DE BEERS
GROUP OF COMPANIES

April 11, 2014 File: MV2011L2-0004/EA1314-002

Simon Toogood
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Rebecca Chouinard
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Dear Mr. Toogood and Ms. Chouinard:

Re: Supplemental Filings Related to IRs, s.117 and Chronic Effects Benchmark Testing

Please accept the following additional information in support of De Beers Canada Inc.'s (De Beers) Water Licence Amendment Application. The information is being provided in response to Information Requests of March 14, and to meet the requirements of section 117 of the *Mackenzie Valley Resource Management Act* as they relate to cumulative effects, accidents and malfunctions and alternatives to the scope of the proposal currently undergoing environmental assessment. Please find the following included in this supplemental submission:

Attachment 1: Snap Lake Water Licence Amendment - Plain Language Summary of Key Proposed Amendments
Attachment 2: Supplemental IR Responses, MVLWB IR 2, 8, and 11
Attachment 3: Snap Lake Water Licence Amendment Environmental Assessment Supplemental Information
Attachment 4: Technical Memorandum Second *Daphnia magna* Toxicity Test Results
Attachment 5: Technical Memorandum Revision of Site Specific Water Quality Objective for Strontium
Attachment 6: Development of Strontium Chronic Effects Benchmark for Aquatic Life in Snap Lake Report

De Beers will provide summaries of, and be prepared to discuss the information provided in the Attachments during the technical session on April 15-16.

Sincerely,

DE BEERS CANADA INC.

Erica Bonhomme
Manager, Environment
Snap Lake Mine

Copied to:

A. Hood; M.Ignasiak (counsel); P. Chapman (Golder Associates)	DBCI
C.Hubert	MVRB
R.Nicoll	MVLWB

SNAP LAKE MINE WATER LICENSE AMENDMENT

Plain Language Summary of Key Proposed Amendments

April 2014

De Beers Canada Inc.

SNAP LAKE MINE WATER LICENSE AMENDMENT
Plain Language Summary of Key Proposed Amendments

Introduction

De Beers Canada Inc.'s (De Beers') Snap Lake diamond mine is located in the Snap Lake property approximately 220 km northeast of Yellowknife. The site is remote with year-round access available by aircraft from Yellowknife. A 35 kilometer winter access road also connects the site to kilometer 222 of the Tibbitt-Contwoyto winter road. Snap Lake is a completely underground mine and mining operations began in 2008 to access kimberlite deposits under Snap Lake.

The 2013 Snap Lake Water License Amendment Application proposes to change the allowable levels of some components within the water that is released to Snap Lake from the mine. The amount of these components which can be released into the aquatic environment are called "Effluent Quality Criteria" or EQC. The Canadian federal government has set guidelines for some EQCs, but most do not apply well to the northern aquatic environment of Snap Lake.

The primary component addressed in the amendment application is called "Total Dissolved Solids" (TDS). TDS refers to the amount of different types of salts in the water. These include chloride, calcium and sodium, with smaller amounts of sulfate, silica, fluoride, ammonia and nitrate, among others. The water at Snap Lake Mine contains TDS because underground mining activities release ancient water from underground, called "connate water." As mining continues into new areas, connate water that is trapped within the rock is released. It is important to note that there is not currently an EQC for TDS. At present, an in-lake limit has been set based upon predictions made during the Environmental Assessment of the mine. De Beers was required to do studies of the aquatic life in Snap Lake in order to recommend the amount of TDS that the water could contain while still making sure that that would fish and the food they depend on will stay healthy.

TDS is a focus of this application because:

- High levels of TDS can be harmful to the animals and plants that live in Snap Lake, including fish.
- The amount of TDS that is currently allowed to be within Snap Lake may be overprotective.
- TDS in Snap Lake is increasing, and studies at Snap Lake show that increasing the allowable levels to a point will not be harmful to the aquatic community.

Groundwater and Site Models

Snap Lake Mine has to pump very large amounts of water out of the underground mine every day. The amount of water pumped from underground will continue to increase over the next 20 years of mine operations. One of the ways De Beers plans operations at Snap Lake Mine, including understanding water volume and water quality, is through the development of models. These are predictions made by geologists and engineers of the rock structure, water flow and water quality using the most current information available. For example, the information gathered prior to mine production was used to design the infrastructure and systems used to collect, treat and release water from the mine. This information is continuously reviewed using actual data for water flow and quality gathered during operations. De Beers has updated underground and surface water models using our understanding of water volume gained since mining at Snap Lake began.

Underground Simulation

The underground model uses current and past measured water flows into the underground mine as well as information about the rock, permafrost and future mine plans to develop predictions of water flows in the future. The current model predicts that up to 60,000 cubic metres of water (the same volume as 24 Olympic swimming pools) could be collected in the underground mine each day.

Site Simulation

Understanding the site water balance helps De Beers understand how water needs to be collected, stored, and managed at surface. This includes water that is collected through rainfall and snow melt and water from the North Pile, where processed kimberlite is stored.

All water collected at Snap Lake from the underground and surface is piped to the Water Treatment Plant. There, sediment from the water is removed and the water is tested before it is released. This is to make sure that water meets license criteria before it enters Snap Lake. This effluent from the mine site is discharged through pipes, called diffusers, with special fittings that slowly release the treated water into Snap Lake allowing the two waters to mix together.

Site Model Water Quality

The Site Water Quality Model helps us to understand the quality of the water coming from different areas of the mine. Water quality data from various facilities on the mine site are used with the Site model to understand both quality and quantity of water. This helps us understand and predict the water that will be released into Snap Lake now and into the future, when the mine is closed.

These predictions suggest that TDS in the managed site water will be highest between now and 2018. After that the increases will be slower. This model shows us that the connate water entering the mine is the main reason for changes in water quality.

Lake Model

The lake model uses the information from both surface and underground models. The lake model predicts how water that interacts with the mine affects Snap Lake. This model focuses on TDS (including nutrients), and metals predicted to enter the lake now and in the future. The models shows that without reducing the amount of TDS and nutrients in the mine effluent, the amount of these components will increase in Snap Lake beyond the proposed limits, indicating that management action will be required.

How Site Specific Limits are set

The Canadian Council of Ministers of the Environment (CCME) determine the level of effluent components that can be released without impacting the aquatic environment and the animals and plants that live in it. The CCME allows specific limits to be developed for effluent components to take into account the conditions that exist at a specific site, such as the temperature and hardness of the water. These "modifying factors" are developed through benchmark studies that are explained below.

TDS, including Fluoride and Nitrate Benchmark Studies

For TDS, including fluoride and nitrate, De Beers completed laboratory tests on fish and small animals and plants that live in Snap Lake. The laboratory tests used water and organisms similar to Snap Lake. Water was spiked with ions that copy the proportions of TDS in the water at Snap Lake. This was used to determine how much of these ions in the water would cause an effect to the various organisms tested. De Beers tested different species of animals and plants, including fish. These animals and plants included lab species that are commonly used for this type of testing as well as species that exist in Snap Lake. The testing has allowed experts to recommend the amount of TDS and its constituents that can be released into Snap Lake without having effects on the plants and animals that live in the Lake. For chloride, De Beers used information from similar studies completed at the EKATI Diamond Mine.

The results of the benchmark studies were used to determine what levels should be set at the Water Treatment Plant (SNP 02-17B) for discharge into the Lake, based on the volumes and water quality experienced at Snap Lake.

TDS Response Plan

The amount of TDS in Snap Lake is increasing, and will exceed allowable limits if additional mitigation is not applied The TDS response plan has identified where TDS in mine water comes from, and identifies some options for how it can be managed. The main source of TDS (including chloride and fluoride) is the underground mine water.

Management efforts to reduce the amount of TDS in mine effluent being released into Snap Lake are focused on studies De Beers started in 2012 on water treatment options. In the first stage of the studies, De Beers looked at different technologies that could be used to remove TDS from all of the mine water. The studies concluded that there are technologies available that are effective at removing TDS, however treatment of all water collected on site is uneconomical. De Beers is now studying options to remove TDS and other components from smaller volumes of mine water.

Nitrogen Response Plan

Two nutrients, nitrate and ammonia, are discussed in this plan. Nitrate and ammonia in effluent water come from the use of explosives during mining. Explosive residue containing nitrate and ammonia enters the water management system in two ways: from underground mine workings, and through seepage from the North Pile. The Nitrogen Response Plan discusses the work that De Beers has completed to understand how these nutrients are increasing in Snap Lake, and what can be done to reduce them. De Beers has identified options for improving blasting practices and efficiency, diluting nutrient-rich water, improving explosives storage and transport, and updating model predictions.

EQC Report

The EQC report takes into consideration the results of the benchmark studies, and makes recommendations for limits of the different water quality components and where these limits should be applied. The proposed EQCs are included in the water licence application, and are summarized below:

Parameter	Average Monthly Limit (mg/L)		Max Grab (mg/L)	
	current	proposed	current	proposed
Total Suspended Solids	7	7	14	14
Ammonia as N	10	10	20	20
Nitrite as N	0.5	1	1	3
Nitrate as N	22	14	44	32
Nitrate as N (January 1, 2015)	4	14	8	32
Chloride	310	378	620	607
Fluoride Jan1 2015	0.15	2.43	0.3	3.73
Sulphate	75	427	150	640
Metals	trace	remove	trace	remove
TDS	Propose removing current whole-lake average TDS Water Licence limit of 350 milligrams per litre (mg/L) and replacing with end-of-pipe AML of 684 mg/L and max grab of 1,003 mg/L.			

Supplemental Information Request Responses

(MVLWB IRs 2, 8, and 11)

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Attachment 1: Additional Information as referenced in Excel Comment Table

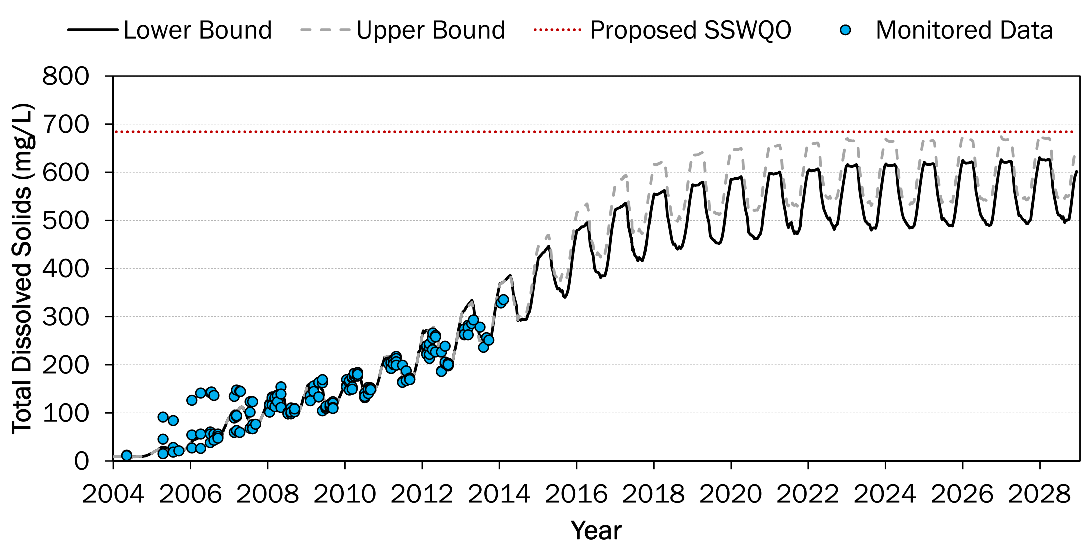
MVLWB 2

Topic: Effectiveness of proposed water management measures to achieve compliance with the proposed SSWQO for TDS in Snap Lake

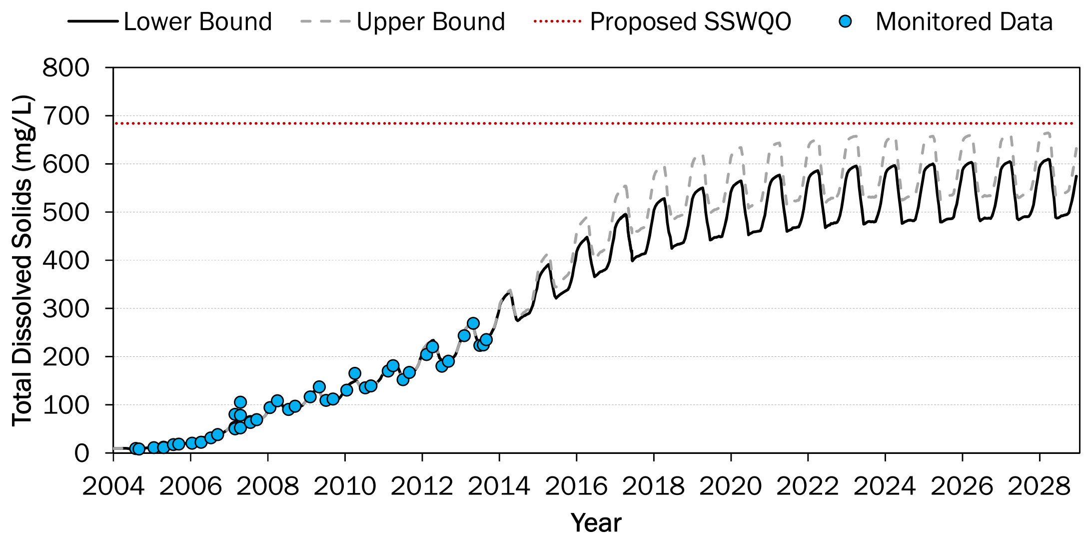
Figure MVLWB 2-1, panels a to c, presents predicted total dissolved solids (TDS) concentrations in the diffuser area, main basin, and outlet of Snap Lake, respectively, assuming that effluent discharged to Snap Lake from the Snap Lake Mine will be treated such that TDS concentrations in the effluent will not exceed the proposed average monthly limit (AML) of 684 milligrams per litre (mg/L) from January 1, 2015 to January 1, 2029. For the simulation, if the concentration of TDS in the effluent was predicted to be greater than 684 mg/L in De Beers (2013a), the concentration of TDS was reduced to 684 mg/L. If the concentration of TDS in the effluent was predicted to be less than 684 mg/L in De Beers (2013a), the concentration of TDS was not changed. Effluent was discharged to Snap Lake at the lower and upper bound discharge rates predicted in De Beers (2013b).

Figure MVLWB 2-1 Predicted Depth Averaged Total Dissolved Solids Concentrations in Snap Lake (with Mitigation)

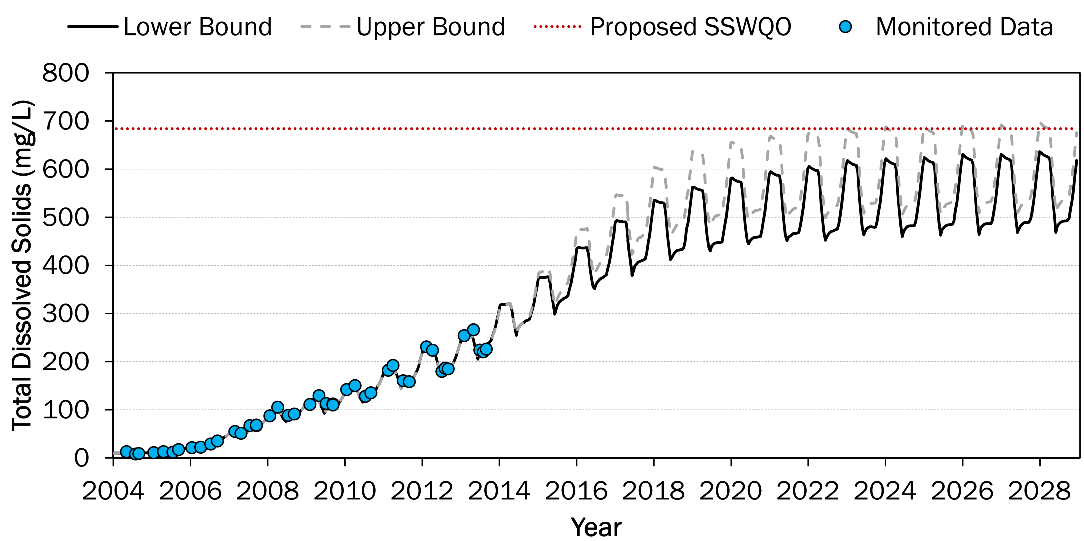
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet



Note: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively.

mg/L = milligrams per litre; SNP = surveillance network program; SSWQO = site-specific water quality objective.

In the Upper Bound Scenario, TDS concentrations are predicted to exceed the proposed site-specific water quality objective (SSWQO) of 684 mg/L from 2023 to 2028. The Upper and Lower Bound Scenarios represent the range of possible effluent discharge rates to Snap Lake. De Beers expects that actual discharge rates to Snap Lake will be intermediate between the two scenarios. The Lower Bound Scenario was used to calculate an AML for TDS because, even at the lower end of expected flows, mitigation will be required to meet the proposed AML over the life of the mine. Effluent discharge rates to Snap Lake will be compared to the predicted Upper and Lower Bound discharge rates. If actual discharge rates begin to follow the Upper Bound Scenario, effluent quality criteria (EQC) will be revised.

