30.3	13.9	15.4
Total Selenium (Se)	ug/L	0.32	0.40	0.41	0.40	0.42	0.45	0.43	0.47	0.40	0.49	0.46	0.19	0.30	0.15	0.23	0.12	0.21	0.14	0.20	0.31	0.19	0.24	0.19	0.26
Total Silicon (Si)	ug/L	2590	2120	2510	2240	2110	2020	2130	2030	1940	2190	3290	3630	2450	4420	4050	3810	4580	2980	7230	10400	8640	12400	12800	12900
Total Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.021	0.044	0.01	0.021
Total Strontium (Sr)	ug/L	124	115	131	126	125	128	124	122	124	123	138	109	91.8	69.9	70.9	70.0	72.2	70.8	79.6	76.9	70.7	67.5	76.4	76.8
Total Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.051	0.053	0.025	0.025	0.025	0.025	0.025	0.025	0.052	0.079	0.069	0.086	0.075	0.076
Total Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	8.3	2.5	2.5	55.8	50.4	45.7	75.3	60.7	139	215	201	362	333	297
Total Uranium (U)	ug/L	1.25	0.84	1.54	1.01	1.04	1.06	0.99	1.36	0.88	0.95	3.49	1.48	0.05	0.69	0.67	0.65	0.60	0.58	0.60	0.68	0.71	0.93	0.8	0.8
Total Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	5.4	2.5	8.1	12.1	10	16.2	16	16.1
Total Zinc (Zn)	ug/L	4170	1650	2580	1390	1120	1330	1470	1700	1120	2010	3990	6110	3530	781	903	574	259	292	189	162	125	112	124	121
Total Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.52	0.25	1.92	1.73	0.52	1.09	1.25	0.99
Total Calcium (Ca)	mg/L	28.1	27.3	29.4	29.4	29.3	29.3	29.0	28.3	27.6	28.6	31.7	26.3	22.4	14.6	14.2	15.7	13.9	12.9	13.9	13.9	13.6	12	14.1	15.4
Total Magnesium (Mg)	mg/L	3.46	2.92	3.19	3.14	3.07	3.12	3.21	3.21	3.10	3.02	3.75	3.00	2.34	2.08	2.19	2.14	2.34	2.17	2.79	3.41	3.19	4.45	4.62	4.71
Total Potassium (K)	mg/L	1.18	1.27	1.31	1.36	1.38	1.34	1.41	1.40	1.43	1.29	1.52	0.936	0.735	1.11	1.23	1.12	1.47	1.24	1.85	2.25	1.94	2.57	2.65	2.73
Total Sodium (Na)	mg/L	1.92	1.86	1.98	2.00	2.08	1.90	2.12	2.02	2.00	1.97	2.26	1.57	1.10	1.11	1.19	1.14	1.21	1.22	1.47	1.64	1.36	1.55	1.56	1.37
Total Sulphur (S)	mg/L	26.1	12.4	15.1	11.9	10.3	12.0	11.2	12.0	11.2	13.9	23.5	28.5	17.3	5.1	8.1	5.9	5.8	6.5	4.8	6.4	1.5	4.3	3.1	5.2