References

De Beers (De Beers Canada Inc.). 2013a. Snap Lake Site Model Water Quality Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

De Beers. 2013b. Snap Lake Site Model Water Balance Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

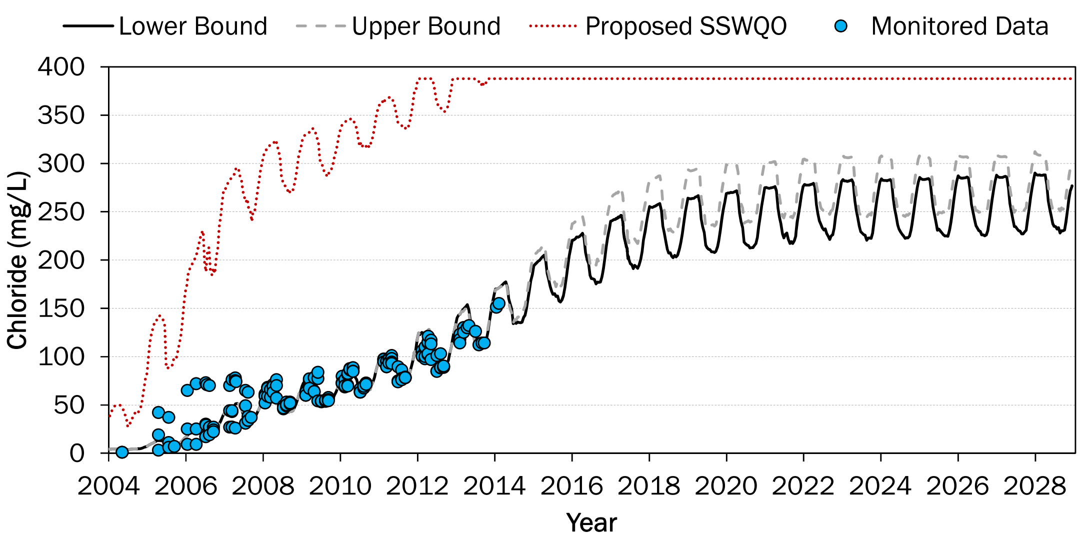
MVLWB 8

Topic: Effectiveness of proposed water management measures to achieve compliance with the proposed SSWQO for Chloride in Snap Lake

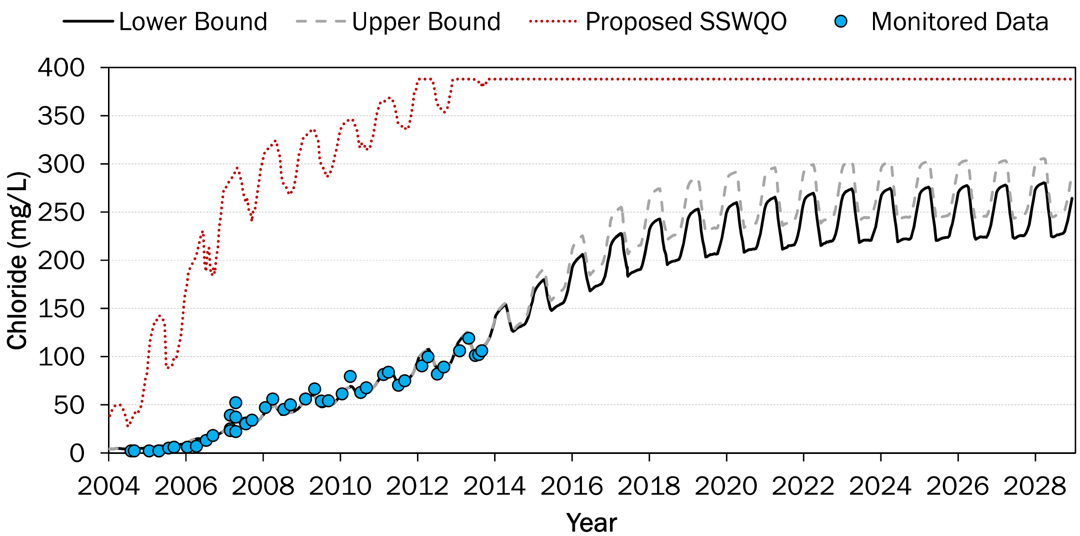
Figure MVLWB 8-1, panels a to c, presents predicted chloride concentrations in the diffuser area, main basin, and outlet of Snap Lake, respectively, assuming that the predicted chloride concentrations make up 46 percent (%) of the predicted TDS concentrations in Snap Lake. Predicted chloride concentrations were generated by taking 46% of the predicted TDS concentrations that were presented in De Beers' response to **MVLWB 2**.

Figure MVLWB 8-1 Predicted Depth Averaged Chloride Concentrations in Snap Lake (with Treatment)

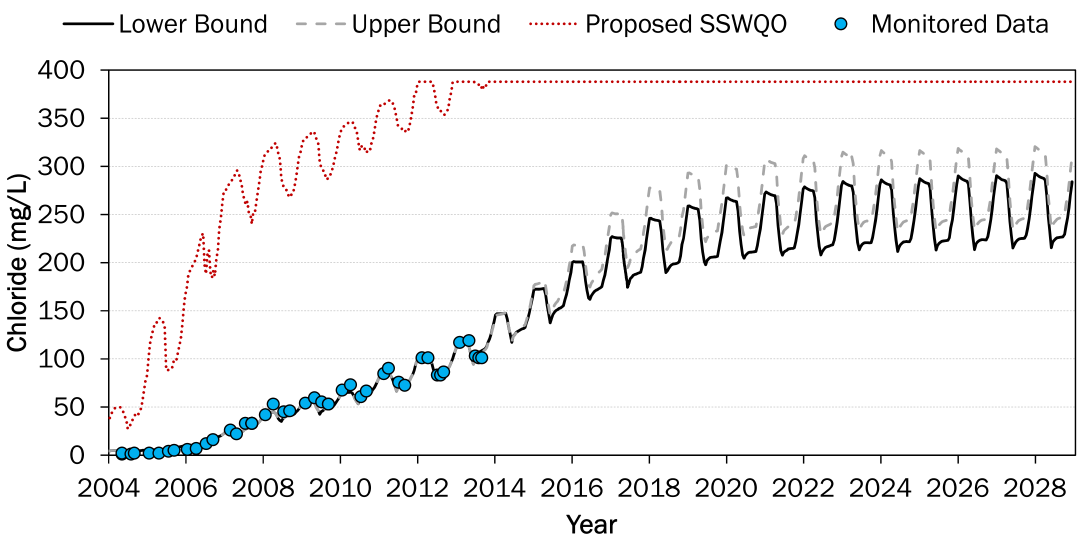
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet



Note: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively.

mg/L = milligrams per litre; SNP = surveillance network program; SSWQO = site-specific water quality objective.

MVLWB 11

Topic: Effectiveness of proposed mitigations

Please see De Beers' response to **MVLWB 2** and **MVLWB 8**.

Snap Lake Water Licence Amendment Environmental Assessment EA201314-002

Supplemental Information

11 April 2014

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Acronyms

Abbreviation	Definition
3-D	three-dimensional
AANDC	Aboriginal Affairs and Northern Development Canada (formerly INAC)
AEMP	Aquatic Effects Monitoring Program
ALS	ALS Canada Ltd.
AML	average monthly limit
AO	aesthetic objective
De Beers	De Beers Canada Inc.
DSL1	Downstream Lake 1
DSL2	Downstream Lake 2
EA	environmental assessment
EAR	Environmental Assessment Report
e.g.	for example
EQC	effluent quality criteria
GEMSS	Generalized Environmental Modelling System for Surfacewaters
i.e.	that is
INAC	Indian and Northern Affairs Canada (now AANDC)
LCB	Lac Capot Blanc
MAC	maximum acceptable concentrations
MDL	maximum daily limit
Mine	Snap Lake Mine
MVLWB	Mackenzie Valley Land and Water Board
MVRB, the Review Board	Mackenzie Valley Review Board
NWT	Northwest Territories
SNP	surveillance network program
SSWQO	site-specific water quality objective
TDS	total dissolved solids
WQG	water quality guideline

Units of Measure

Abbreviation	Definition
°C	degrees Celsius
%	percent
<	less than
>	greater than
≤	less than or equal to
cm	centimetre
g/d	grams per day
km	kilometre
m	metre
m^3/s	cubic metres per second
m^3/d	cubic metres per day
mg/L	milligrams per litre

1 INTRODUCTION

1.1 Background

On December 20, 2013, De Beers Canada Inc. (De Beers) made an application to the Mackenzie Valley Land and Water Board (MVLWB) to amend its existing water licence for the Snap Lake Mine (MV2011L2-0004). De Beers requested 17 amendments to existing water licence conditions. On January 22, 2014 this application was referred by the MVLWB to the Mackenzie Valley Review Board (the Review Board) for environmental assessment (EA; EA1314-02). The water licence amendment application was referred based on jurisdictional questions, and concerns raised by parties, regarding proposed amendments that exceed a limit for one water quality parameter (total dissolved solids or "TDS"). On March 28, 2014, the Review Board determined that the components of the proposed water licence amendment application that will be assessed in the EA process include TDS and its constituents including, but not limited to: nitrite, nitrate, chloride, fluoride, and sulphate (MVRB 2014).

The Review Board reviewed De Beers' water licence amendment application and decided that it provided sufficient information to commence an assessment on items the Review Board decided are within the scope of this EA. Because sufficient information was provided in the amendment application, the Review Board did not issue a Terms of Reference and, hence, no Developer's Assessment Report was required. The Review Board, in conducting an EA of a development proposal must, however, consider the factors listed in section 117.(2) of the *Mackenzie Valley Resource Management Act*. In its application of December 19, 2013, De Beers provided information regarding the potential impact on the environment of the proposed amendment to TDS. In this submission, De Beers is providing supplemental information to enable the Review Board to specifically consider, in regards to the proposal, the cumulative impact and impact of accidents and malfunctions on the environment, as well as alternative means of carrying out the proposal.

1.2 Scope of the Development and Supplemental Information

The development proposal to which this supplemental filing pertains is the discharge of treated effluent to Snap Lake with effluent quality criteria (EQCs) (Table 1-1).

Table 1-1 Proposed Effluent Quality Criteria for Nitrate, Chloride, Fluoride, Sulphate and Total Dissolved Solids

Parameter	Proposed Average Monthly Limit (AML) (mg/L)	Proposed Max Grab (MDL) (mg/L)
Nitrate	14	32
Chloride	378	607
Fluoride	2.43	3.73
Sulphate	427	640
Total dissolved solids	684	1,003

Note: Effluent quality criteria are limits that apply at end-of-pipe (i.e., at the last point of discharge to the receiving environment).

AML = average monthly limit; MDL = maximum daily limit; mg/L = milligrams per litre; max = maximum.

The supplemental filing includes the following information:

- updated water quality modeling predictions addressing comments received on the application March 14;
- cumulative effects of TDS in the Lockhart River watershed;
- accident and malfunctions related to discharge of TDS; and,
- alternatives to the proposal.

The supplemental information is focused predicted changes to water quality, and possible impacts to aquatic life. No linkage between increased TDS in Snap Lake and socio-economic or cultural factors could be determined; thus, these factors were excluded from further review.

2 UPDATED WATER QUALITY PREDICTIONS

2.1 Snap Lake

2.1.1 Introduction

Effluent quality criteria are limits that apply at end-of-pipe (i.e., at the last point of discharge to the receiving environment). As part of the Water Licence Amendment Application, EQC were derived such that parameter concentrations in Snap Lake would remain below appropriate site-specific water quality objectives (SSWQOs) if EQC values were adopted and met for the duration of operations (De Beers 2013b).

The Snap Lake Mine Hydrodynamic and Water Quality Model Report (De Beers 2013a), submitted as part of the Water Licence Amendment Application, presents predicted concentrations of TDS, ions, nutrients, metals, and metalloids in Snap Lake, assuming potential mitigation would not be in place to reduce TDS concentrations below recommended effluent quality criteria (EQC). Since the submission of the Water Licence Amendment Application, further modelling has been completed to predict concentrations in Snap Lake assuming that the proposed EQCs for TDS and other parameters will be adopted, and not exceeded over mine life. This section describes predictions of TDS, chloride, fluoride, sulphate, and nitrate concentrations in Snap Lake assuming thateffluent discharged from the Snap Lake Mine (Mine) to Snap Lake will undergo mitigation such that parameter concentrations in the effluent will not exceed the proposed average monthly limits as presented in Table 1-1 (De Beers 2013b).

Set-up and calibration of the hydrodynamic and water quality model for Snap Lake is described in Section 2.1.2. Model predictions for Snap Lake are presented in Sections 2.1.3, comparisons to SSWQOs and drinking water guidelines are presented in Section 2.1.4.

2.1.2 Methods

The Snap Lake model setup and model inputs were identical to those described in De Beers (2013a) with the exception of the parameters simulated and concentration of TDS in the effluent discharge to Snap Lake (Sections 2.1.2.1 and 2.1.2.2).

2.1.2.1 Model Parameters

Concentrations of TDS, chloride, fluoride, sulphate, and nitrate were carried forward in this assessment, aligning with those parameters identified in the EA scoping document (MVRB 2014). Nitrite was not simulated in either the site model or the Snap Lake model, due to its rapid transformation to nitrate.

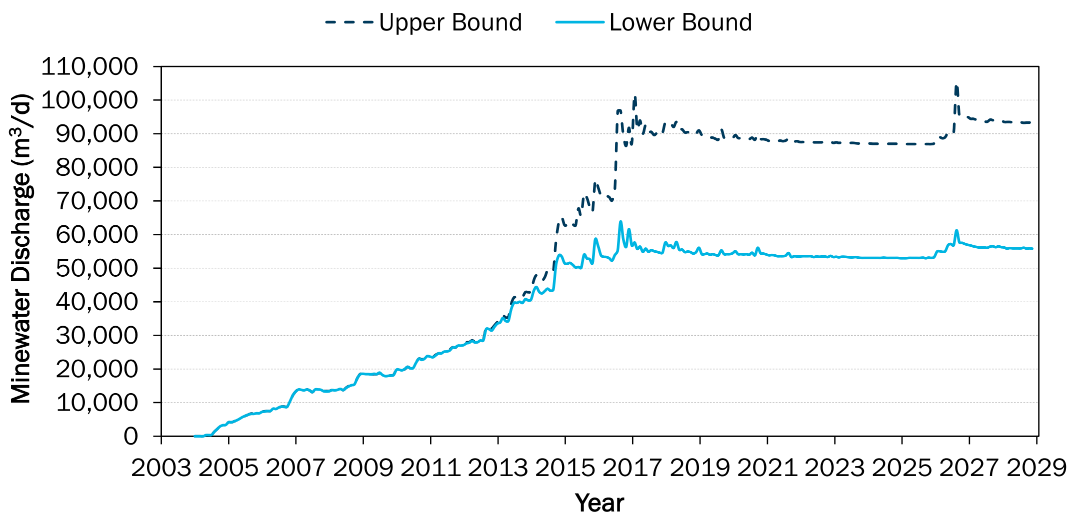
2.1.2.2 Model Scenarios

Two model scenarios were considered for the operational period from 2014 to 2028. The model scenarios assumed that mitigation would be in place such that TDS concentrations in the effluent discharge to Snap Lake would not exceed the proposed AML of 684 mg/L. Where the concentration of TDS in the effluent discharge to Snap Lake was predicted to be greater than 684 mg/L in De Beers (2013c), the concentration of TDS was reduced to 684 mg/L in the model. If the concentration of TDS in the effluent discharge to Snap Lake was predicted to be less than 684 mg/L in De Beers (2013c), the concentration of TDS in the model was not changed. The model scenarios were based on the expected range of groundwater discharge rates from the Mine (Figure 2-1) (Itasca 2013).

The two model scenarios were:

- Base Case A: Lower Bound effluent discharge rate and TDS concentrations in the effluent do not exceed 684 mg/L from January 1, 2015 to January 1, 2029; and,
- Base Case B: Upper Bound effluent discharge rate and TDS concentrations in the effluent do not exceed 684 mg/L from January 1, 2015 to January 1, 2029.

Figure 2-1 Upper and Lower Bound Minewater Discharge



m^3/d = cubic metres per day

2.1.3 Model Results

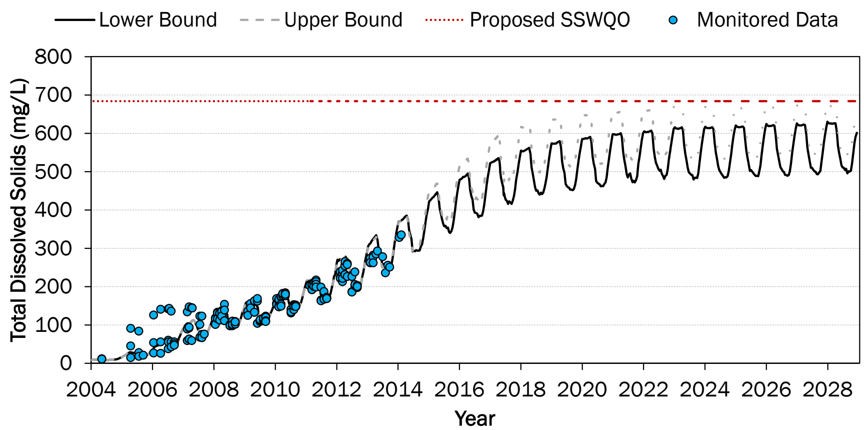
With mitigation in place to meet the proposed EQC at end-of-pipe, predicted depth-averaged concentrations of TDS, chloride, fluoride, sulphate, and nitrate concentrations were predicted to remain below proposed SSWQOs in Snap Lake (Figures 2-2 to 2-6), with one exception. In the Upper Bound Scenario, depth-averaged TDS concentrations at the outlet of Snap Lake were predicted to exceed the proposed TDS SSWQO of 684 mg/L during ice-cover between 2023 and 2028 (Figure 2-2). The increase was due to the influence of modelled salt exclusion at the shallow outlet location. Current monitoring data indicate that TDS concentrations near the outlet of Snap Lake are lower than near the diffuser. However, TDS concentrations were predicted to be sufficiently elevated under the Upper Bound scenario that ice formation and salt exclusion results in exceedance of the SSWQO as the lake approaches equilibrium. The Upper and Lower Bound scenarios represent the range of possible effluent discharge rates to Snap Lake. De Beers expects that actual discharge rates to Snap

Lake will be intermediate between the two scenarios. The Lower Bound Scenario was used to calculate an AML for TDS because, even at the lower end of expected flows, mitigation will be required to meet the proposed AML over the life of the mine.

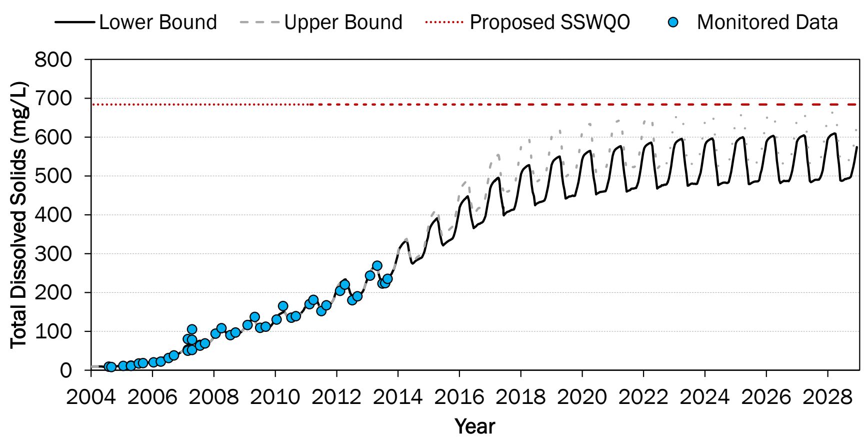
Actual monitored effluent discharge rates to Snap Lake will be compared to the predicted Upper and Lower Bound discharge rates. If actual discharge rates begin to follow the Upper Bound Scenario, and TDS concentrations near the outlet approach the 684 mg/L (would be identified under the Aquatic Effects Monitoring Program [AEMP] Response Framework), EQC may need to be revisited to remain below 684 mg/L at all locations throughout the lake.

Figure 2-2 Depth-Averaged Total Dissolved Solids Concentrations in Snap Lake (Proposed Effluent Quality Criteria Are Met)

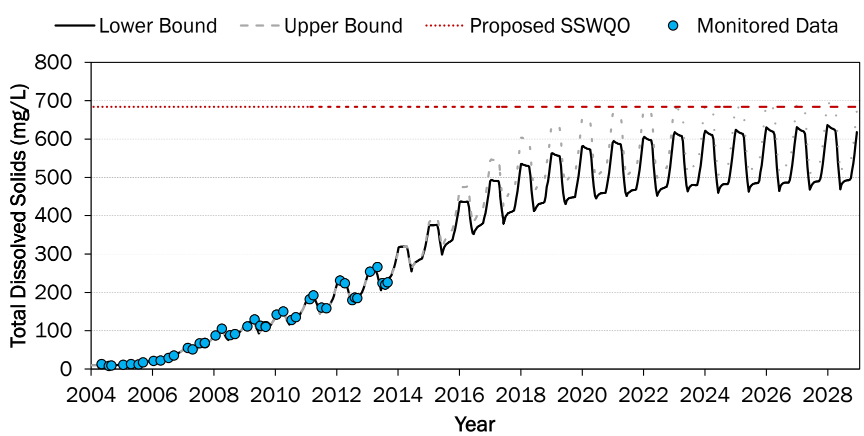
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet

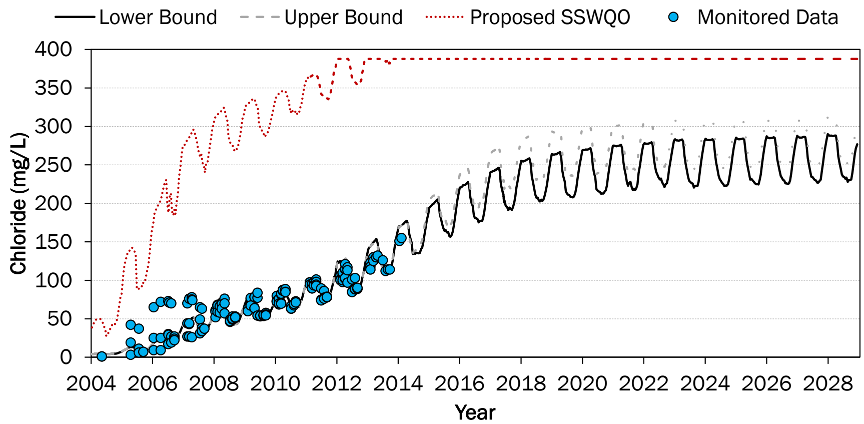


Notes: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively. Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

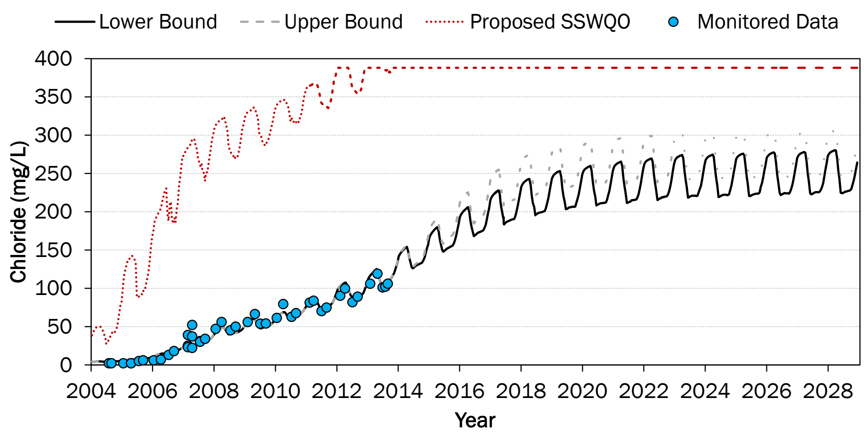
mg/L = milligrams per litre; SSWQO = site-specific water quality objective; SNP = surveillance network program.

Figure 2-3 Depth-Averaged Chloride Concentrations in Snap Lake (Proposed Effluent Quality Criteria Are Met)

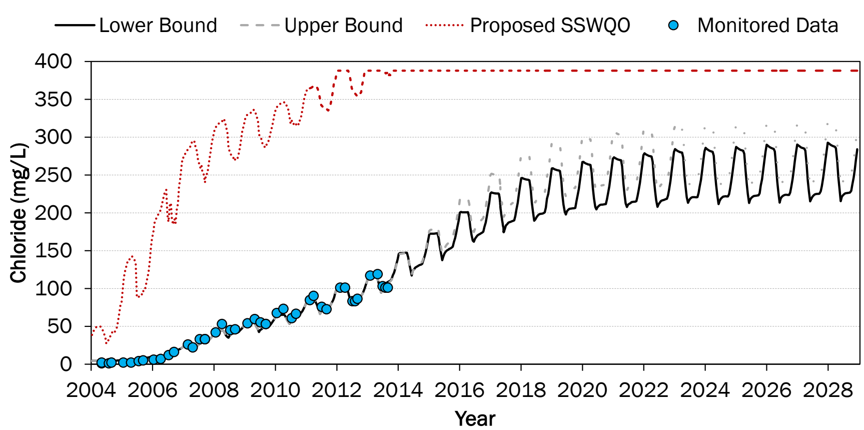
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet

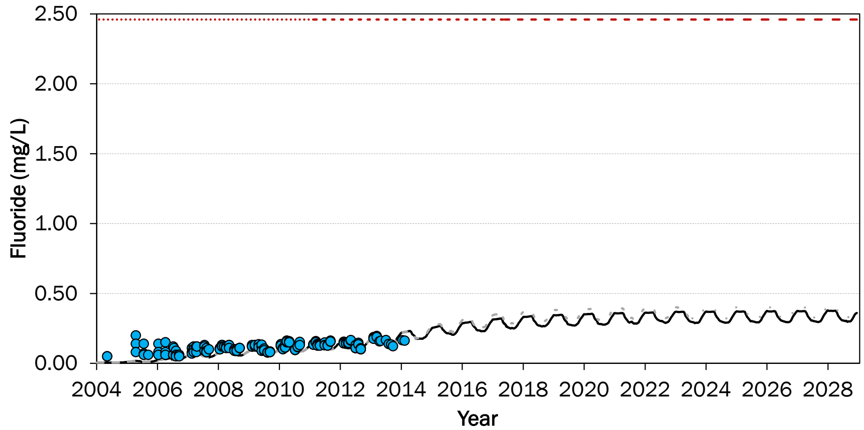


Notes: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively. Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

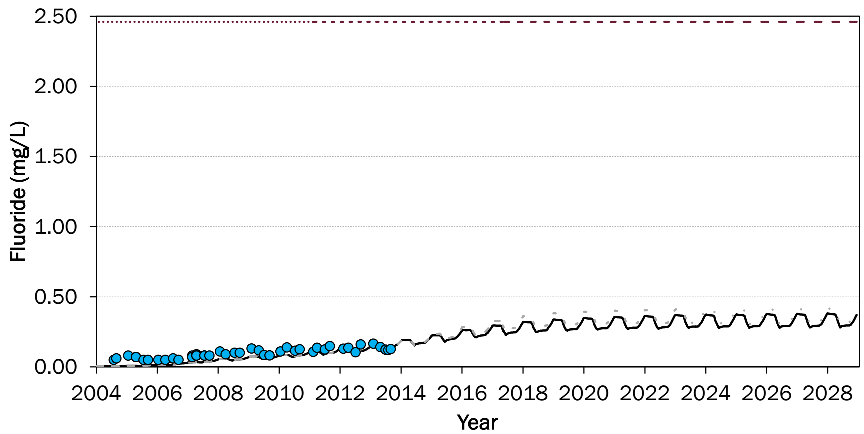
mg/L = milligrams per litre; SSWQO = site-specific water quality objective; SNP = surveillance network program.

Figure 2-4 Depth-Averaged Fluoride Concentrations in Snap Lake (Proposed Effluent Quality Criteria Are Met)

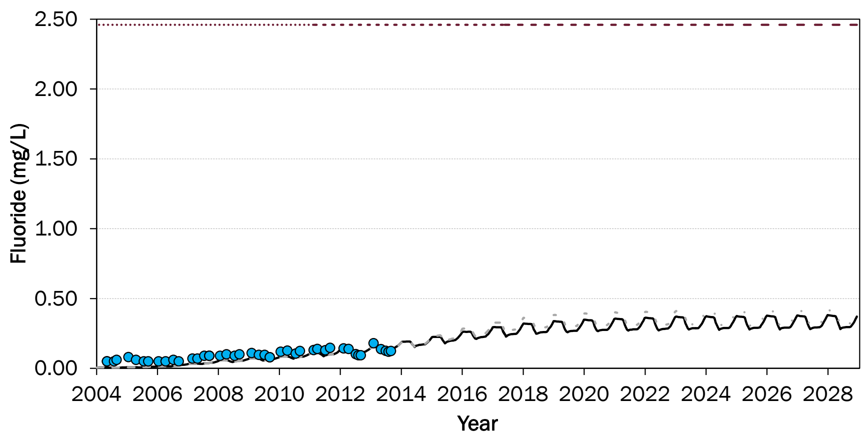
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet

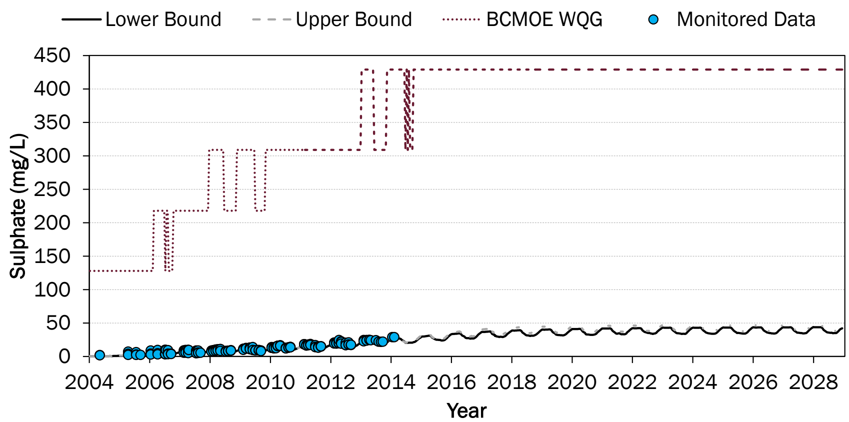


Notes: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively. Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

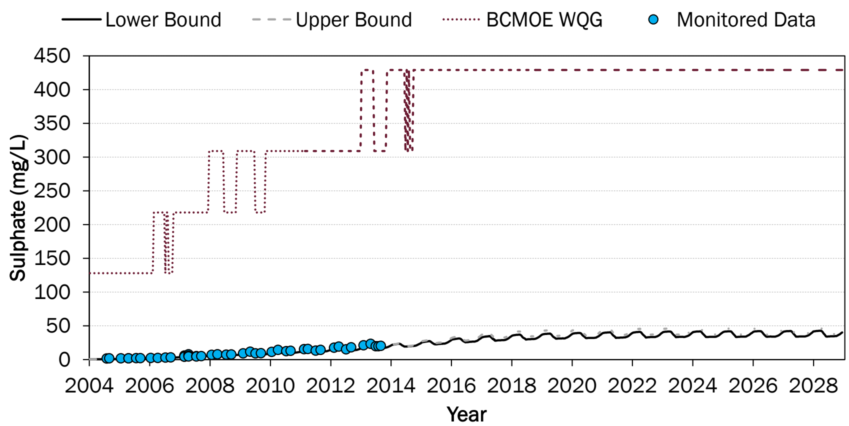
mg/L = milligrams per litre; SSWQO = site-specific water quality objective; SNP = surveillance network program.

Figure 2-5 Depth-Averaged Sulphate Concentrations in Snap Lake (Proposed Effluent Quality Criteria Are Met)

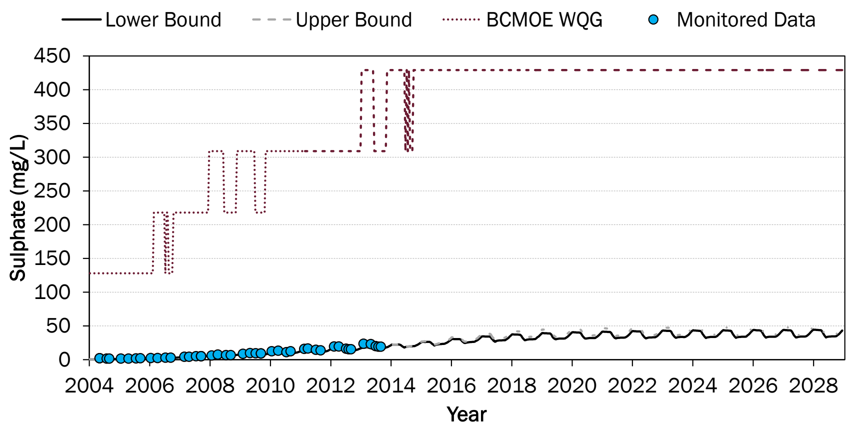
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet

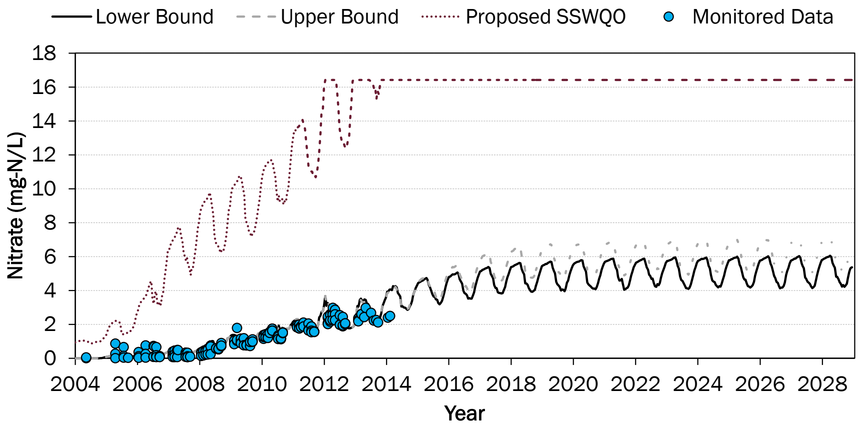


Notes: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively. Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

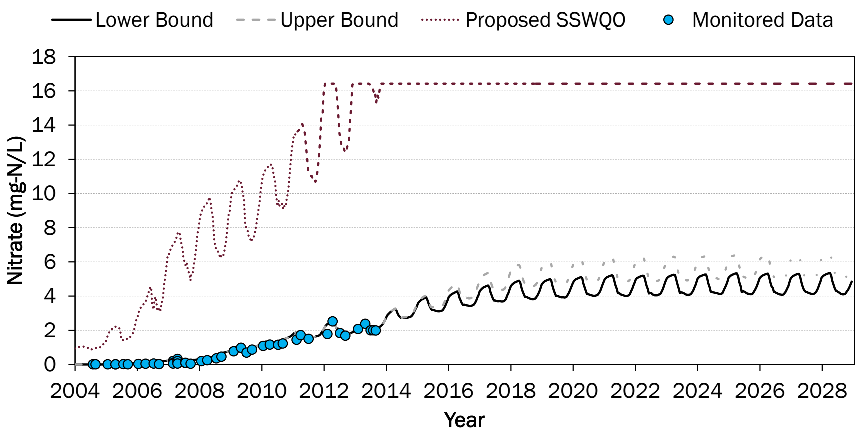
mg/L = milligrams per litre; BCMOE WQG = British Columbia Ministry of Environment water quality guideline; SNP = surveillance network program

Figure 2-6 Depth-Averaged Nitrate Concentrations in Snap Lake (Proposed Effluent Quality Criteria Are Met)

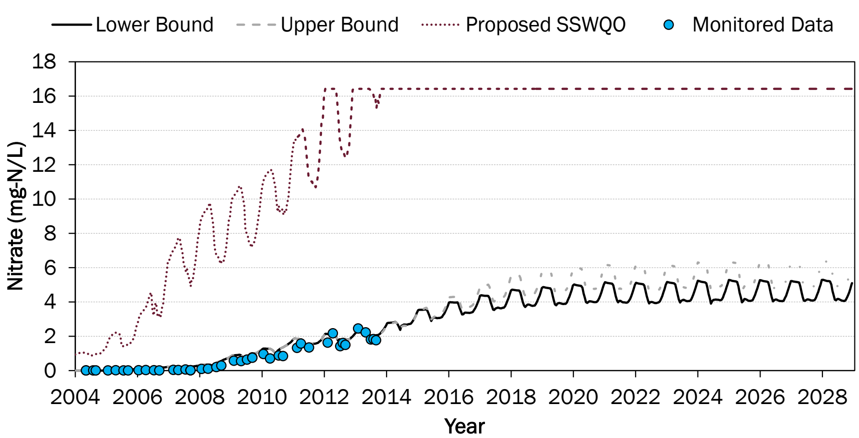
(a) Near Diffuser



(b) Main Basin



(c) Near Outlet



Notes: Monitored data near the diffuser, in the main basin, and near the outlet are from representative stations SNP 02-20e, SNAP09, and SNAP08, respectively. Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

mg/L = milligrams per litre; SSWQO = site-specific water quality objective; SNP = surveillance network program.