Values in red were reported as ND (Not Detecte

PARAMETERS	Unit	28-Jun-08	25-Aug-08	21-Sep-08	18-Oct-08	13-Dec-08	24-Jan-09	20-Feb-09	02-Aug-11	04-Sep-11	03-Oct-11	06-Dec-11	23-Apr-12	23-May-12	17-Jun-12	12-Sep-12	29-Sep-12	13-Oct-12	28-Oct-12	06-Nov-12	10-Nov-12	25-Nov-12	09-Dec-12	25-Dec-12	05-Jan-13	19-Jan-13	26-Jan-13
Misc. Inorganics																											
Acidity (pH 4.5)	mg/L		0.25	0.25	0.25	0.25	0.25	0.25	0.25																		
Acidity (pH 8.3)	mg/L		1.2	1.0	1.6	0.25	0.25	0.50	0.25																		
Fluoride (F)	mg/L		0.040	0.050	0.070	0.090	0.070	0.090																			
Preparation																											
Filter and HNO3 Preservation	N/A		LAB	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS																											
Nitrite (N)	mg/L	0.00050	0.029	0.0025	0.0025	0.0025	0.0070	0.0025																			
Calculated Parameters																											
Nitrate (N)	mg/L	0.0576	0.030	0.030	0.090	0.11	0.26	0.15																			
Misc. Inorganics																											
Alkalinity (Total as CaCO3)	mg/L	23.4	31	27	30	47	55	54	30	33	33	42.0	48.6	29.3		26.0	25.5	29.4	40.8	40.9	44.4	47	45	54	51	50.6	
Total Organic Carbon (C)	mg/L	0.25	0.25	2.8	2.7	0.80	0.70	0.25																			
Alkalinity (PP as CaCO3)	mg/L		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Bicarbonate (HCO3)	mg/L		38	33	37	57	68	66	37	40	40	51.2	59.2	35.7		31.8	31.1	35.8	49.7	49.9	54.2	58	55	65	63	61.8	
Carbonate (CO3)	mg/L		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Hydroxide (OH)	mg/L		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Anions																											
Dissolved Sulphate (SO4)	mg/L	14	9.9	11	14	21	24	23	15	9	12	22	25.6	7.79	12	11.2	9.14	13.0	16.0	17.0	18.2	19	20	23	22	21.7	
Dissolved Chloride (Cl)	mg/L	0.25	0.70	0.25	1.0	0.25	2.2	1.6					1.4	0.85	0.82	1.3	1.3	0.72	1.1	1.0	1.2	1.6	1.3	2.5	1.7	2.6	
Nutrients																											
Ammonia (N)	mg/L		0.0050	0.0050	0.020	0.0050	0.0050	0.0050	0.016																		
Orthophosphate (P)	mg/L	0.0011	0.060	0.0025	0.037	0.0025	0.0025	0.0025																			
Nitrate plus Nitrite (N)	mg/L		0.050	0.030	0.090	0.11	0.26	0.15																			
Physical Properties																											
Conductivity	uS/cm	82.8	87	80	95	140	170	160	95	79	89	134	154	79.7	98	73.2	70.8	87.9	125	123	130	144	142	163	155	161	
pH	pH Units	7.56	7.7	7.7	7.8	7.9	8.0	8.0	7.7	7.7	7.4	7.61	7.85	7.63	7.7	7.55	7.63	7.38	7.78	7.70	7.69	7.8	7.8	7.6	7.78	7.78	
Physical Properties																											
Total Suspended Solids	mg/L	16.5	62	75	37	11	4.0	0.50	60		15	10.3	2	2	18	28.0	36.7	18.0	2	2	2	2.0	2.0	2.0	2.0	2.0	
Total Dissolved Solids	mg/L	64	68	40	72	96	90	86																			
Turbidity	NTU	83.5	113	63	50	5.3	0.80	1.2					2.59	2.96	18												
Calculated Parameters																											
Dissolved Hardness (CaCO3)	mg/L		38		42	59	76	73	37	41	42	62	71.9	39.7	43	31.9	31.6	42.6	61.9	53.5	56.7	65	61	76	70	68.6	69.5
Total Hardness (CaCO3)	mg/L	42.9	42	37	44	57	79	69	52	43	48	61	71.6	43.9	42	34.8	33.5	44.6	54.1	53.0	60.2	65	60	72	70	68.1	
Dissolved Metals by ICPMS																											
Dissolved Aluminum (Al)	ug/L	1,180	125	18	39	36	10	6.9	50	135	42	56.1	30.6	116	30	40.9	45.8	36.8	16.9	20.7	18.7	17	16	39	13	19.9	13.4
Dissolved Antimony (Sb)	ug/L	0.25	0.17	0.040	0.19	0.24	0.33	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	1.9	0.75	0.57	0.59	0.78	0.64	0.53	0.80	1.0	0.70	0.71	0.75	0.97	0.77	0.56	0.53	0.60	0.70	0.65	0.56	0.67	0.60	0.64	0.66	0.65	0.57
Dissolved Barium (Ba)	ug/L	47	22	65	22	33	42	35	20	20	19	27.4	32.2	17.7	14	16.4	15.1	19.8	27.3	26.7	28.1	33	31	38	38	36.0	38.1