2.1.4 Comparisons to Drinking Water Guidelines

Water quality predictions were compared against Canadian drinking water quality guidelines (WQGs; Health Canada 2012; Table 2-1). Canadian drinking water quality guidelines (WQGs) that are health-based are reported as maximum acceptable concentrations (MACs). Water quality guidelines related to the physical characteristics of the water (i.e., taste, odour, colour) are referred to as aesthetic objectives (AOs). Aesthetic objectives (TDS, chloride, sulphate) were considered in the assessment, as these can influence a user's perception of water drinkability. However, these objectives are not an indication of adverse effects to human health.

The SSWQOs recommended for total dissolved solids and chloride and the maximum predicted concentrations in Snap Lake exceed AOs, which are based on taste. The palatability of drinking water has been rated by panels of tasters, according to TDS concentration: excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 900 and 1,200 mg/L; and, unacceptable, greater than or equal to 1,200 mg/L (Health Canada 2012; WHO 1996).

Table 2-1 Comparison to Drinking Water Guidelines

Parameter	Health Canada Guidelines for Drinking Water[(a)] (mg/L)	Site-Specific Water Quality Objective	Maximum Predicted Concentration in Snap Lake with Proposed Effluent Quality Criteria Are Met [(b)]			
			Lower Bound		Upper Bound	
			Diffuser	Outlet	Diffuser	Outlet
TDS	≤500 (AO)	**684**	**633**	**638**	**679**	**697**
Nitrate (as N)	10 (MAC)	**16.4**	6.2	5.3	7.2	6.4
Chloride (46% of TDS)	≤250 (AO)	**388**	**291**	**293**	**312**	**321**
Fluoride (0.06% of TDS)	1.5 (MAC)	**2.46**	0.38	0.38	0.41	0.42
Sulphate (7% of TDS)	≤500 (AO)	429	44	45	48	49

Bold concentrations are above a drinking WQG

a) Guidelines shown are from the Health Canada Guidelines for Canadian Drinking Water Quality (updated to August 2012).

b) Assumes TDS in effluent will be below the AML of 684 mg/L.

AO = aesthetic objective; MAC = maximum acceptable concentration; % = percent; TDS = total dissolved solids; N = nitrogen; mg/L = milligrams per litre.

2.2 Downstream Lakes

2.2.1 Introduction

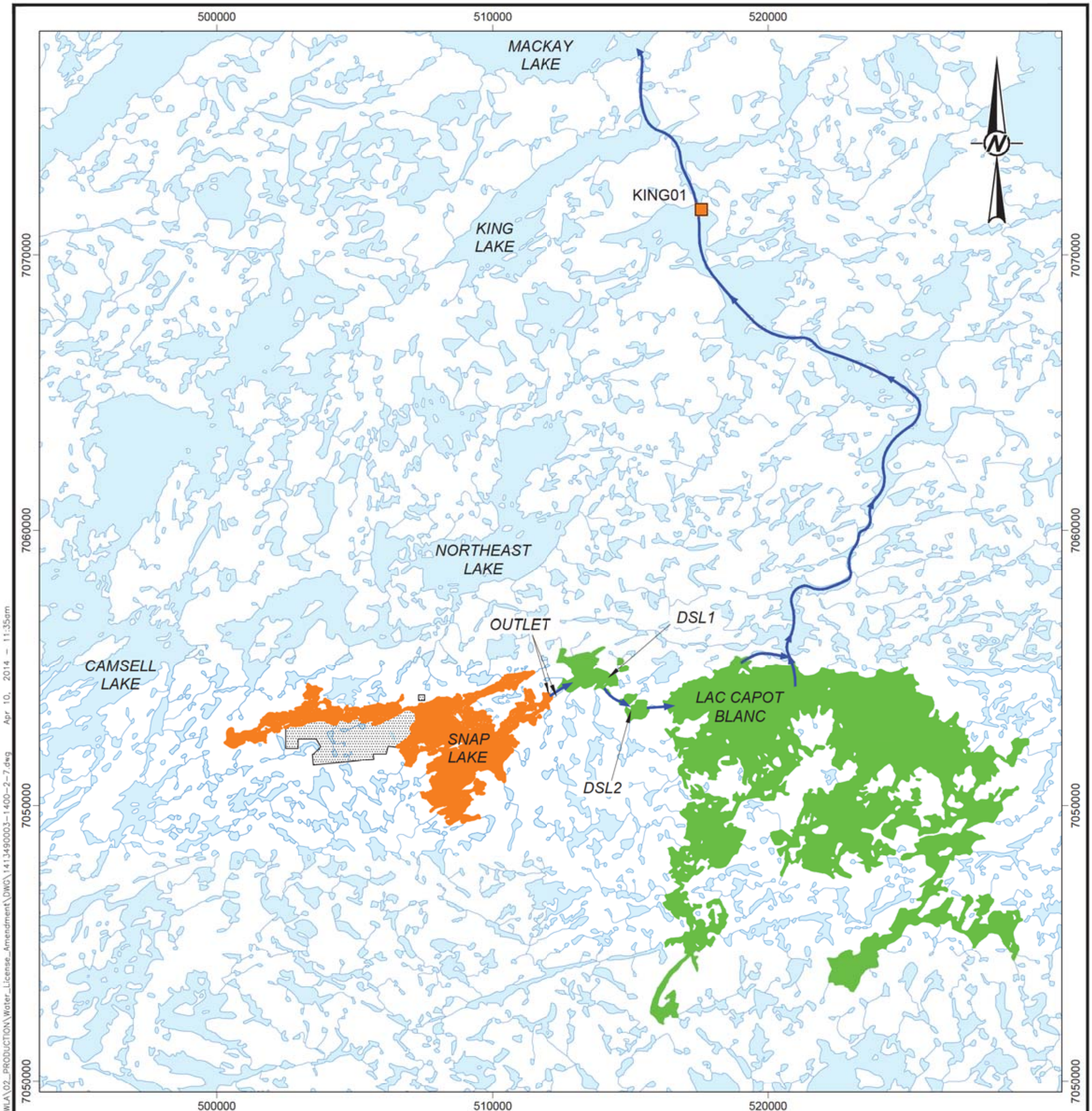
Snap Lake receives treated effluent from the Mine. Daily discharge rates from the Mine have steadily increased since discharge began in 2004, resulting in changes to water quality in Snap Lake. Treated effluent is becoming evenly mixed throughout the main basin of Snap Lake and, as predicted, is present in lakes downstream of Snap Lake (De Beers 2013d). Results from monitoring programs conducted in 2011 and 2012 showed evidence of treated effluent and dissolved salts and nutrients concentrations above baseline levels throughout the first two small lakes immediately downstream of Snap Lake and near the inlet of Lac Capot Blanc, respectively.

Based on results from the 2011 and 2012 monitoring programs, it was recommended that further information be collected in the first three downstream lakes (i.e., Downstream Lake 1 [DSL1], Downstream Lake 2 [DSL2], and Lac Capot Blanc) and that downstream modelling completed as part of the Environmental Assessment Report (EAR) be updated (De Beers 2013d, 2014). Accordingly, the Downstream Lakes Special Study was completed in 2013 to collect additional monitoring information (i.e., bathymetry, supporting environmental variables, water and sediment quality, and chlorophyll) from these lakes and to further document the extent of treated effluent downstream of Snap Lake (Figure 2-7).

Results from 2013 Downstream Lakes Special Study indicate that treated effluent was evident in DSL1, DSL2, and Lac Capot Blanc (De Beers 2014). Concentrations of dissolved salts and nutrients decreased with distance downstream. The extent of the effluent plume was observed up to 5 kilometres (km) from the inlet of Lac Capot Blanc, which is farther from the inlet than in 2012. The treated effluent mixed rapidly as it entered Lac Capot Blanc (as evidenced by a notable decrease in salt and nutrient concentrations near the inlet) then dispersed gradually, with concentrations returning to background levels within approximately 5 km of the inlet, which is approximately 11 km downstream of Snap Lake. In the EAR, concentrations were conservatively predicted to reach near background concentrations approximately 44 km downstream of Snap Lake at the end of operations, using a steady-state mixing model and assuming maximum concentrations during operations (De Beers 2002).

Additional modelling has been completed to predict TDS concentrations in lakes downstream of Snap Lake using the proposed SSWQO. The geographic extent of the modelling included DSL1, DSL2, Lac Capot Blanc, and the modelling nodes downstream through the Lockhart River watershed identified as part of the EAR (Figure 2-8).

Setup of the mass-balance models for DSL1, DSL2, and Lac Capot Blanc: set-up and calibration of the hydrodynamic model for Lac Capot Blanc; and setup of the mass-balance model for lakes downstream of Lac Capot Blanc are described in Section 2.2.2. Predictions of TDS concentrations in DSL1, DSL2, Lac Capot Blanc, and lakes downstream of Lac Capot Blanc are presented in Section 2.2.3. Data gaps and model uncertainty are discussed in Section 2.2.4, followed by conclusions and recommendations in Sections 2.2.5 and 2.2.6, respectively.



LEGEND

- AEMP Water Quality Station
- Snap Lake Mine Footprint
- Monitoring Area
- 2013 Downstream Lakes Special Study Area
- Waterbody
- Watercourse
- Flow Direction

NOTE

DSL1 First lake downstream of Snap Lake

DSL2 Second lake downstream of Snap Lake

REFERENCE

Digital map from Mackay Lake, Northwest Territories, produced by Department of Energy, Mines and Resources. map 75m, original scale 1:250,000, projection: Transverse Mercator, Datum: NAD83, coordinate system: UTM zone 12.

SNAP LAKE MINE

Downstream Lakes Overview, 2013

PROJECTION:	DATUM:
UTM Zone 12	NAD83

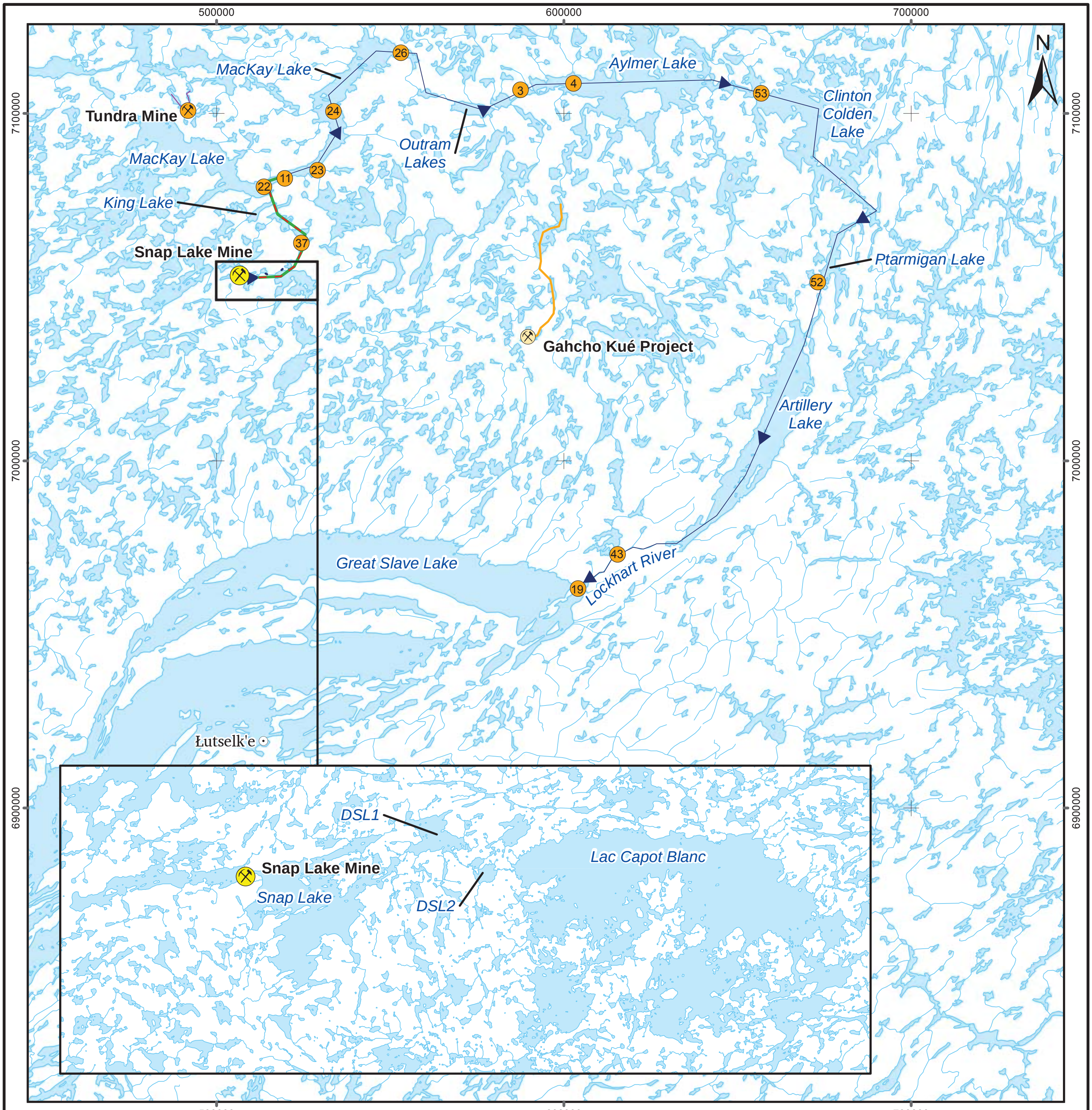
4 0 4

SCALE 1:200,000 KILOMETRES

DE BEERS GROUP OF COMPANIES

FILE No:		DATE:
1413490003-1400-2-7		April 10, 2014
JOB No: 14-1349-0003	REVISION No: A	
OFFICE: GOLDER VICTORIA	DRAWN: JEF	CHECK:

Figure 2-7



LEGEND

	Snap Lake Mine		Extent of the Total Dissolved Solids plume downstream of the Tundra Mine (AANDC 2013)
	Existing Mine		Predicted extent of the Total Dissolved Solids plume downstream of the Snap Lake Mine (De Beers 2002)
	Proposed Mine		Predicted extent of the Total Dissolved Solids plume downstream of the Gahcho Kué Project (De Beers 2012)
	Model Node		Predicted extent of the Total Dissolved Solids plume with mitigation downstream of the Snap Lake Mine
	Populated Place		
	Flow Direction		
	Watercourse		
	Waterbody		

REFERENCES

Base Data Source: CanVec

SNAP LAKE MINE

Downstream Lake Water Quality Model Nodes

PROJECTION: UTM Zone 12

DATUM: NAD83

30 0 30

SCALE 1:1,600,000 KILOMETRES

DE BEERS GROUP OF COMPANIES

FILE No: 1413490003_1503_DSL_WQ_Model_Nodes_2-8

DATE: April 9, 2014

JOB NO: 14-1349-0003

REVISION NO: A

OFFICE: GOLD-CAL

DRAWN: JC

CHECK:

Figure **2-8**

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2.2.2 Methods

2.2.2.1 Mass-Balance Models of Downstream Lakes 1 and 2 and Lac Capot Blanc

A mass-balance model of DSL1, DSL2, and Lac Capot Blanc was set up in GoldSim (GoldSim Technology Group 2009). GoldSim is a graphical, object-oriented mathematical model where all input parameters and functions are defined by the user, and are built as individual objects or elements linked together by mathematical expressions. The GoldSim model was used to calculate:

- inflows to and outflows from DSL1, DSL2, and Lac Capot Blanc; and,
- daily average TDS concentrations in DSL1 and DSL2.

The inputs to the GoldSim model were divided into hydrological and chemical inputs.

Hydrological Inputs

The main hydrological inputs to DSL1 are the inflow from Snap Lake and point and non-point source inflows from the DSL1 basin. The main hydrologic inputs to DSL2 are the inflow from DSL1 and point and non-point source inflows from the DSL2 basin. The main hydrological inputs to Lac Capot Blanc are the inflow from DSL2 and point and non-point source inflows from the Lac Capot Blanc basin. The main outflows from DSL1 and DSL2 are the discharges to DSL2 and Lac Capot Blanc, respectively. The main outflow from Lac Capot Blanc consists of the two outlet channels located on the north side of that lake (Figure 2-7). Other inflows to and outflows from DSL1, DSL2, and Lac Capot Blanc are direct precipitation and evaporation. To construct the water balance used in this model, time series of flows were generated based on the following sources:

- estimates of monthly runoff; and,
- estimates of monthly precipitation and evaporation data from the local study area (De Beers 2002).

Historical discharge data from Snap Lake to DSL1 used in the mass-balance model were obtained from the gauged tributary outflows at Snap Lake. For future simulations, the discharge from Snap Lake to DSL1 was obtained from the hydrodynamic and water quality model of Snap Lake (De Beers 2013a).

A water withdrawal was included for ice formation each winter from October to January in DSL1, DSL2, and Lac Capot Blanc, and a discharge was returned back to the lake each spring from April to June to simulate melting. In 2011 and 2012, ice formation and melting volumes were derived from the annual average of maximum ice thickness measurements at Snap Lake. In DSL1, DSL2, and Lac Capot Blanc, an ice thickness of 130 centimetres (cm) was used for 2011 (the average of maximum measured ice thickness in Snap Lake that year), and an ice thickness of 140 cm was used for 2012 (the average of maximum measured ice thickness in Snap Lake that year). In 2013, an ice thickness of 130 cm was used (the average of measured ice thickness in DSL1, DSL2, and Lac Capot Blanc that year). For every year afterwards, an ice thickness of 130 cm was used (130 cm is the long-term average of maximum measured ice thickness for Snap Lake). The water withdrawn and returned for ice formation had no associated constituents, meaning that salts were rejected from the ice and remained in the lake.

Chemical Inputs

The TDS concentrations in the discharge from Snap Lake to DSL1 were obtained from the hydrodynamic and water quality model of Snap Lake (De Beers 2013a). Inflows from the drainage areas of DSL1, DSL2, and Lac Capot Blanc were assigned the same water quality time series as that of the gauged tributary inflow to Snap Lake. Initial concentrations of TDS in DSL1, DSL2, and Lac Capot Blanc were estimated based on field data from monitoring programs completed during the 2011 open-water season (De Beers 2012a).

2.2.2.2 Hydrodynamic Model of Lac Capot Blanc

Three-dimensional (3-D) hydrodynamic modelling was completed to predict concentrations of temperature and TDS in Lac Capot Blanc. A hydrodynamic model of Lac Capot Blanc was developed to model processes such as water circulation and stratification and to predict the concentration of TDS in different areas of the lake. The hydrodynamic model of Lac Capot Blanc was developed in the Generalized Environmental Modelling System for Surfacewaters (GEMSS) platform.