Dissolved Beryllium (Be)	ug/L	0.50	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.050	0.050	0.050	0.050	0.05	0.05	0.050	0.05	0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.050	0.050	0.05
Dissolved Bismuth (Bi)	ug/L		0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.50	0.50	0.50	0.50	0.5	0.5	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.5
Dissolved Boron (B)	ug/L	50	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.10	0.013	0.052	0.034	0.076	0.081	0.368 (1)	0.020	0.10	0.10	0.475	0.298	0.061	0.027	0.058	0.041	0.138	0.069	0.115	0.232	0.31	0.18	0.52	0.17	0.278	0.191
Dissolved Chromium (Cr)	ug/L	2.3	0.10	0.20	0.050	0.050	0.050	0.050	0.50	0.50	0.50	0.50	0.5	0.5	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.5
Dissolved Cobalt (Co)	ug/L	1.4	0.081	0.035	0.029	0.030	0.019	0.011	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	6.2	0.44	0.92	0.70	2.2	0.62	0.62	0.40	4.1	3.8	14.6	17.6	3.52	0.65	1.26	1.37	1.68	0.90	2.12	3.95	7.6	4.5	13	4.6	9.12	5.91
Dissolved Iron (Fe)	ug/L	1,590	110	100	15	34	13	6.0	22	225	36	82.6	36.9	120	12	24.3	17.4	30.4	2.5	8.2	2.5	2.5	2.5	33	2.5	26.4	2.5
Dissolved Lead (Pb)	ug/L	1.8	0.11	0.37	0.034	0.18	0.039	0.031	0.10	0.30	0.10	0.23	0.21	0.28	0.10	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.10	0.10	0.10	0.10	0.1
Dissolved Lithium (Li)	ug/L	2.5	0.25	1.5	0.60	0.60	0.60	0.60	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	63	8.8	29	4.1	2.9	3.4	7.2	1.0	17	6.0	26.7	10.3	5.8	5.1	3.2	2.4	5.0	1.1	5.8	3.4	1.4	2.0	4.8	0.50	4.5	0.5
Dissolved Mercury (Hg)	ug/L	0.010	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.025	0.025	0.025	0.025	0.005	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025		0.025
Dissolved Molybdenum (Mo)	ug/L	1.3	1.3	0.31	2.1	2.7	2.9	2.6	3.0	1.0	1.0	2.4	2.6	1.0	1.7	1.4	1.6	2.0	2.4	2.2	2.4	2.6	2.8	2.9	2.9	2.8	2.8
Dissolved Nickel (Ni)	ug/L	5.1	0.45	0.36	0.44	0.27	0.23	0.21	0.50	0.50	0.50	0.50	0.5	0.5	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	0.5
Dissolved Selenium (Se)	ug/L	0.50	0.17	0.020	0.14	0.32	0.45	0.41	0.20	0.10	0.10	0.28	0.31	0.19	0.21	0.17	0.18	0.19	0.32	0.22	0.30	0.32	0.38	0.39	0.46	0.34	0.50
Dissolved Silicon (Si)	ug/L		914	1,640	1,070	1,220	1,450	1,530	1,040	1,290	1,270	1640	1810	1770	1,080	735	840	904	1410	1260	1290	1,440	1,290	1,720	1,500	1610	1460
Dissolved Silver (Ag)	ug/L	0.025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.010	0.010	0.010	0.010	0.01	0.01	0.010	0.01	0.01	0.01	0.01	0.01	0.01	0.010	0.010	0.010	0.010	0.010	0.01
Dissolved Strontium (Sr)	ug/L		56	205	65	87	113	100	61	59	66	95.7	103	54.3	70	52.2	49.4	68.9	81.1	79.7	82.6	90	86	105	97	99.6	97.5
Dissolved Thallium (Tl)	ug/L	0.10	0.0070	0.0010	0.0050	0.0030	0.0030	0.0030	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	0.25	0.0050	0.10	0.0050	0.040	0.0050	0.0050	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Titanium (Ti)	ug/L	63	4.8	1.5	0.25	2.7	0.25	0.25	2.5	2.5	2.5	2.5	2.5	5.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.64	0.32	0.017	0.52	0.61	0.73	0.61	0.50	0.30	0.30	0.60	0.64	0.33	0.41	0.30	0.30	0.36	0.47	0.45	0.42	0.50	0.51	0.56	0.58	0.56	0.56
Dissolved Vanadium (V)	ug/L	4.0	0.40	0.10	0.10	0.10	0.10	0.10	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zinc (Zn)	ug/L	14.6	0.60	4.0	3.4	28	5.4	8.9	2.5	16	21	101	64.6	17.4	2.5	13.4	8.0	30.5	11.8	21.1	47.7	68	38	87	34	68.5	41.2
Dissolved Zirconium (Zr)	ug/L		0.10	0.050	0.050	0.050	0.050	0.050	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	13.8	13	46	14	20	26	25	13	14	14	21.3	24.6	13.7	15	10.7	10.8	14.5	21.3	18.2	19.4	22	21	26	24	23.2	23.6

PARAMETERS	Unit	28-Jun-08	25-Aug-08	21-Sep-08	18-Oct-08	13-Dec-08	24-Jan-09	20-Feb-09	02-Aug-11	04-Sep-11	03-Oct-11	06-Dec-11	23-Apr-12	23-May-12	17-Jun-12	12-Sep-12	29-Sep-12	13-Oct-12	28-Oct-12	06-Nov-12	10-Nov-12	25-Nov-12	09-Dec-12	25-Dec-12	05-Jan-13	19-Jan-13	26-Jan-13
Dissolved Magnesium (Mg)	mg/L	2.05	1.5	4.3	1.7	2.1	2.7	2.5	1.4	1.1	1.4	2.18	2.52	1.35	1.5	1.25	1.15	1.55	2.11	1.96	2.02	2.3	2.1	2.7	2.4	2.57	2.56
Dissolved Potassium (K)	mg/L	1.0	0.84	1.6	0.89	1.2	1.3	1.3	1.5	0.49	0.60	0.985	1.14	0.559	0.53	0.660	0.634	0.823	1.08	0.973	0.979	1.1	1.1	1.3	1.3	1.29	1.30
Dissolved Sodium (Na)	mg/L	1.0	0.72	0.94	0.62	1.2	2.3	1.5	1.4	0.57	0.74	1.20	2.18	0.765	0.73	0.532	0.503	0.701	1.31	1.04	1.24	1.8	1.5	2.2	2.2	2.51	2.67
Dissolved Sulphur (S)	mg/L		4.0	11	5.0	6.0	8.0	8.0	5.0	3.0	4.0	7.2	8.6	1.5	4.3	3.1	3.2	5.1	6.0	5.9	6.4	7.7	5.7	7.9	7.4	5.4	7.7
Total Metals by ICPMS																											
Total Aluminum (Al)	ug/L	2,550	1,180	868	724	94	29	27	2,810	1,520	844	697	104	409	557	862	1300 (2)	540	166	668	366	70	56	44	30	39.4	
Total Antimony (Sb)	ug/L	0.25	0.18	0.14	0.17	0.24	0.32	0.27	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Total Arsenic (As)	ug/L	2.7	1.9	1.3	1.1	0.93	0.65	0.65	3.3	2.6	1.3	1.8	0.82	1.53	1.4	0.98	1.20	0.99	0.88	0.89	0.84	0.79	0.76	0.75	0.67	0.70	
Total Barium (Ba)	ug/L	74	54	43	42	35	40	39	69	39	36	39	34.0	22.4	23	36.3	42.7	34.1	28.4	36.1	36.5	35	33	38	38	35.1	
Total Beryllium (Be)	ug/L	0.50	0.060	0.040	0.030	0.0050	0.0050	0.0050	0.050	0.050	0.050	0.050	0.05	0.05	0.050	0.05	0.05	0.05	0.05	0.05	0.05	0.050	0.050	0.050	0.050	0.050	
Total Bismuth (Bi)	ug/L		0.048	0.028	0.022	0.0025	0.0025	0.0025	0.50	0.50	0.50	0.50	0.5	0.5	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.50	0.50	0.50	0.50	0.50	
Total Boron (B)	ug/L	50	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Total Cadmium (Cd)	ug/L	0.11	0.082	0.066	0.077	0.018	0.079	0.074	0.17	0.15	0.15	0.47	0.282	0.081	0.054	0.094	0.106	0.201	0.058	0.101	0.255	0.31	0.19	0.91	0.17	0.281	
Total Chromium (Cr)	ug/L	4.8	1.7	1.1	0.80	0.10	0.050	0.050	5.0	3.0	1.0	2	0.5	0.5	0.50	1.2	2.0	0.5	0.5	1.0	0.5	0.50	0.50	0.50	0.50	0.50	
Total Cobalt (Co)	ug/L	1.9	1.2	0.89	0.69	0.085	0.028	0.021	2.0	1.1	0.70	0.25	0.25	0.25	0.25	0.84	0.93	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Total Copper (Cu)	ug/L	3.5	5.3	4.3	3.9	0.95	0.75	0.92	9.1	7.7	8.6	22.9	11.3	3.58	1.6	6.82	6.65	10.1	2.68	5.07	11.5	13	8.0	16	5.8	10.6	
Total Iron (Fe)	ug/L	3,100	1,620	929	778	133	38	44	4,520	2,080	1,210	917	145	560	671	1160	1540	592	235	585	375	70	57	57	22	57.6	
Total Lead (Pb)	ug/L	2.2	2.1	1.7	1.4	0.17	0.084	0.043	3.0	1.2	1.2	1.1	0.35	0.42	0.37	1.31	1.47	1.04	0.1	0.37	0.39	0.36	0.10	0.44	0.10	0.10	
Total Lithium (Li)	ug/L	2.5	1.4	1.1	1.1	0.60	0.25	0.50	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Total Manganese (Mn)	ug/L	84	63	43	36	5.4	3.1	8.1	90	60	35	43	11.8	16.4	18	40.2	53.2	25.9	5.1	16.4	10.0	2.9	2.8	5.5	1.7	4.7	
Total Mercury (Hg)	ug/L	0.010	0.0050	0.020	0.0050	0.0050	0.0050	0.0050	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025	
Total Molybdenum (Mo)	ug/L	2.3	0.79	0.85	1.3	2.8	2.8	2.9	3.0	1.0	1.0	3	2.8	1.6	1.8	0.5	1.1	1.5	2.5	2.1	2.7	2.6	2.9	2.9	3.0	2.5	
Total Nickel (Ni)	ug/L	6.8	3.9	3.2	2.5	0.33	0.28	0.29	7.0	4.0	2.0	3	0.5	1.6	1.6	3.3	3.5	1.9	0.5	1.4	1.5	0.50	0.50	0.50	0.50	0.50	
Total Selenium (Se)	ug/L	0.50	0.17	0.14	0.17	0.36	0.46	0.43	0.30	0.20	0.20	0.2	0.25	0.18	0.17	0.15	0.05	0.14	0.39	0.30	0.17	0.29	0.36	0.34	0.46	0.29	
Total Silicon (Si)	ug/L		2,430	1,650	1,760	1,290	1,620	1,700	6,560	3,570	2,470	2740	2050	2050	2,180	1840	2750	1700	1340	2370	1990	1,570	1,250	1,520	1,490	1700	
Total Silver (Ag)	ug/L	0.020	0.027	0.0025	0.0025	0.0025	0.0025	0.0025	0.030	0.010	0.010	0.010	0.01	0.01	0.010	0.01	0.01	0.01	0.01	0.01	0.01	0.010	0.010	0.010	0.010	0.010	
Total Strontium (Sr)	ug/L		60	54	66	90	108	99	75	56	70	97	99.7	63.8	69	52.1	49.3	70.3	79.6	81.0	89.9	91	88	102	95	100	
Total Thallium (Tl)	ug/L	0.10	0.028	0.019	0.019	0.0030	0.0030	0.0040	0.025	0.050	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
Total Tin (Sn)	ug/L	0.25	0.010	0.0050	0.0050	0.0050	0.0050	0.0050	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Total Titanium (Ti)	ug/L	162	56	34	30	3.7	1.6	0.90	176	57	44	27	2.5	14.5	23	42.4	60.6	22.1	9.3	22.6	11.9	2.5	2.5	2.5	2.5	2.5	
Total Uranium (U)	ug/L	0.74	0.53	0.57	0.63	0.62	0.65	0.61	0.80	0.30	0.40	0.7	0.68	0.52	0.48	0.40	0.44	0.49	0.46	0.47	0.55	0.68	0.53	0.55	0.55	0.57	
Total Vanadium (V)	ug/L	7.9	2.8	1.8	1.1	0.10	0.10	0.10	9.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Total Zinc (Zn)	ug/L	14.9	11	9.4	13	4.0	5.5	9.9	20	27	31	101	57.8	11.1	6.3	23.6	20.9	40.3	18.1	24.7	56.3	73	43	90	36	58.0	
Total Zirconium (Zr)	ug/L		0.0050	0.050	0.050	0.050	0.050	0.050	0.25	1.2	0.25	0.25	0.25	0.25	0.25	0.25	0.63	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Total Calcium (Ca)	mg/L	13.6	13	12	14	19	27	23	16	14	16	20.2	24.7	15.0	14	11.1	10.7	14.6	18.3	17.7	20.4	22	20	24	24	23.0	
Total Magnesium (Mg)	mg/L	2.71	2.2	1.9	2.1	2.0	2.8	2.6	2.8	2.0	1.8	2.43	2.40	1.55	1.8	1.73	1.67	2.00	2.01	2.12	2.27	2.4	2.3	2.6	2.6	2.57	
Total Potassium (K)	mg/L	1.0	1.2	1.1	1.1	1.0	1.4	1.2	2.0	0.78	0.72	1.12	1.14	0.591	0.64	0.872	0.982	0.980	1.07	1.09	1.15	1.2	1.2	1.3	1.3	1.36	
Total Sodium (Na)	mg/L	1.0	0.80	0.51	0.67	0.91	2.3	1.5	1.7	0.69	0.79	1.13	2.36	0.798	0.73	0.574	0.575	0.815	1.28	1.09	1.34	1.8	1.5	2.3	2.1	2.48	
Total Sulphur (S)	mg/L		4.0	5.0	5.0	7.0	10	8.0	4.0	1.5	4.0	6.1	7.8	1.5	1.5	1.5	1.5	7.0	5.3	5.2	6.8	6.9	7.3	8.1	7.6	6.9	