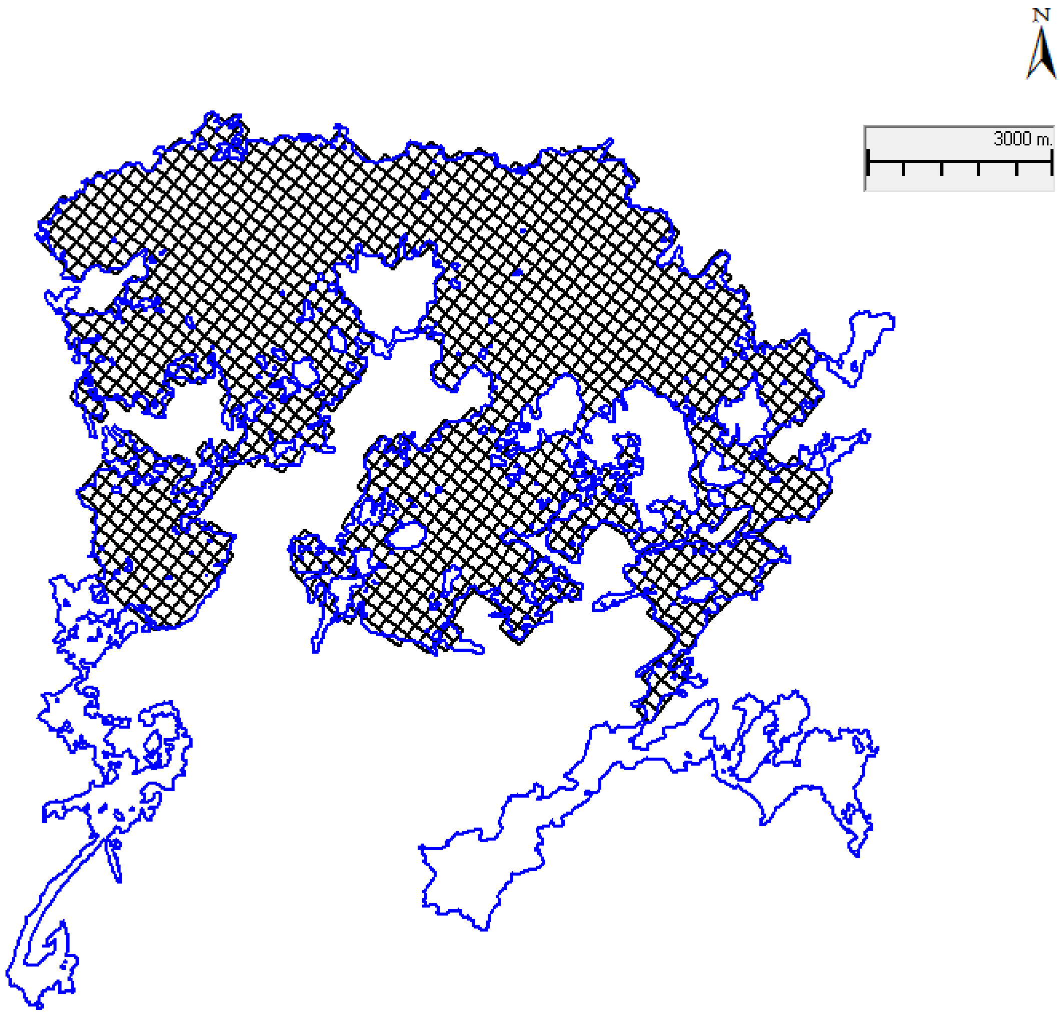
Model Segmentation

A 3-D grid (Figure 2-9) was developed for Lac Capot Blanc where measured bathymetric data were available. This portion of Lac Capot Blanc is expected to cover the majority of the area of the lake affected by inflows from Snap Lake. The grid spacing was approximately 200 metres (m) horizontally; the vertical resolution was approximately one metre. The grid comprised a total of 29 active layers and 8,813 active cells.

Inputs

All known and anticipated point and non-point source inflows to the lake were included as inputs to the Lac Capot Blanc model. Inputs to the lake are classified as meteorological, hydrological, and chemical, as described in the following sections.

Figure 2-9 Lac Capot Blanc Model Grid in Plan View



m = metre; N = north.

Meteorological Inputs

Meteorological inputs are key drivers of lake circulation and thermal dynamics. The forcing data required and used for this hydrodynamic model were:

- air temperature;
- dew point temperature;
- wet bulb temperature;
- atmospheric pressure;
- wind direction;
- wind speed; and,
- solar radiation.

The meteorological data from onsite meteorological stations at Snap Lake were used for the Lac Capot Blanc model. This dataset provides adequate representation of meteorological conditions, given that Lac Capot Blanc is located approximately 5 km downstream of Snap Lake. An hourly time series was constructed for each of the meteorological inputs from the meteorological stations at Snap Lake during the calibration time period from July 1, 2010 to December 31, 2013, with the exception of the solar radiation time series from 2010 to 2012. For the solar radiation input data from 2010 to 2012, an hourly time series of modelled solar radiation data was obtained for Yellowknife, Northwest Territories (NWT) from Environment Canada's Canadian Weather Energy and Engineering Datasets (Environment Canada 2013). Where gaps existed in the site-specific data, data from the Environment Canada station at the Yellowknife Airport were used. For simulations of future conditions, the time series used to calibrate the model was repeated.

Hydrological Inputs

The hydrological inputs to the Lac Capot Blanc hydrodynamic model were the same as those described for the mass-balance model.

Chemical Inputs

Water quality input data to Lac Capot Blanc were the same as those described for the mass-balance model. In-lake samples were used to initialize lake concentrations for the start of simulations (July 1, 2010). Subsequently, in-lake samples were used for calibration, and not as forcing data. Concentrations of TDS in the inflow to Lac Capot Blanc from DSL2 were obtained from the output of the mass-balance model. Because the mass-balance model cannot simulate temperature, the temperature of the inflow to Lac Capot Blanc from DSL2 was assumed to be identical to the temperature of the Snap Lake outflow, and was obtained from the hydrodynamic and water quality model of Snap Lake (De Beers 2013a).

Modelled Constituents

Parameters included in the hydrodynamic model of Lac Capot Blanc were temperature and TDS. Other parameters (i.e., chloride, fluoride, sulphate, nitrate and nitrite) were not carried forward at this time; TDS provides an indication of the extent of the effluent plume and it's selections as a representative parameter was consistent with the approach used in the EAR (De Beers 2002). The calibration of temperature and TDS are described below.

Hydrodynamic Model Calibration

The model was calibrated to individual temperature and TDS data collected during sampling events in 2011, 2012, and 2013. In 2013, the model was also calibrated to continuous temperature and TDS datasets collected at the outlet of Lac Capot Blanc during the open-water season. The first step in the calibration was to achieve a water balance within the model. The water balance was achieved by setting the discharge from DSL2 to Lac Capot Blanc equal to that predicted in the DSL2 mass-balance model, estimating non-point source tributary inflows from the Lac Capot Blanc basin based on runoff calculations in De Beers' Site Water Balance Report, setting precipitation and evaporation rates equal to those estimated in the Snap Lake EAR (De Beers 2002, 2013d) and calculating the outflow from Lac Capot Blanc so that the capacity of the lake remained constant.

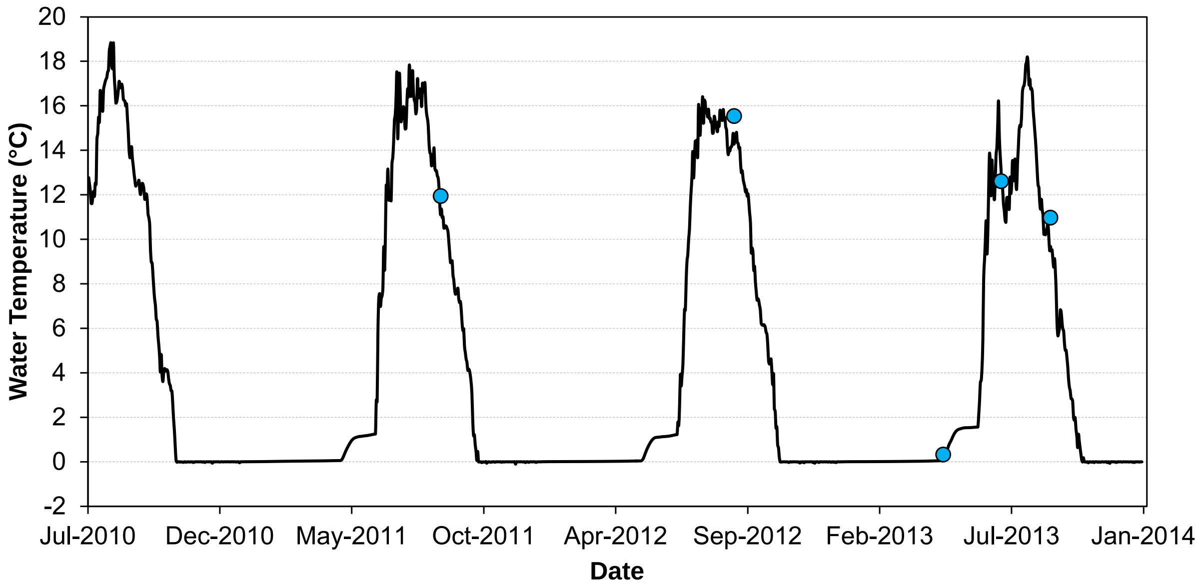
The hydrodynamic component of the model was calibrated to align measured and modelled thermal and transport behaviour in Lac Capot Blanc. Because of the limited calibration dataset, default model values were used for thermal and transport variables. Time series plots of surface water temperatures in Lac Capot Blanc showed that the model matched surface water temperatures reasonably well (Figures 2-10 and 2-11). The modelled thermal profiles fit the measured profiles well (Attachment I).

The transport calibration considered the horizontal distribution and vertical stratification of TDS in Lac Capot Blanc. For the horizontal component of the transport calibration, the model matched TDS concentrations reasonably well (Figures 2-12 and 2-13). The alignment between calculated and modelled TDS profiles in Lac Capot Blanc was generally good, with the exception of TDS profiles at the inlet of the lake in 2012 (Attachment I). Because of the coarseness of the model grid (i.e., the grid spacing was approximately 200 m horizontally and 1 m vertically), detail regarding plume behaviour was lost near the inlet of the lake.

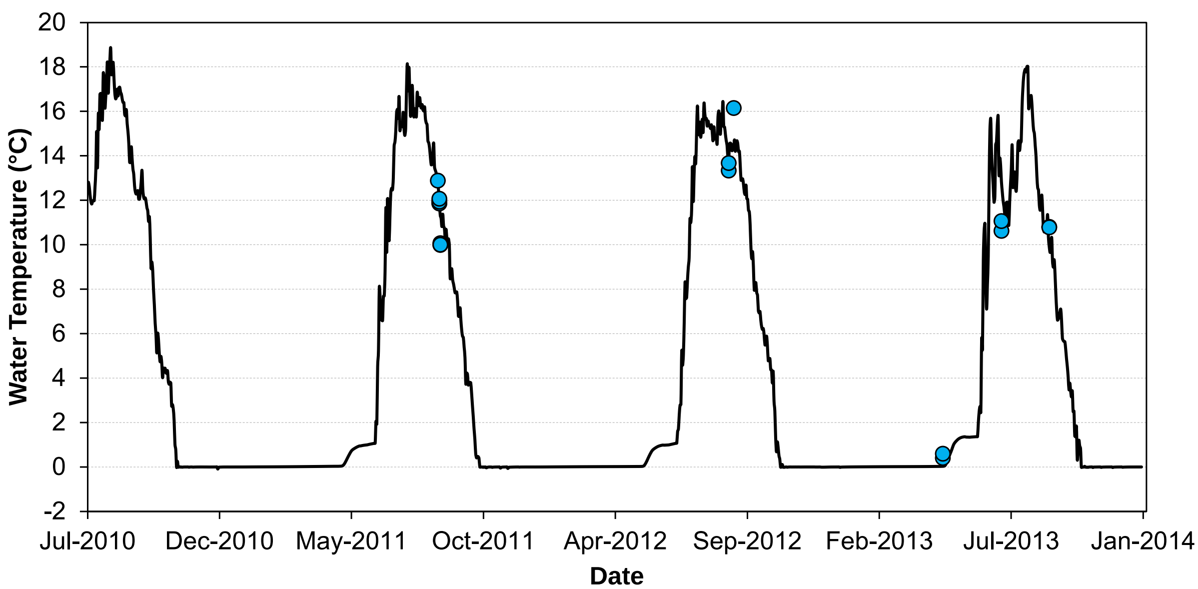
The cyclical annual patterns evident in time series figures presented in this submission are due to salt rejection during ice formation and melting. The magnitude of these cycles varies depending on the year and the depth of the lake at the location that the time series represents.

Figure 2-10 Surface Water Temperature Time Series Calibration Results

(a) Monitoring Station: LCB-1



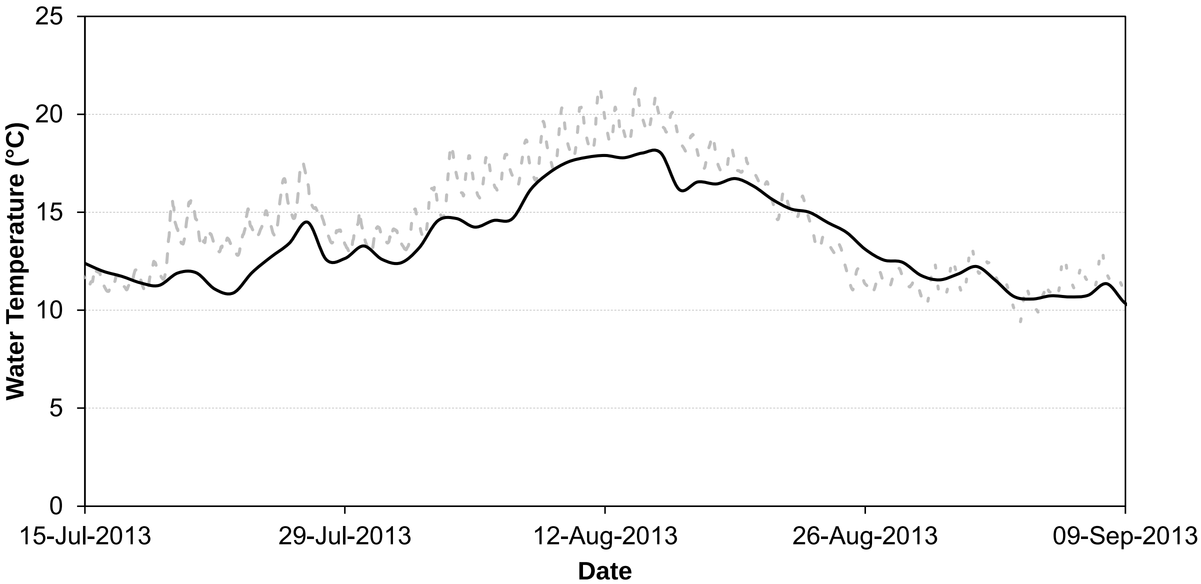
(b) Monitoring Station: Outlet



Note: Solid line represents model results; dots represent measured water temperatures.

°C = degrees Celsius.

Figure 2-11 Surface Water Temperature Time Series Calibration Results at the Outlet of Lac Capot Blanc

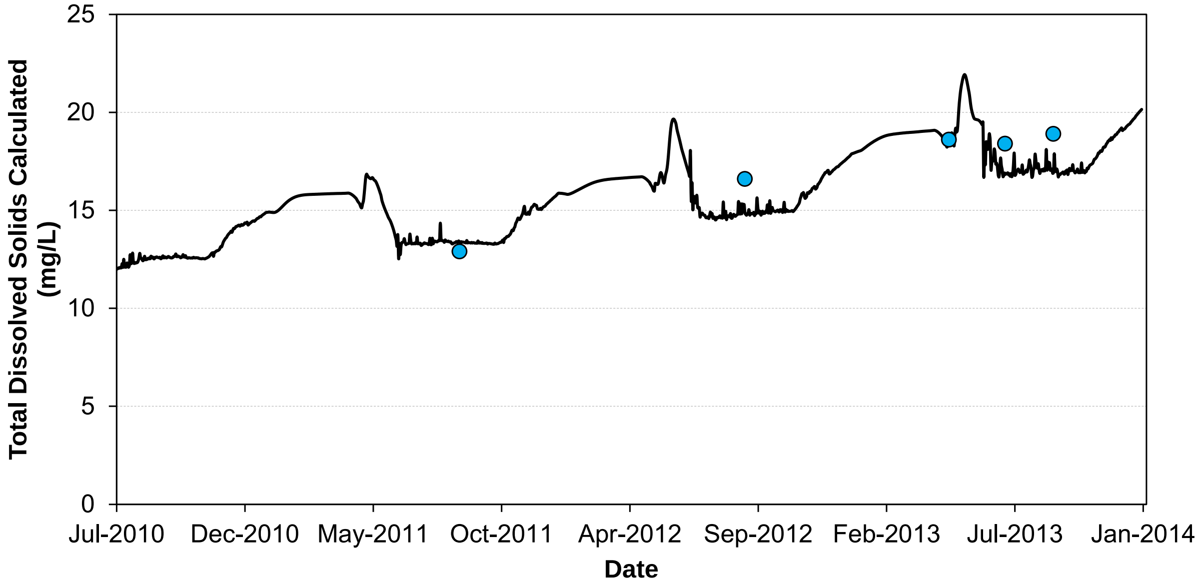


Note: Solid line represents model results; dashed line represents continuously monitored water temperatures.