PARAMETERS	Unit	02-Feb-13	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Misc. Inorganics																										
Acidity (pH 4.5)	mg/L																									
Acidity (pH 8.3)	mg/L																									
Fluoride (F)	mg/L																									
Preparation																										
Filter and HNO3 Preservation	N/A	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD	FIELD
ANIONS									82.3	81.8																
Nitrite (N)	mg/L																									
Calculated Parameters																										
Nitrate (N)	mg/L																									
Misc. Inorganics																										
Alkalinity (Total as CaCO3)	mg/L	52.9		50.1		55.9		56.9		58.3		57.1		48.2		27.7		29.7		25.7		24.9		24.5		23.9
Total Organic Carbon (C)	mg/L																									
Alkalinity (PP as CaCO3)	mg/L	0.5		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Bicarbonate (HCO3)	mg/L	64.5		61.1		68.2		69.4		71.1		69.6		58.8		33.8		36.3		31.3		30.4		29.9		29.2
Carbonate (CO3)	mg/L	0.5		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Hydroxide (OH)	mg/L	0.5		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25		0.25
Anions																										
Dissolved Sulphate (SO4)	mg/L	24.0		21.3		24.3		26.5		26.4		27.3		28.0		12.8		12.8		12.0		9.93		8.5		9.79
Dissolved Chloride (Cl)	mg/L	3.0		2.8		3.1		2.7		3.3		3.3		1.7		0.95		0.84		1.2		0.77		0.73		
Nutrients																										
Ammonia (N)	mg/L																									
Orthophosphate (P)	mg/L																									
Nitrate plus Nitrite (N)	mg/L																									
Physical Properties																										
Conductivity	uS/cm	170		155		177		183		184		182		155		87.4		87.2		82.5		73.5		65.9		70.4
pH	pH Units	7.79		7.63		7.77		7.92		7.89		7.92		7.66		7.67		7.67		7.50		7.40		7.41		7.27
Physical Properties																										
Total Suspended Solids	mg/L	4		2		2		2		2		2		2		5.3		8.5		12.3		37.8		87.5		47
Total Dissolved Solids	mg/L																									
Turbidity	NTU																									
Calculated Parameters																										
Dissolved Hardness (CaCO3)	mg/L	69.0	62.2	66.9	76.0	76.7	72.5	93.4	83.0	81.0	84.3	77.0	79.3	70.1	51.9	40.0	37.1	37.2	32.9	35.8	32.1	30.7	28.2	27.9	29.8	29.7
Total Hardness (CaCO3)	mg/L	73.1	62.6	69.3	74.8	78.9	75.5	80.3			82.4	76.2	83.0	67.8	53.7	41.8	39.9	39.7	36.9	41.0	43.8	42.2	41.4	46.5	47.9	54.3
Dissolved Metals by ICPMS																										
Dissolved Aluminum (Al)	ug/L	12.7	25.9	17.4	14.3	15.7	12.8	6.4	11.3	11.5	18.2	12.6	19.0	107	50.6	49.9	45.3	42.3	37.0	32.3	39.1	90.6	50.5	55.4	44.5	44.4
Dissolved Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Arsenic (As)	ug/L	0.58	0.70	0.62	0.58	0.54	0.54	0.51	0.56	0.53	0.59	0.57	0.53	0.74	0.56	0.64	0.62	0.61	0.60	0.63	0.67	0.67	0.63	0.67	0.55	0.54
Dissolved Barium (Ba)	ug/L	38.6	32.6	34.6	41.7	42.4	41.1	38.7	43.8	44.1	46.5	44.1	43.5	37.2	25.0	17.7	16.7	16.1	13.1	15.0	13.1	13.6	12.3	13.5	14.6	14.3
Dissolved Beryllium (Be)	ug/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved Bismuth (Bi)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dissolved Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Dissolved Cadmium (Cd)	ug/L	0.171	0.519	0.229	0.258	0.218	0.136	0.071	0.143	0.173	0.196	0.196	0.385	0.827	0.759	0.220	0.153	0.134	0.059	0.088	0.053	0.042	0.035	0.039	0.034	0.031
Dissolved Chromium (Cr)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.8	0.5	0.5
Dissolved Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Copper (Cu)	ug/L	5.21	14.1	8.01	7.03	8.53	4.63	1.24	3.65	4.66	6.26	6.02	11.8	37	33.0	8.44	5.02	4.31	1.69	2.08	1.00	1.06	0.51	0.66	0.51	0.46
Dissolved Iron (Fe)	ug/L	2.5	165	11.1	2.5	2.5	2.5	6.4	2.5	5.1	10.8	2.5	7.8	94	40.9	23.3	17.1	12.5	20.3	14.7	6.8	77.0	20.1	30.2	20	16.5
Dissolved Lead (Pb)	ug/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.61	0.34	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dissolved Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Manganese (Mn)	ug/L	0.5	21.7	1.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.3	6.8	9.7	4.7	3.5	3.1	4.4	2.9	3.2	5.7	3.7	3.3	2.9	2.8
Dissolved Mercury (Hg)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.005	0.005	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Molybdenum (Mo)	ug/L	2.8	2.1	2.3	2.8	2.9	2.7	3.1	2.9	3.0	3.1	3.0	2.8	2.3	1.7	1.7	1.9	2.0	1.6	2.0	1.8	1.8	2.1	1.2	2.7	2.1
Dissolved Nickel (Ni)	ug/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	8.5	4.7	3.5
Dissolved Selenium (Se)	ug/L	0.36	0.35	0.33	0.41	0.49	0.37	0.51	0.59	0.52	0.61	0.57	0.55	0.34	0.18	0.16	0.15	0.12	0.17	0.17	0.14	0.05	0.15	0.14	0.16	0.13
Dissolved Silicon (Si)	ug/L	1380	1600	1630	1610	1570	1530	1560	1680	1660	1650	1560	1770	1870	1750	1310	1120	1080	864	909	902	938	876	871	845	714
Dissolved Silver (Ag)	ug/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dissolved Strontium (Sr)	ug/L	96.6	83.0	88.6	103	106	96.7	115	110	109	114	109	109	98.6	77.8	62.8	60.7	61.4	55.6	61.7	51.2	46.6	44.4	43.3	46	45.2
Dissolved Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Dissolved Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Uranium (U)	ug/L	0.56	0.41	0.50	0.58	0.64	0.68	0.65	0.70	0.68	0.67	0.65	0.62	0.54	0.41	0.45	0.43	0.42	0.32	0.37	0.34	0.33	0.33	0.3	0.29	0.28
Dissolved Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Dissolved Zinc (Zn)	ug/L	35.0	124	53.2	51.5	46.9	26.9	12.5	28.4	34.4	41.8	40.7	80.0	185	164	48.9	30.8	28.2	9.9	17.9	6.2	2.5	2.5	2.5	2.5	2.5
Dissolved Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Dissolved Calcium (Ca)	mg/L	23.5	21.3	22.8	26.0	26.1	24.3	32.3	28.5	27.6	28.7	26.2	27.3	24.1	17.8	13.5	12.4	12.6	11.3	12.2	10.9	10.4	9.81	9.68	10.1	10