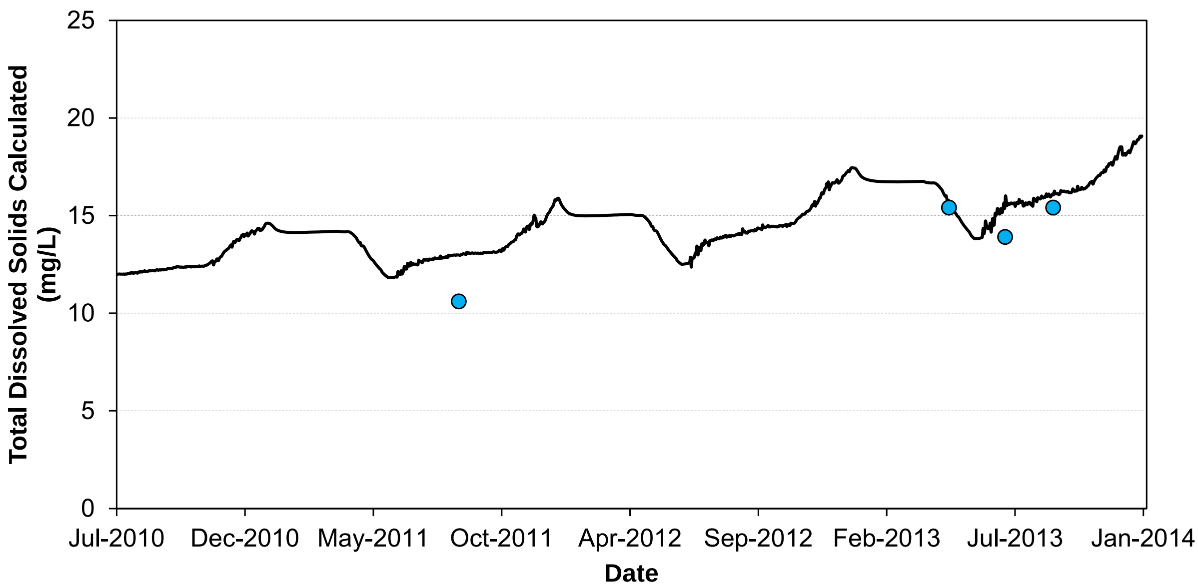
°C = degrees Celsius.

Figure 2-12 Total Dissolved Solids Time Series Calibration Results

(a) Monitoring Station: LCB-1



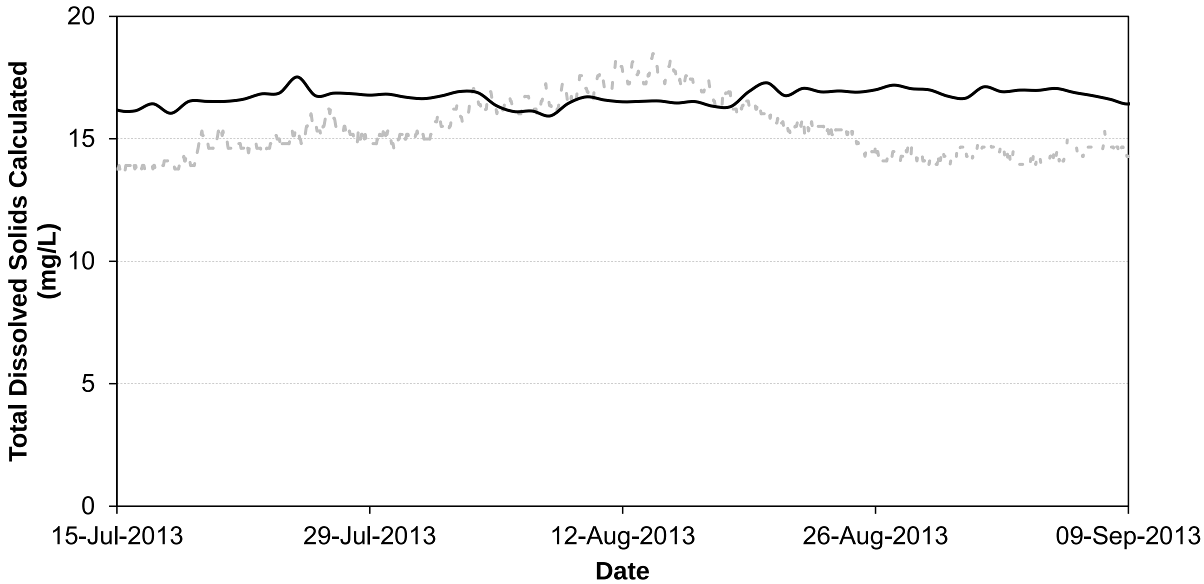
(b) Monitoring Station: LCB-3



Note: Solid line represents model results; dots represent calculated total dissolved solids concentrations.

mg/L = milligrams per litre.

Figure 2-13 Total Dissolved Solids Time Series Calibration Results at the Outlet of Lac Capot Blanc



Note: Solid line represents model results; dashed line represents continuously monitored total dissolved solids concentrations.
mg/L = milligrams per litre.

2.2.2.3 Mass-Balance Model for Lakes Downstream of Lac Capot Blanc

An Excel-based mixing model was used to calculate TDS concentrations in lakes downstream of Lac Capot Blanc. The model included a series of calculations that were used to predict the TDS concentrations at each downstream node (Figure 2-7). The downstream nodes were consistent with those used in the EAR (De Beers 2002); node numbering originated from station numbers used for the 1993/94 and 1999 Lockhart watershed monitoring initiative by the then Department of Indian and Northern Affairs Canada (INAC) (Puznicki 1996; Blais 2001, pers. comm.). The same historical dataset used in the EAR was used in this updated downstream lakes assessment (refer to Model Inputs below).

The model calculated the maximum potential incremental increase in TDS load from Lac Capot Blanc, and then added this load to the downstream nodes assuming that there was no attenuation except for dilution. The increase in TDS load from Lac Capot Blanc, when comparing baseline and operational values, was calculated using Equation 1:

$$\Delta L = (C_o \times Q_o) - (C_b \times Q_b) \qquad \text{(Equation 1)}$$

where:

ΔL = incremental increase in TDS load from Lac Capot Blanc (grams per day [g/d]);

Co = maximum TDS concentration at the Lac Capot Blanc outlet during operations (mg/L);

Qo = average annual outflow from Lac Capot during operations (cubic metres per day [m^3/d]);

Cb = baseline TDS concentration in Lac Capot Blanc (mg/L); and,

Qb = average annual outflow from Lac Capot Blanc during baseline conditions (m^3/d).

The incremental TDS load was then added to the baseline load at each downstream site. The new downstream TDS concentrations were determined by dividing this sum by the average flow at the node using Equation 2:

$$C_{xo} = (C_{xb} \times Q_{xb} + \Delta L)/(Q_{xb} + Q_o - Q_b) \qquad \text{(Equation 2)}$$

where:

Cxo = TDS concentration at node “x” during operations (mg/L);

Cxb = average TDS concentration at node “x” during baseline conditions (mg/L); and,

Qxb = flow at node “x” during baseline conditions (m^3/d).

The predicted downstream TDS concentrations were compared to baseline TDS concentrations to determine the maximum potential change in water quality. The mass-balance model was steady-state, so it conservatively represented a snapshot in time, as if peak TDS concentrations remained in

Lac Capot Blanc indefinitely. The model did not compute a time-varying estimate of concentrations at particular nodes, nor did it account for time of travel through the Lockhart River system.

Model Inputs

The baseline TDS load from Lac Capot Blanc was calculated using the initial TDS concentration and the average annual outflow from the hydrodynamic model of Lac Capot Blanc. The baseline TDS concentrations at nodes downstream of Lac Capot Blanc were consistent with those used in the EAR (De Beers 2002). However, the average annual outflow from the hydrodynamic model of Lac Capot Blanc was greater than originally estimated in the EAR. To produce baseline flows at nodes downstream of Lac Capot Blanc, the difference in outflow from Lac Capot Blanc was added to the downstream flows estimated in the EAR (Table 2-2). The operational TDS load was calculated using the maximum concentration predicted for the Lac Capot Blanc outflow for each of the model simulations (Section 2.2.3). The baseline load at the downstream nodes was calculated using the average baseline TDS concentrations from the 1993/94 and 1999 Lockhart watershed studies (De Beers 2002).

Table 2-2 Inputs Used in the Model Downstream of Lac Capot Blanc

Downstream Site	Distance Downstream From Snap Lake (km)	EAR Inputs		2013 Model Inputs	
		Baseline TDS Concentration (mg/L)	Flow (m^3/s)	Baseline TDS Concentrations (mg/L)[(a)]	Flow (m^3/s)[(b)]
Lac Capot Blanc (outlet)	11	18	0.7	12	1.6
37 (upstream of King Lake)	24	17	0.9	17	1.8
22 (Mackay Lake)	44	20	4.4	20	5.3
11 (Mackay Lake)	54	12	22.4	12	23.3
23 (Mackay Lake)	65	10	28.4	10	29.3
24 (Mackay Lake)	81	14	38.7	14	39.6
26 (Mackay Lake)	109	17	40.9	17	41.8
3 (Inlet of Alymer Lake)	155	20	55.5	20	56.4
4 (Aylmer Lake)	172	24	79.0	24	79.9
53 (Clinton Colden Lake)	227	35	88.7	35	89.6
52 (Ptarmigan Lake)	310	24	109.2	24	110.1
43 (Lockhart River)	419	53	121.7	53	122.6
19 (Lockhart River outlet)	434	14	122.6	14	123.5

a) Baseline TDS concentrations used as 2013 model inputs were consistent with those used in the EAR with the exception of the baseline TDS concentration for Lac Capot Blanc. The baseline TDS concentration for Lac Capot Blanc was consistent with the initial TDS concentration from the calibrated hydrodynamic model.

b) Baseline flows used as 2013 model inputs at nodes downstream of Lac Capot Blanc were calculated by adding the difference in outflow from the hydrodynamic model of Lac Capot Blanc (i.e., 1.6 m^3/s) and the EAR baseline flow for Lac Capot Blanc (i.e., 0.7 m^3/s) to the downstream flows estimated in the EAR.

km = kilometre; mg/L = milligrams per litre; m^3/s = cubic metres per second; EAR = Environmental Assessment Report; TDS = total dissolved solids.

2.2.3 Model Simulations

A total of six model scenarios were considered for the operational period from 2014 to 2028. Four of the model scenarios assumed that the effluent would be discharged from the Mine to Snap Lake without mitigation for TDS and two of the model scenarios assumed that mitigation would be in place starting January 1, 2015 (e.g., the effluent discharged from the Mine to Snap Lake would be treated to remove salts). The model scenarios were based on the expected range of groundwater discharge rates from the Mine and the expected range of TDS concentrations in the discharge from the Mine. The four non-mitigation model scenarios were the same groundwater scenarios identified in support of the Water Licence Amendment Application submitted in 2013 (Itasca 2013):

- Upper Bound Scenario A: discharge quantity and quality from Snap Lake to DSL1 based on minewater discharge from Scenario 4 and arithmetic mean connate water TDS concentrations from the Snap Lake groundwater model;
- Upper Bound Scenario B: discharge quantity and quality from Snap Lake to DSL1 based on minewater discharge from Scenario 4 and geometric mean connate water TDS concentrations from the Snap Lake groundwater model;
- Lower Bound Scenario A: discharge quantity and quality from Snap Lake to DSL1 based on minewater discharge from Base Case and arithmetic mean connate water TDS concentrations from the Snap Lake groundwater model; and,
- Lower Bound Scenario B: discharge quantity and quality from Snap Lake to DSL1 based on minewater discharge from Base Case and geometric mean connate water TDS concentrations from the Snap Lake groundwater model.

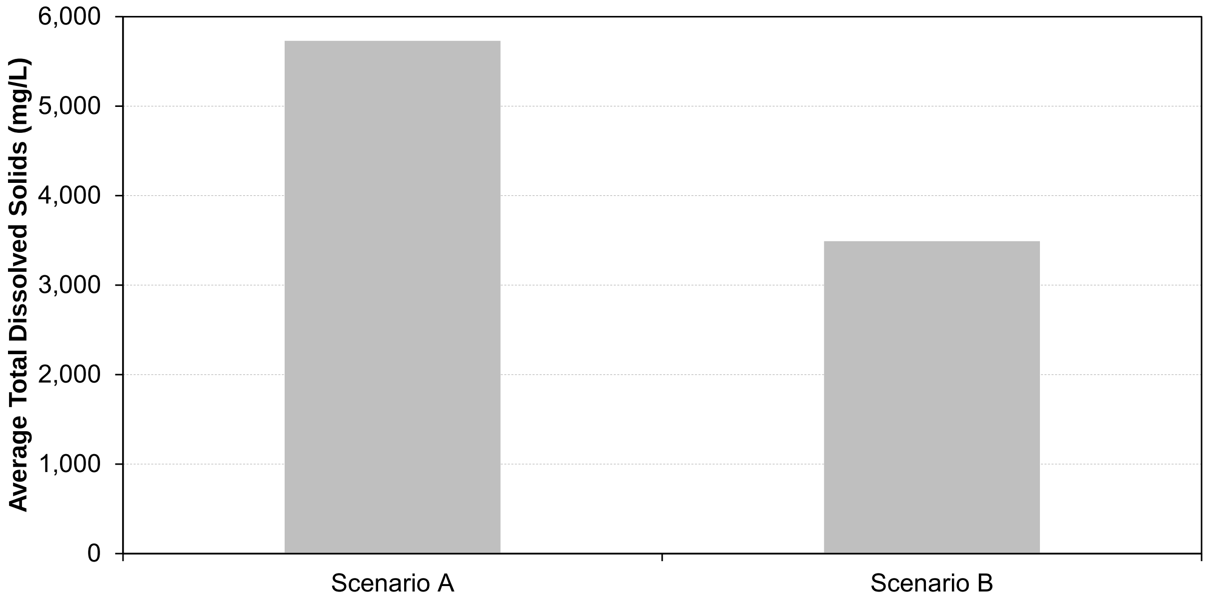
Upper Bound scenarios had a higher minewater discharge rate than Lower Bound scenarios (Figure 2-1) and Scenario A had a higher connate water TDS concentration than Scenario B (Figure 2-14).

For the two model scenarios with mitigation in place, the discharge quantity and quality from Snap Lake to DSL1 were based on results from Base Cases A and B (Section 2.1).

The two mitigation scenarios were:

- Upper Bound Mitigation: same discharge quantity as Upper Bound Scenarios, but TDS concentrations in the effluent discharge to Snap Lake do not exceed 684 mg/L from January 1, 2015 to January 1, 2029; and,
- Lower Bound Mitigation: same discharge quantity as Lower Bound Scenarios, but TDS concentrations in the effluent discharge to Snap Lake do not exceed 684 mg/L from January 1, 2015 to January 1, 2029.

Figure 2-14 Average Connate Water Total Dissolved Solids Concentrations



mg/L = milligrams per litre.

2.2.4 Model Results

2.2.4.1 Mass-Balance Models of Downstream Lakes 1 and 2

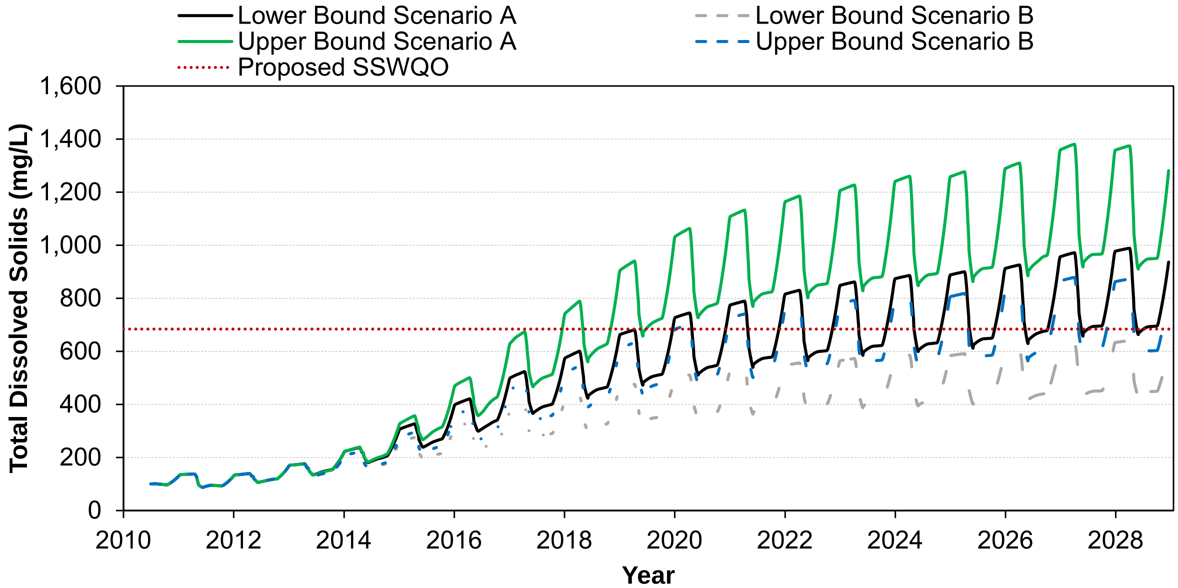
Non-mitigation Scenarios

Concentrations of TDS in DSL1 were predicted to exceed the proposed SSWQO of 684 mg/L in every scenario with the exception of Lower Bound Scenario B. Concentrations of TDS during ice-covered conditions were predicted to range from approximately 600 to 1,400 mg/L in 2028 (Figure 2-15). Concentrations of TDS in DSL2 were predicted to exceed the proposed SSWQO of 684 mg/L in all four scenarios. Concentrations of TDS during ice-covered conditions were predicted to range from approximately 700 to 1,500 mg/L in 2028 (Figure 2-16). Maximum TDS concentrations were predicted to be higher in DSL2 than in DSL1 during ice-covered conditions, even though DSL2 is further downstream, because its smaller volume results in greater influence of salt rejection.

Mitigation Scenarios

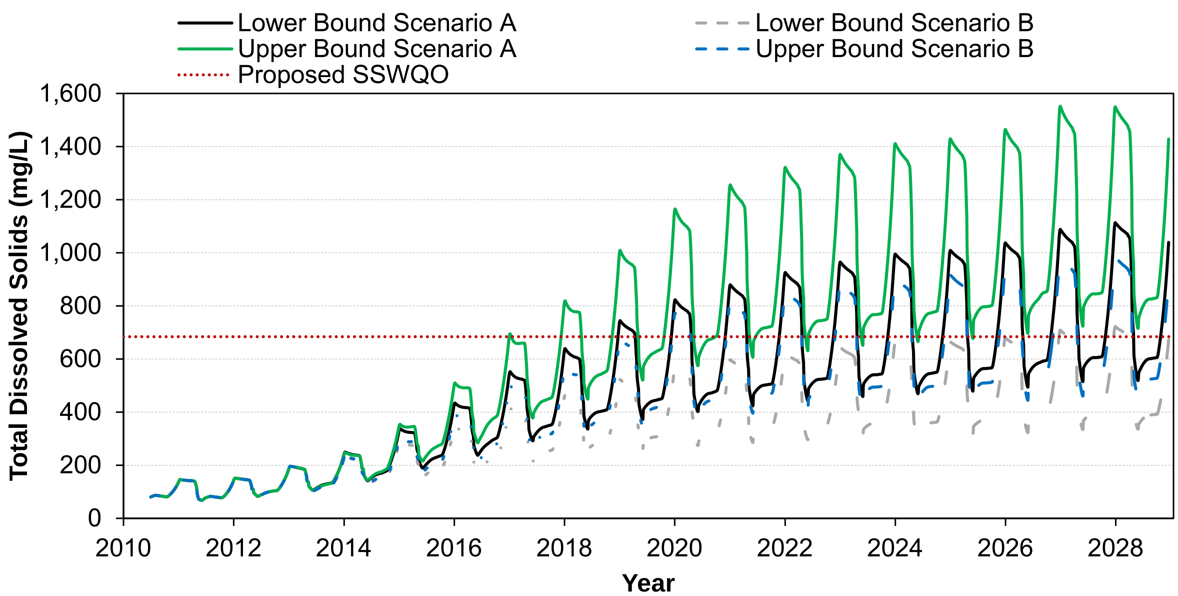
Concentrations of TDS in DSL1 and DSL2 were predicted to remain below the proposed SSWQO of 684 mg/L with mitigation in place. Concentrations of TDS in DSL1 during ice-covered conditions were predicted to range from approximately 475 to 525 mg/L in 2028 (Figure 2-17). Concentrations of TDS in DSL2 during ice-covered conditions were predicted to range from 525 to 600 mg/L in 2028 (Figure 2-18).

Figure 2-15 Predicted Whole-Lake Average Total Dissolved Solids Concentrations in Downstream Lake 1



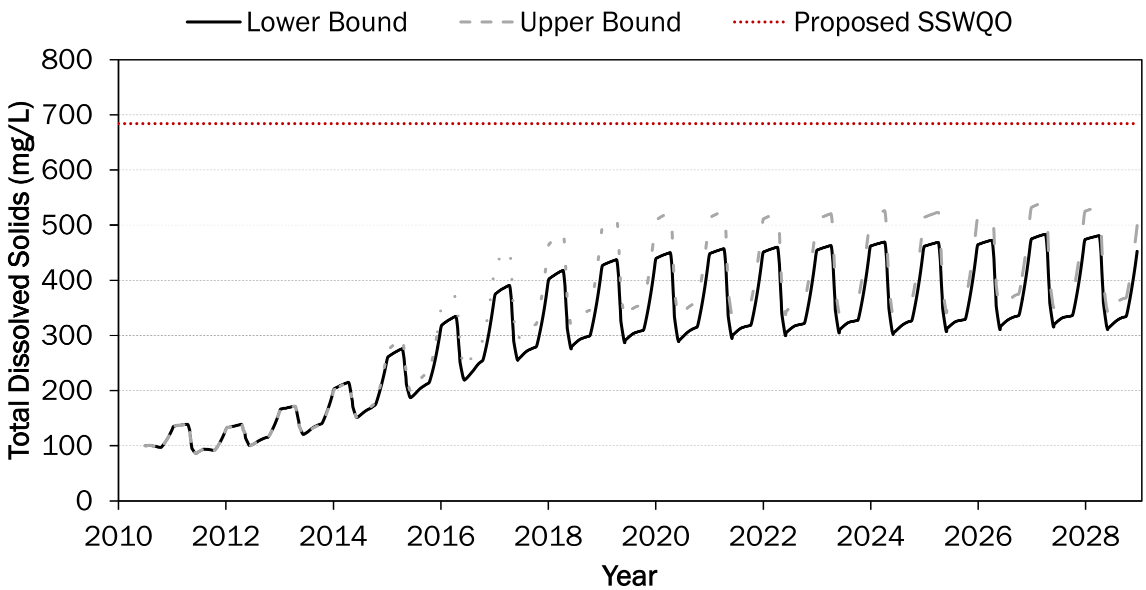
mg/L = milligrams per litre; SSWQO= site-specific water quality objective.

Figure 2-16 Predicted Whole-Lake Average Total Dissolved Solids Concentrations in Downstream Lake 2



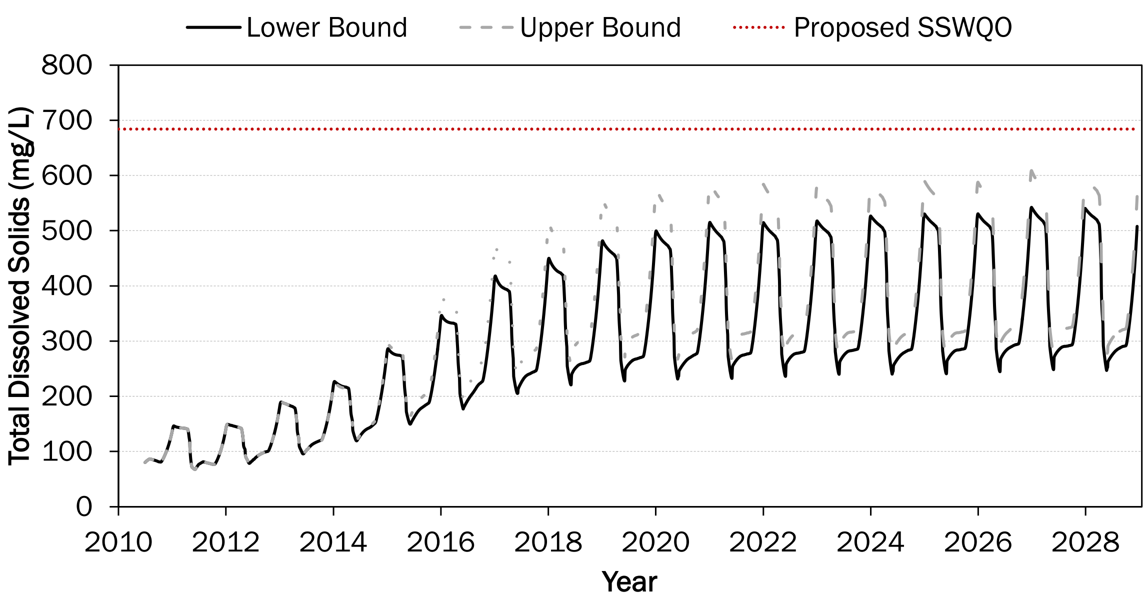
mg/L = milligrams per litre; SSWQO= site-specific water quality objective.

Figure 2-17 Predicted Whole-lake Average Total Dissolved Solids Concentrations in Downstream Lake 1 (With Proposed EQC)



mg/L = milligrams per litre; SSWQO= site-specific water quality objective.

Figure 2-18 Predicted Whole-lake Average Total Dissolved Solids Concentrations in Downstream Lake 2 (Proposed Effluent Quality Criteria Are Met)



Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

mg/L = milligrams per litre; SSWQO= site-specific water quality objective.

2.2.4.2 Hydrodynamic Model of Lac Capot Blanc

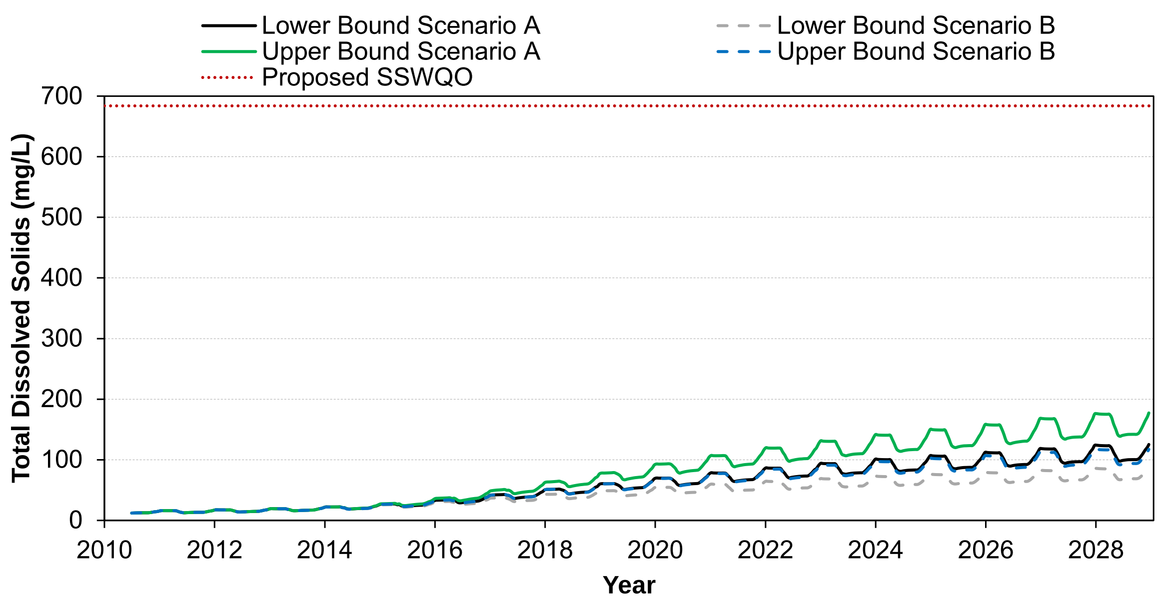
Non-mitigation Scenarios

Concentrations of TDS in Lac Capot Blanc were predicted to remain below the proposed SSWQO of 684 mg/L for all scenarios. Concentrations of TDS during ice-covered conditions were predicted to range from approximately 85 to 180 mg/L in 2028 (Figure 2-19). The lower TDS concentrations were predicted to occur under Lower Bound Scenario B; higher TDS concentrations occurred under Upper Bound Scenario A.

Mitigation Scenarios

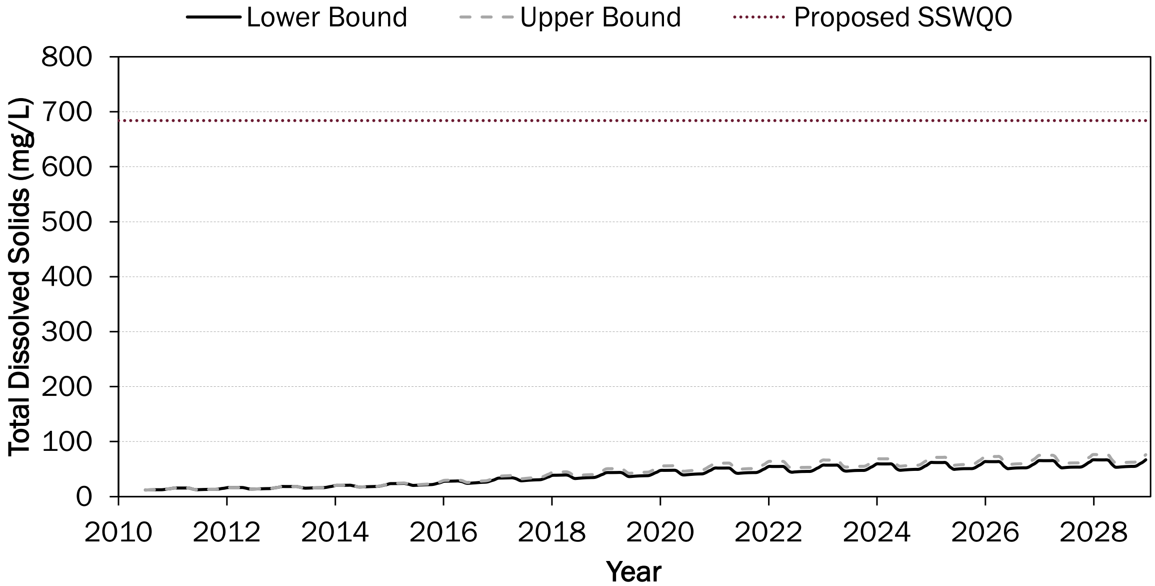
Concentrations of TDS in Lac Capot Blanc were predicted to remain below the proposed SSWQO of 684 mg/L. Concentrations of TDS during ice-covered conditions were predicted to range from approximately 65 to 75 mg/L in 2028 (Figure 2-20).

Figure 2-19 Predicted Whole-Lake Average Total Dissolved Solids Concentrations in Lac Capot Blanc



mg/L = milligrams per litre; SSWQO= site-specific water quality objective.

Figure 2-20 Predicted Whole-Lake Average Total Dissolved Solids Concentrations in Lac Capot Blanc (Proposed Effluent Quality Criteria Are Met)



Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

mg/L = milligrams per litre; SSWQO= site-specific water quality objective.

2.2.4.3 Mass-Balance Model for Lakes Downstream of Lac Capot Blanc

Non-mitigation Scenarios

Consistent with EAR predictions, maximum TDS concentrations in lakes downstream of Lac Capot Blanc were predicted to decrease with distance downstream (Figure 2-21). As total watershed areas and inflows to the lakes increase, the influence from the Mine is reduced. Without treatment, predicted concentrations ranged up to 50% higher compared to EAR values immediately downstream from Lac Capot Blanc, but were near background TDS concentrations and EAR predictions by Site 11 (MacKay Lake), which is approximately 54 km downstream of Snap Lake (Figure 2-21).

Mitigation Scenarios

With mitigation in place (i.e., TDS in effluent discharge less than or equal to 684 mg/L), predicted TDS concentrations ranged up to 10% lower compared to EAR predictions (De Beers 2002) immediately downstream from Lac Capot Blanc. Predicted TDS concentrations were generally within EAR predictions and the baseline range at Site 22 (MacKay Lake), which is approximately 44 km downstream of Snap Lake (Table 2-3; Figure 2-22). The reason for the lower predicted TDS concentrations downstream of Lac Capot Blanc compared to EAR predictions was due to the assimilative capacity of Lac Capot Blanc, not previously considered. Concentrations at the outlet of Lac Capot Blanc were lower than previously predicted, once mixing and in-lake processes were captured in the modelling.

Table 2-3 Maximum Predicted Changes in Total Dissolved Solids Concentrations in Lakes Downstream of Snap Lake

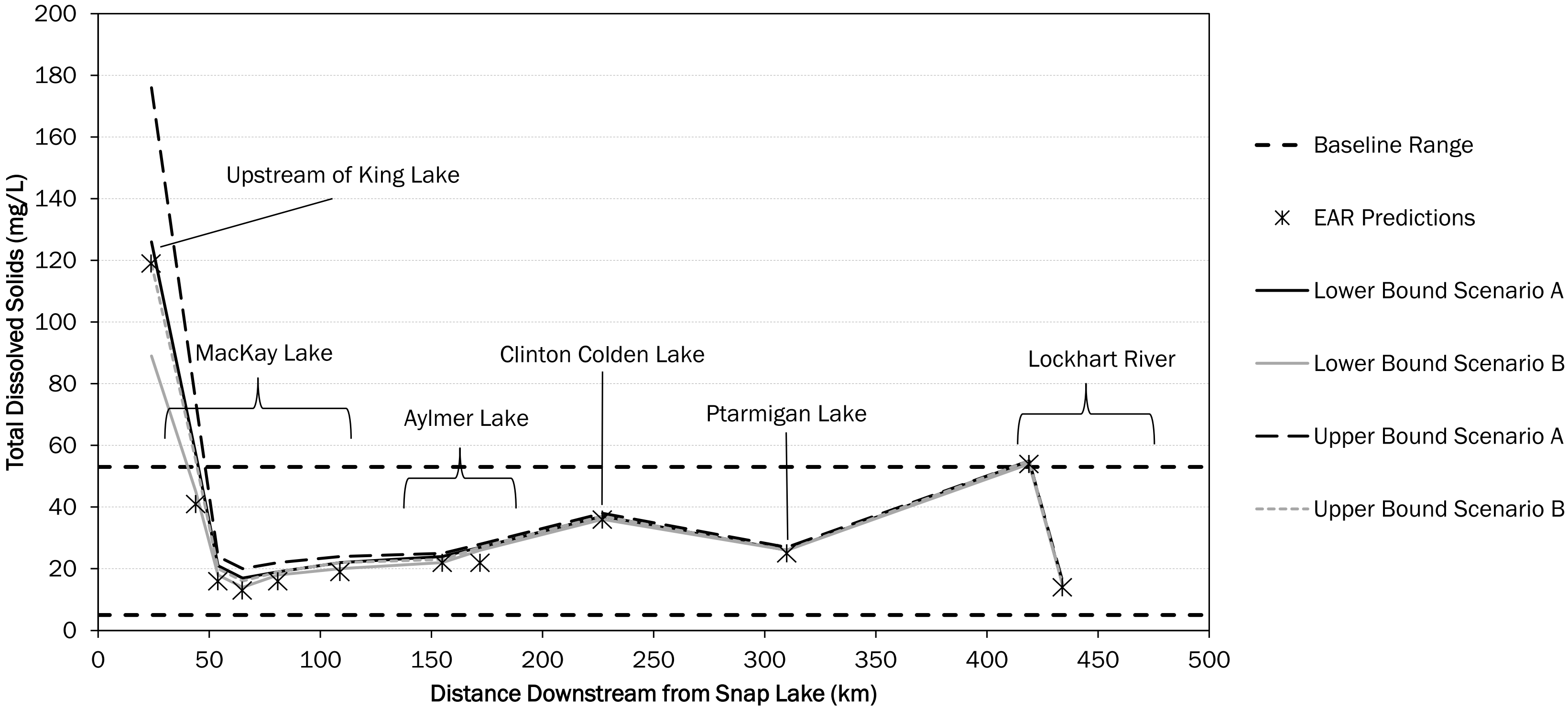
Downstream Site	Distance Downstream from Snap Lake (km)	Baseline TDS (mg/L) (range = 10 to 53)	Maximum TDS Concentrations (mg/L)[a]		
			EAR Predictions	2013 Model Predictions	
				Base Case A	Base Case B
37 (upstream of King Lake)	24	17	119	66	74
22 (Mackay Lake)	44	20	41	37	39
11 (Mackay Lake)	54	12	16	16	16
23 (Mackay Lake)	65	10	13	13	13
24 (Mackay Lake)	81	14	16	17	17
26 (Mackay Lake)	109	17	19	19	20
3 (Inlet of Aylmer Lake)	155	20	22	22	22
4 (Aylmer Lake)	172	24	22	26	26
53 (Clinton Colden Lake)	227	35	36	36	36
52 (Ptarmigan Lake)	310	24	25	25	25
43 (Lockhart River)	419	53	54	54	54
19 (Lockhart River outlet)	434	14	14	14	14

Note: Shaded cells indicate where TDS concentrations are predicted to be outside of the baseline range.