PARAMETERS	Unit	02-Feb-13	10-Feb-13	16-Feb-13	23-Feb-13	02-Mar-13	09-Mar-13	16-Mar-13	23-Mar-13	30-Mar-13	06-Apr-13	13-Apr-13	20-Apr-13	27-Apr-13	04-May-13	11-May-13	18-May-13	25-May-13	01-Jun-13	08-Jun-13	15-Jun-13	22-Jun-13	29-Jun-13	06-Jul-13	13-Jul-13	20-Jul-13
Dissolved Magnesium (Mg)	mg/L	2.53	2.19	2.42	2.67	2.77	2.88	3.10	2.90	2.93	3.08	2.84	2.70	2.42	1.83	1.51	1.48	1.43	1.12	1.30	1.22	1.13	0.907	0.909	1.1	1.14
Dissolved Potassium (K)	mg/L	1.26	1.08	1.20	1.36	1.46	1.67	1.51	1.46	1.43	1.45	1.41	1.39	1.22	0.824	0.737	0.778	0.730	0.653	0.786	0.760	0.769	0.685	0.704	0.733	0.73
Dissolved Sodium (Na)	mg/L	2.57	2.03	2.50	2.73	2.89	3.59	1.81	2.94	3.00	3.06	3.33	2.43	1.82	1.08	0.942	0.959	0.934	0.769	0.896	0.832	0.782	0.675	0.668	0.594	0.476
Dissolved Sulphur (S)	mg/L	7.3	6.9	7.8	8.6	8.6	8.2	7.9	8.7	8.8	9.9	9.0	9.2	8.5	6.6	4.2	4.4	3.9	3.3	5.0	3.9	3.2	1.5	1.5	4.4	4.1
Total Metals by ICPMS																										
Total Aluminum (Al)	ug/L	24.3	77.1	32.8	25.6	23.3	23.3	20.8	21.0	19.9	11.7	27.1	46.7	34.9	412	1190	968	943	1340	1070	2850	3400	3650	5580	5200	5470
Total Antimony (Sb)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Arsenic (As)	ug/L	0.62	1.12	0.68	0.61	0.62	0.61	0.54	0.55	0.53	0.52	0.57	0.59	0.44	1.35	1.05	1.10	1.16	2.04	1.23	2.75	3.64	2.58	4.75	3.42	3.31
Total Barium (Ba)	ug/L	40.1	33.4	36.3	41.6	42.5	42.6	43.2	45.5	44.2	44.8	44.8	45.1	35.5	28.2	33.6	31.2	28.5	34.4	32.0	55.8	63.1	68.3	99.1	96.9	102
Total Beryllium (Be)	ug/L	0.050	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.13	0.1	0.13
Total Bismuth (Bi)	ug/L	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Boron (B)	ug/L	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Total Cadmium (Cd)	ug/L	0.189	0.544	0.234	0.250	0.217	0.137	0.198	0.158	0.179	0.192	0.188	0.428	0.793	0.838	0.248	0.181	0.172	0.093	0.122	0.275	0.093	0.097	0.18	0.133	0.135
Total Chromium (Cr)	ug/L	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.7	1.7	1.6	2.8	2.2	4.5	5.6	5.7	9.5	9.7	9.3
Total Cobalt (Co)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.50	0.51	0.85	0.66	1.31	1.79	1.87	3.33	2.78	2.71
Total Copper (Cu)	ug/L	6.35	23.6	9.58	9.03	7.61	5.62	6.63	4.45	5.89	5.47	7.31	15.3	21.6	66.0	14.5	12.1	10.1	6.03	7.32	8.29	7.73	8.03	13.9	11.6	11.2
Total Iron (Fe)	ug/L	18.1	284	33.6	17.8	15.4	22.2	12.1	22.7	17.7	2.5	19.2	15.1	14.3	506	954	967	892	1740	1410	2780	3570	3780	6740	6100	6310
Total Lead (Pb)	ug/L	0.28	0.46	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.98	0.72	0.65	0.52	0.85	0.69	1.35	1.64	2.03	3.74	2.83	2.93
Total Lithium (Li)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Manganese (Mn)	ug/L	1.2	22.5	1.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.4	5.9	16.9	20.6	20.8	20.0	38.3	27.2	58.7	79.7	86.7	153	123	122
Total Mercury (Hg)	ug/L	0.025	0.025	0.025			0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Total Molybdenum (Mo)	ug/L	2.9	2.0	2.3	2.6	2.7	2.9	2.7	2.9	3.0	2.9	2.9	2.5	2.3	1.9	2.0	2.1	2.0	1.8	2.2	2.2	2.2	2.2	2.6	4.1	2.7
Total Nickel (Ni)	ug/L	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.2	2.5	2.4	3.5	2.8	5.7	6.6	7	11.8	19.2	12.8
Total Selenium (Se)	ug/L	0.48	0.37	0.38	0.53	0.56	0.57	0.56	0.45	0.53	0.54	0.47	0.53	0.34	0.26	0.23	0.18	0.13	0.11	0.15	0.21	0.12	0.18	0.21	0.22	0.24
Total Silicon (Si)	ug/L	1580	1640	1690	1680	1760	1630	1720	1670	1680	1630	1530	1790	1650	2280	3870	2980	2960	3210	2750	6930	8110	7800	10300	9420	11000
Total Silver (Ag)	ug/L	0.010	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.022	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.023	0.036	0.025	0.021
Total Strontium (Sr)	ug/L	100	81.5	91.7	104	108	102	106	109	108	112	107	113	96.8	76.5	62.9	60.0	60.6	56.6	66.9	67.8	60.0	59.4	59.6	64.2	70.3
Total Thallium (Tl)	ug/L	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.056	0.05	0.066	0.065	0.074
Total Tin (Sn)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Titanium (Ti)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	12.5	48.7	35.2	38.1	54.7	42.5	120	167	193	311	268	267
Total Uranium (U)	ug/L	0.55	0.43	0.52	0.58	0.62	0.62	0.62	0.67	0.67	0.64	0.65	0.62	0.51	0.62	0.52	0.48	0.47	0.42	0.48	0.50	0.47	0.53	0.73	0.64	0.65
Total Vanadium (V)	ug/L	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	7.3	8.9	9.8	14.2	13.7	13.4
Total Zinc (Zn)	ug/L	41.0	127	55.8	51.3	44.1	30.5	44.4	30.2	36.0	37.4	39.9	92.1	167	192	54.0	42.4	37.9	22.5	29.6	26.7	23.8	24.3	38.6	31.5	30.1
Total Zirconium (Zr)	ug/L	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.96	2.24	0.61	0.85	0.74	2.57
Total Calcium (Ca)	mg/L	24.8	21.5	23.7	25.4	26.9	25.6	27.7	28.0	27.8	28.2	25.8	28.6	23.3	18.5	13.7	12.9	12.8	11.6	13.1	13.4	12.5	11.8	12	12.8	14.7
Total Magnesium (Mg)	mg/L	2.71	2.14	2.49	2.74	2.88	2.83	2.73	3.01	2.99	2.94	2.85	2.83	2.32	1.85	1.82	1.89	1.86	1.89	1.97	2.53	2.66	2.92	4.04	3.84	4.24
Total Potassium (K)	mg/L	1.30	1.08	1.21	1.35	1.40	1.66	1.44	1.45	1.46	1.43	1.45	1.43	1.15	0.845	1.02	1.04	0.992	1.04	1.11	1.57	1.72	1.74	2.13	2.16	2.4
Total Sodium (Na)	mg/L	2.80	1.96	2.57	2.86	2.95	3.77	2.81	2.99	3.08	2.91	3.33	2.59	1.78	1.05	1.04	1.06	1.00	0.956	1.09	1.29	1.26	1.33	1.37	1.36	1.21
Total Sulphur (S)	mg/L	7.9	6.7	7.1	8.0	8.7	9.2	9.5	8.4	9.0	9.0	8.9	8.7	7.5	6.0	3.2	3.7	4.2	4.1	4.8	4.3	3.0	3.6	1.5	4.1	4.4

APPENDIX D

Toxicity Data considered for TRVs

Appendix D. Toxicity Data Considered for TRVs

Chemical	Toxicity	Species	Endpoint	Hardness	Concentration	Units	References
Cadmium	Chronic	O. mykiss	98-d NOEC	50	1.3	ug/L	BKH. 1995. Update toxiciteitsgegevens voor vier stoffen in het kader van MILBOWA. Versie 1995.
Cadmium	Chronic	S. salar	46-d EC11	soft	0.47	ug/L	Rombough, P.J., and E.T. Garside. 1982. Cadmium toxicity and accumulation in eggs and alevins of Atlantic salmon Salmo salar. Can. J. Zool. 60:2006–2014.
Cadmium	Chronic	M. saxatilis	12-d LC12.5	soft	0.5	ug/L	Wright, D.A., M.J. Meteyer, and F.D. Martin. 1985. Effect of calcium on cadmium uptake and toxicity in larvae and juveniles of striped bass (Morone saxatilis). Bull. Environ. Contam. Toxicol. 34:196–204.
Cadmium	Chronic	J. floridae	30-d LC19	soft	8.5	ug/L	Spehar, R.L., R.L. Anderson, and J.T. Fiandt. 1978. Toxicity and bioaccumulation of cadmium and lead in aquatic invertebrates. Environ. Pollut. 15:195–208.
Cadmium	Chronic	O. latipes	18-d LC25	soft	7	ug/L	Canton, J.H., and W. Slooff. 1982. Toxicity and accumulation studies of cadmium (Cd2+) with freshwater organisms of different trophic levels. Ecotoxicol. Environ. Saf. 6:113–128.
Cadmium	Acute	O. tshawytscha	96h LC50	23	1.3	ug/L	Chapman GA (1978) Toxicities of cadmium, copper and zinc to four juvenile stages of chinook salmon and steelhead. Trans Am Fish Soc 107:841–847
Arsenic	Chronic	O. mykiss	28-h LC50		550	ug/L	Birge, W.J., J.E. Hudson, J.A. Black, and A.G. Westerman. 1979. Embryo-larval bioassays on inorganic coal elements and in situ biomonitoring of coal-waste effluents. In: Surface mining and fish/wildlife needs in the eastern United States, D.E. Samuel, J.R. Stauffer, C.H. Hocutt, and W.T. Mason Jr., eds., pp. 97-104. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-78/81.
Zinc	Chronic	O. tshawytscha	Chronic	23	371	ug/L	Chapman, G.A. 1975. Toxicity of copper, cadmium, and zinc to Pacific Northwest salmonids. USEPA, Corvallis, OR.
Zinc	Chronic	O. tshawytscha	Chronic	22	187	ug/L	Chapman Manuscript
Zinc	Acute	O. tshawytscha	96h LC50	23	460	ug/L	Chapman GA (1978) Toxicities of cadmium, copper and zinc to four juvenile stages of chinook salmon and steelhead. Trans Am Fish Soc 107:841–847
Lead	Chronic	O. mykiss	chronic	28	31	ug/L	Goetti et al. 1972; Davies et al., 1976
Lead	Chronic	O. mykiss	570-d NOEC	28	7.2	ug/L	Davies, P.H.,Goettl,J.P.,Sinley,J.R.,Smith,N.F.,1976.Acuteandchronictoxicityof lead torainbowtrout Salmo gairdneri, inhardandsoftwater.WaterRes.10, 199–206.
Lead	Chronic	O. mykiss	570-d EC10	50*	15	ug/L	Mebane, C.A., Hennessy, D.P., Dillon, F.S., 2008. Developing acute-to-chronic toxicity ratios for lead, cadmium, and zinc using rainbow a Mayfly,and a Midge. Water, Air, & Soil Pollution, 188(1-4):41–66
Lead	Chronic	S. fontenalis	545-d chronic	44	58	ug/L	Christensen et al., 1976
Lead	Acute	O. mykiss	LC50	28	1170	ug/L	Goetti et al. 1972; Davies and Everhart, 1973; Davies et al., 1976
Lead	Acute	S. fontenalis	545-d LC50	44	4100	ug/L	Holcombe et al., 1977
Copper	Chronic	O. tshawytscha	120-d EC10	24	1.9	ug/L	Chapman, G. A. 1982. Chinook salmon early life stage tests with cadmium, copper, and zinc. Letter of December 6, 1982 to Charles Stephan, EPA Environmental Research Laboratory, Duluth. Environmental Protection Agency, Corvallis, Oregon. Online at http://www.epa.gov/ow/ docket.html [accessed 27 September 2007].
Copper	Chronic	O. tshawytscha	60-d LOEC	27	21	ug/L	Mudge, J. E., T.E. Northstrom, G.S. Jeane, W. Davis, and J. L. Hickam. 1993. Effect of varying environmental conditions on the toxicity of copper to salmon. In J. W. Gorsuch, F. J. Dwyer, C. G. Ingersoll, and T. W. La Point, (eds.), Environmental toxicology and risk assessment, ASTM STP 1216, p. 19–33. American Society for Testing and Materials, Philadelphia, PA.
Copper	Chronic	O. ksutch	182 days	69	76	ug/L	Nichols, J.W., Wedmeyer G.A., Mayer, F.L., Dickoff S.V., Yasutake W.T., Smith S.D. 1984. Effects of freshwater exposure to arsenic trioxide on the parr-smolt transformation of coho salmon (O. kisutch). Environmental toxicology and Chemistry, 3, 143-149.
Copper	Chronic	O. mykiss	120-d EC10	23	2.8	ug/L	Marr, J. C. A., J. Lipton, D. Cacela, J. A. Hansen, H. L. Bergman, J. S. Meyer, and C. Hogstrand. 1996. Relationship between copper exposure duration, tissue copper concentration, and rainbow trout growth. Aquat. Toxicol. 36:17–30.
Copper	Chronic	O. trutta	126-d NOEC	45	22	ug/L	McKim J.M., Eaton J.G., Holcombe G.W. 1978, Metal toxicity to embroys and larvae of eight species of freshwater fish - II. Copper. Bull. Environ. Contam. Toxicol., 19, 608-616.
Copper	Acute	O. tshawytscha	96h LC50	23	19	ug/L	Chapman GA (1978) Toxicities of cadmium, copper and zinc to four juvenile stages of chinook salmon and steelhead. Trans Am Fish Soc 107:841–847

* Hardness Adjusted to 50 mg/L

There were several more toxicity studies that could have been added to this list. Only those toxicity studies that were considered for use as TRVs were included.

APPENDIX E

Descriptive Statistics for Hazard Quotients

Table 1: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Cadmium IWTP Operational (April 2012 to June 2012)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	47	47	8	7	2	2	4	4
Minimum	0.007	0.007	0.07	0.08	0.09	0.2	0.04	0.07
Maximum	0.1	**2.0**	0.8	0.8	**2.5**	**2.3**	0.4	0.4
1st Quartile	0.007	0.02	0.1	0.2	0.96	0.7	0.07	0.1
Median	0.007	0.04	0.2	0.2	**1.8**	**1.2**	0.1	0.1
3rd Quartile	0.02	0.1	0.5	0.4	**2.2**	**1.8**	0.2	0.2
Mean	0.02	0.1	0.3	0.3	**1.5**	**1.2**	0.2	0.2
Variance (n-1)	0.0005	0.08	0.09	0.05	1.6	2.4	0.02	0.02
Standard deviation (n-1)	0.02	0.3	0.3	0.2	1.3	1.5	0.2	0.1

Bold values represent HQs > 1

Table 2: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Cadmium IWTP Not Operational (June 2012 to July 2013)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	47	47	45	36	33	35	47	46
Minimum	0.004	0.004	0.004	0.004	0.2	0.4	0.01	0.01
Maximum	0.06	**1.2**	0.4	0.4	**19**	**20**	0.6	0.7
1st Quartile	0.004	0.01	0.01	0.03	0.9	**1.1**	0.05	0.08
Median	0.004	0.02	0.03	0.04	**3.0**	**2.8**	0.1	0.1
3rd Quartile	0.01	0.06	0.04	0.08	**4.6**	**4.7**	0.2	0.2
Mean	0.01	0.06	0.04	0.07	**3.8**	**4.0**	0.1	0.2
Variance (n-1)	0.0002	0.03	0.003	0.006	15	19	0.02	0.02
Standard deviation (n-1)	0.01	0.2	0.06	0.08	3.9	4.3	0.1	0.2

Bold values represent HQs > 1

Table 3: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Copper IWTP Operational (April 2012 to June 2012)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	48	47	8	7	3	2	4	4
Minimum	0.008	0.04	0.04	0.2	0.1	0.3	0.05	0.1
Maximum	0.5	**1.3**	**2.0**	0.8	**2.0**	**7.0**	**1.4**	0.9
1st Quartile	0.02	0.2	0.06	0.2	0.95	**2.0**	0.1	0.2
Median	0.02	0.3	0.2	0.3	**1.8**	**3.7**	0.2	0.3
3rd Quartile	0.05	0.4	0.3	0.5	**1.9**	**5.3**	0.5	0.5
Mean	0.04	0.4	0.4	0.4	**1.3**	**3.7**	0.5	0.4
Variance (n-1)	0.005	0.08	0.4	0.06	1.0	22	0.4	0.1
Standard deviation (n-1)	0.07	0.3	0.7	0.2	1.0	4.7	0.6	0.3

Bold values represent HQs > 1

Table 4: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Copper IWTP Not Operational (June 2012 to July 2013)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	48	47	45	36	44	35	47	46
Minimum	0.008	0.04	0.02	0.008	0.1	**2**	0.03	0.06
Maximum	0.5	**1.3**	**2.1**	**3.3**	**92**	**131**	**2.8**	**5.1**
1st Quartile	0.02	0.2	0.03	0.1	**1.2**	**5.3**	0.08	0.4
Median	0.03	0.3	0.06	0.2	**6.4**	**15**	0.3	0.6
3rd Quartile	0.05	0.4	0.1	0.4	**14**	**26**	0.5	0.9
Mean	0.04	0.4	0.1	0.4	**11**	**24**	0.4	0.8
Variance (n-1)	0.005	0.08	0.1	0.3	293	846	0.3	0.6
Standard deviation (n-1)	0.07	0.3	0.3	0.6	17	29	0.6	0.8

Bold values represent HQs > 1

Table 5: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Lead IWTP Operational (April 2012 to June 2012)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	48	47	8	7	46	47	45	45
Minimum	0.002	0.007	0.007	0.007	0.007	0.06	0.007	0.02
Maximum	0.04	0.3	0.03	0.07	0.01	0.1	0.02	0.03
1st Quartile	0.007	0.04	0.007	0.02	0.007	0.08	0.007	0.02
Median	0.007	0.08	0.007	0.03	0.007	0.1	0.01	0.02
3rd Quartile	0.007	0.2	0.01	0.05	0.01	0.1	0.02	0.03
Mean	0.008	0.1	0.01	0.03	0.009	0.1	0.01	0.03
Variance (n-1)	0.00004	0.007	0.0001	0.0005	0.00002	0.003	0.00003	0.000004
Standard deviation (n-1)	0.006	0.09	0.01	0.02	0.005	0.06	0.006	0.002

Bold values represent HQs > 1

Table 6: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Lead IWTP Not Operational (June 2012 to July 2013)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of missing values	1	2	4	13	5	14	2	3
Minimum	0.002	0.007	0.007	0.007	0.007	0.07	0.002	0.003
Maximum	0.04	0.3	0.05	0.3	**1.1**	**2.8**	0.1	0.2
1st Quartile	0.007	0.04	0.007	0.007	0.007	0.2	0.007	0.007
Median	0.007	0.08	0.007	0.02	0.02	0.2	0.007	0.03
3rd Quartile	0.007	0.2	0.007	0.1	0.04	0.3	0.007	0.09
Mean	0.008	0.1	0.008	0.07	0.05	0.4	0.01	0.06
Variance (n-1)	0.00004	0.007	0.00004	0.007	0.03	0.3	0.0003	0.004
Standard deviation (n-1)	0.006	0.09	0.006	0.08	0.2	0.5	0.02	0.06

Bold values represent HQs > 1

Table 7: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Zinc IWTP Operational (April 2012 to June 201)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	48	47	8	7	3	2	4	4
Minimum	0.001	0.00003	0.01	0.04	0.04	0.09	0.01	0.03
Maximum	0.2	0.008	0.7	0.2	**2.3**	**2.3**	0.3	0.3
1st Quartile	0.01	0.00009	0.01	0.06	0.8	0.6	0.07	0.05
Median	0.01	0.0002	0.1	0.1	**1.7**	**1.2**	0.1	0.1
3rd Quartile	0.01	0.0004	0.2	0.2	**2.0**	**1.8**	0.2	0.2
Mean	0.02	0.0004	0.2	0.1	**1.3**	**1.2**	0.1	0.1
Variance (n-1)	0.0006	0.000001	0.05	0.006	1.4	2.5	0.02	0.02
Standard deviation (n-1)	0.02	0.001	0.2	0.08	1.2	1.6	0.1	0.1

Bold values represent HQs > 1

Table 8: Descriptive Statistics for Hazard Quotient due to Fish Exposure to Zinc IWTP Not Operational (June 2012 to July 2013)

Statistic	W10 Dissolved Metals	W10 Total Metals	W46 Dissolved Metals	W46 Total Metals	W51 Dissolved Metals	W51 Total Metals	W32 Dissolved Metals	W32 Total Metals
No. of observations	48	47	45	36	44	35	47	46
Minimum	0.001	0.01	0.01	0.01	0.2	0.6	0.003	0.02
Maximum	0.2	0.2	0.5	0.6	**31**	**33**	0.99	**1.03**
1st Quartile	0.01	0.03	0.01	0.04	**1.5**	**1.7**	0.05	0.1
Median	0.01	0.05	0.03	0.05	**4.9**	**4.8**	0.2	0.2
3rd Quartile	0.01	0.07	0.06	0.08	**8.0**	**8.3**	0.3	0.3
Mean	0.02	0.06	0.05	0.08	**6.2**	**6.8**	0.2	0.2
Variance (n-1)	0.0006	0.002	0.007	0.009	40	52	0.05	0.04
Standard deviation (n-1)	0.02	0.04	0.08	0.1	6.3	7.2	0.2	0.2

Bold values represent HQs > 1