(a) Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.

mg/L = milligrams per litre; km = kilometre; EAR = Environmental Assessment Report; TDS = total dissolved solids.

Figure 2-21 Predicted Total Dissolved Solids Concentrations in Lakes Downstream of Lac Capot Blanc

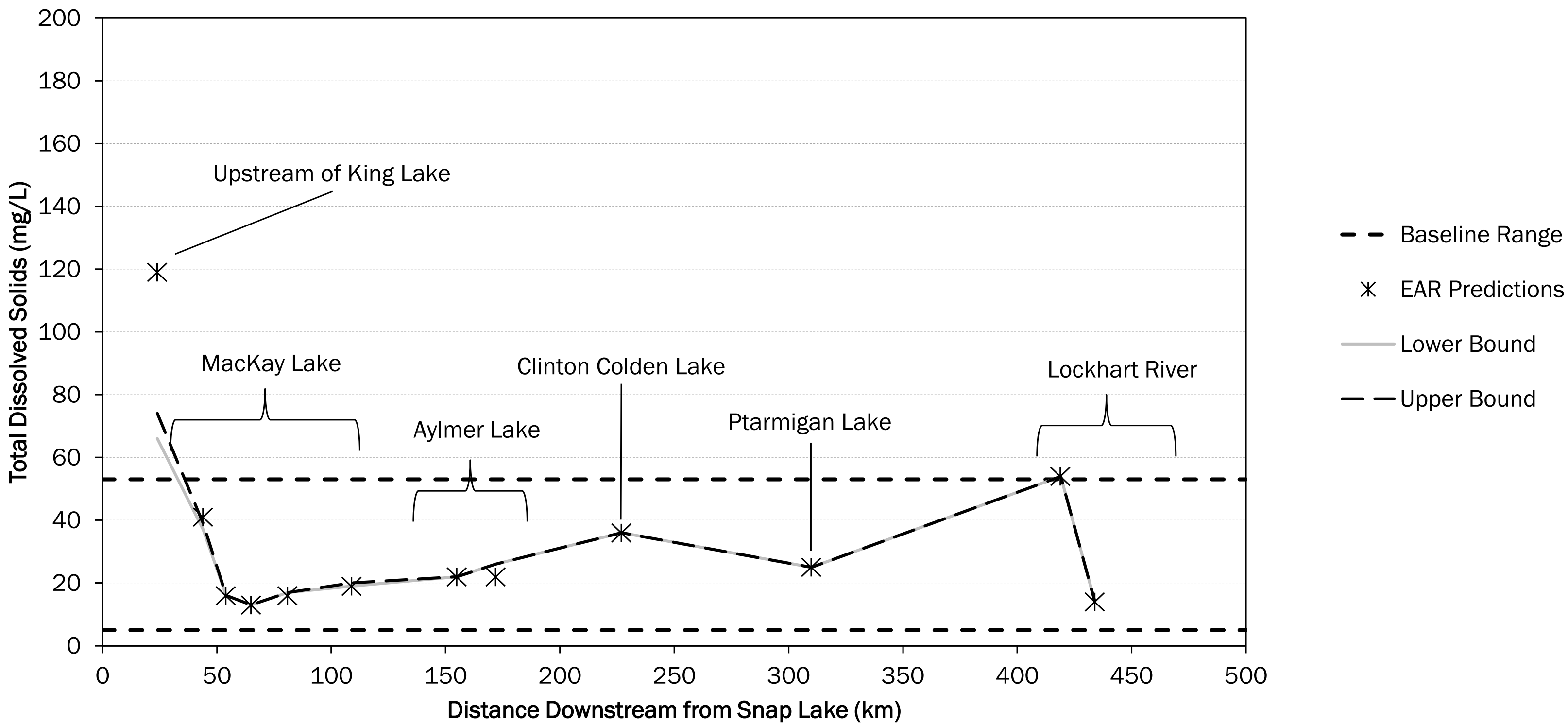


Source: Baseline TDS concentrations at the downstream nodes were from the 1993/94 and 1999 Lockhart watershed studies (De Beers 2002).

Note: Baseline range was set to the maximum and minimum TDS concentration from the 1993/94 and 1999 Lockhart watershed studies.

mg/L = milligrams per litre; km = kilometre; EAR = Environmental Assessment Report; TDS = total dissolved solids.

Figure 2-22 Predicted Total Dissolved Solids Concentrations in Lakes Downstream of Lac Capot Blanc (Proposed Effluent Quality Criteria are Met)



Source: Baseline TDS concentrations at the downstream nodes were from the 1993/94 and 1999 Lockhart watershed studies (De Beers 2002).

Notes: Baseline range was set to the maximum and minimum TDS concentration from the 1993/94 and 1999 Lockhart watershed studies.

Assumes TDS in the Snap Lake Mine effluent will be below the AML of 684 mg/L.mg/L = milligrams per litre; km = kilometre; EAR = Environmental Assessment Report; TDS = total dissolved solids.

2.2.5 Data Gaps and Model Uncertainty

Total Dissolved Solids

Data-related uncertainty in TDS concentrations was moderate because the dataset used for the calibration time period was limited. As discussed in Section 2.2.2.2, the hydrodynamic model of Lac Capot Blanc was calibrated to measured data collected during 2011, 2012, and 2013.

Predicted TDS concentrations in the lakes downstream of Snap Lake only apply to the modelled scenarios presented in this report. Predicted TDS concentrations downstream of Snap Lake would change if the scenarios do not effectively capture TDS concentrations in the effluent (non-mitigation scenario) or effective mitigation is not implemented (mitigation scenario).

Hydrologic Inputs

Data-related uncertainty in inflows to and outflows from DSL1, DSL2, and Lac Capot Blanc was high because inflows to and outflows from DSL1, DSL2, and Lac Capot Blanc were not gauged. As discussed in Section 2.2.2.1, inflows to, and outflows from DSL1, DSL2, and Lac Capot Blanc relied on calculations from the mass-balance model.

Model Segmentation

Data-related uncertainty in model segmentation for the hydrodynamic model of Lac Capot Blanc was moderate for the following reason:

- As discussed in Section 2.2.2.2, the 3-D grid that was developed for Lac Capot Blanc did not cover the entire lake. As a result, the area and volume of Lac Capot Blanc that were used in the hydrodynamic model were not representative of true values because the bathymetry is not yet complete. As recommended in Section 2.2.6, the 2014 to 2016 Downstream Lakes Special Study will be collecting additional bathymetric surveys of the southern arms of Lac Capot Blanc to provide a complete bathymetry map for Lac Capot Blanc.

Ice Formation and Melting

Data-related uncertainty with respect to ice formation and melting was low for the following reason:

- The length of the ice-covered season was not monitored. In the model, ice forms on DSL1, DSL2, and Lac Capot Blanc from mid-October to January of each year, and ice melts from mid-April to mid-June of each year. Therefore, the length of the ice-covered season is assumed to be eight months, as is the case for Snap Lake.

Baseline Dataset

- The baseline dataset was limited to the 1993/94 and 1999 Lockhart watershed studies as presented in the EAR. Additional information downstream of Snap Lake has been collected and may be of value for future model refinements.

2.2.6 Conclusions

In 2013, treated effluent was evident in DSL1, DSL2, and Lac Capot Blanc. Concentrations of dissolved salts and nutrients decreased with distance downstream. The extent of the effluent plume was observed up to 5 km from the inlet of Lac Capot Blanc, which is farther from the inlet than in 2012, and approximately 11 km downstream of Snap Lake.

With TDS in effluent discharge less than or equal to the proposed EQC of 684 mg/L, predicted TDS concentrations decreased with distance downstream, remained below the SSWQO of 684 mg/L, and were generally within EAR predictions and the baseline range at Site 22, which is approximately 44 km downstream of Snap Lake (Table 2-3 and Figure 2-22).

2.2.7 Recommendations

Recommendations to improve the downstream lakes models are:

- Maintain and calibrate the downstream lakes model annually to include water quality data collected during the 2014 to 2016 Downstream Lakes Special Study, including parameters other than TDS.
- Measure the main point source inflows to and outflows from DSL1, DSL2, and Lac Capot Blanc when water quality samples are collected to determine whether the water balances developed for the downstream lakes are representative of conditions
- Update the Lac Capot Blanc model grid once additional bathymetric data are collected so that the entire area and volume of Lac Capot Blanc can be modelled.
- Record ice thickness routinely in DSL1, DSL2, and Lac Capot Blanc. Ice formation, melting dates, and ice thickness drive salt rejection and freshwater replacement in the downstream lakes models, which in turn affect mixing and overall concentrations.
- Re-visit the baseline TDS data downstream of Lac Capot Blanc to include more recent data collected in the area as outlined in the Northwest Territories Water Stewardship Program (GNWT and AANDC 2014).

3 CUMULATIVE EFFECTS

3.1 Introduction

Cumulative effects are those effects that result from a combination of the Snap Lake minewith other past, present, and reasonably foreseeable future developments (MVEIRB 2004). A cumulative effects assessment requires qualifying, and if possible quantifying the development proposal's contribution to the combined residual effects from other projects or activities.

The proposed development will involve discharge of treated effluent with TDS concentrations at the SSWQO of 684 mg/L (i.e., the proposed average monthly limit). The objective of this section is to review the potential for cumulative effects resulting from the proposed development discharge of treated effluent with TDS concentrations in combination with other developments. This review considered cumulative effects from past, present, and reasonably foreseeable future developments within the area potentially affected by the release of TDS and associated ions – namely the Lockhart River watershed.

3.2 Methods

The approach to reviewing potential for cumulative effects involved consideration of the following:

- What is the magnitude and extent of the proposed development?
- Does the extent of the proposed development overlap with other past, present, or reasonably foreseeable developments?
- Are there other non-development impacts that can and should be included? If, yes, how would they influence the answers to the preceding two questions?
- What is the combined effect from the proposed development, other developments, and non-development factors?

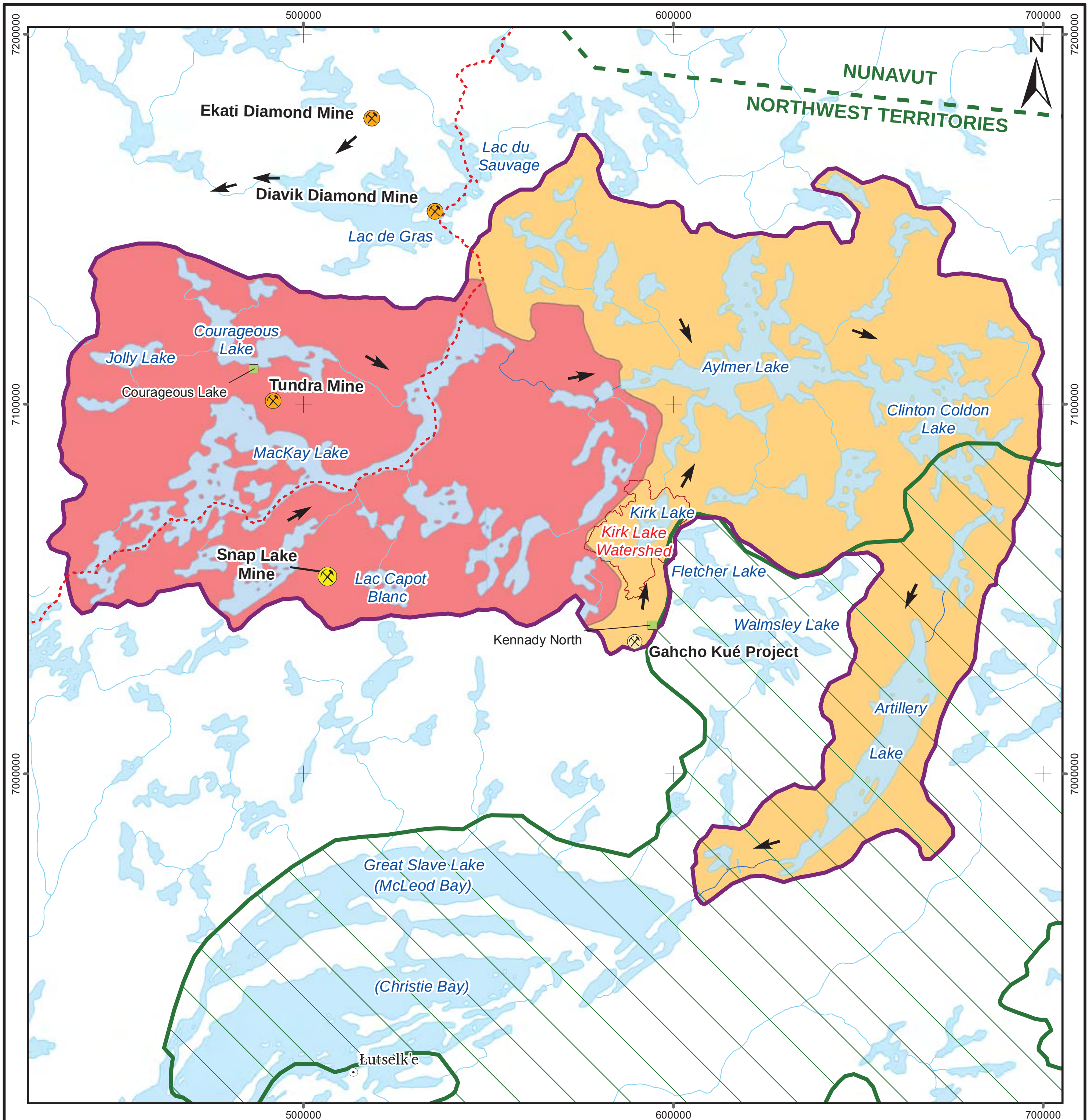
If an overlap between developments or non-developments was identified in this review, then assessment of the potential cumulative effects was required.

To evaluate the magnitude and extent of the proposed development, the results of water quality modelling from Snap Lake were reviewed, to determine the extent of the plume of treated effluent in lakes downstream of Snap Lake (Section 2 of this submission). The study area for the assessment included the Lockhart River Watershed (Figure 3-1). Major developments within the Lockhart River Watershed were reviewed for the potential for interaction with Snap Lake Mine treated effluent release to the watershed and the potential for cumulative effects from TDS. Developments were identified using the Gahcho Kué Project cumulative effects database developed during the Gahcho Kué Project environmental assessment (De Beers 2010) as well as a review of the 2013 NWT Mineral Exploration Overview (Falck and Gochnauer 2013).

Current developments include the De Beers Gahcho Kué Project, the Tibbitt-Contwoyto winter road, and the potential East Arm National Park (Thaidene Nene). Past developments of note in the Lockhart River watershed include the Tundra/Salmita Mine, which is located south of Courageous Lake. This gold mine was active in the 1960s and 1980s; the site is the final stages of remediation (MVLWB Licence MV2009L8-0008). In 2013, the site treated and released over 100,000 m^3 of effluent; this is predicted to reduce to 75,000 m^3 in 2014 (WESA 2014). Future releases will not require treatment (WESA 2014) and the volume of those releases may be variable. Given the potential for past, present, and future releases containing TDS, the Tundra Mine was included in this review.

Other developments such as exploration sites, tourist lodges, or hunting camps were not included as they are not permitted for water releases to the Lockhart River watershed. There are two active exploration sites in the watershed but their operations are currently restricted to exploration drilling: Seabridge Gold Inc. Courageous Lake Project (MVLWB Permit MVC20120025); and, Kennady Diamonds Kennady North Project (MVLWB Licence MV2013L20005) (Figure 3-1). No prediction of water quality from these projects can be made as they are still early in mine exploration and planning stages. Further development, including mining is considered hypothetical, and as such, they were excluded from further review. Potential developments that had recent proposals for work in the Lockhart River watershed but will no longer occur within the foreseeable future (e.g., Talston Hydroelectric Expansion Project) were also excluded.

Changes due to natural causes or to climate change were excluded from this review. It is possible that changes in water quality through climate change may occur, such as melting permafrost contributing additional TDS to surface water (Murdoch et al 2000). Such a phenomenon has been documented in the Yellowknife area in a small stream (Spence et al. 2013); however it is uncertain whether a similar effect would be observed in a larger watershed with a large dilution factor (Spence et al. 2013). Therefore, the potential effects of climate change on TDS sources to the Lockhart River were excluded from further review.



LEGEND

- Drainage Direction
- Snap Lake Mine
- Existing Mine
- Proposed Mine
- Exploration Site
- Populated Place
- Territorial/Provincial Boundary
- Tibbitt-to-Contwoyo Winter Road
- Lockhart River
- Watercourse
- Regional Study Area
- Proposed Area of Interest for East Arm National Park
- Waterbody
- Watershed Boundary
- Upper Lockhart River Watershed
- Lower Lockhart River Watershed

REFERENCES

Base Data Source: CanVec

SNAP LAKE MINE

Select Developments in the Lockhart River Drainage

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS GROUP OF COMPANIES
35 0 35 SCALE 1:1,500,000 KILOMETRES		
FILE No: 1413490003-DevelopmentLockhartDrainage_3_1		DATE: April 9, 2014
JOB NO: 14-1349-0003	REVISION NO: A	Figure 3-1
OFFICE: GOLD-CAL	DRAWN: JC	CHECK:

I:\CLIENTS\DE_BEERS\Snap_Lake\Mapping\MXD\WLA_2014\Fig 3_1_SelectDevelopments_in_LockhartRiverDrainage_2014-04-08.mxd

3.3 Results

The treated effluent from Snap Lake is predicted to be near background concentrations within approximately 40 km of the mine, similar to the original predictions from the EAR (De Beers 2002) (Figure 2-8). As such, the extent of the plume is restricted to a small area of the upper Lockhart River (Figure 2-8) as in the original project proposal. The Gahcho Kué Project is not expected to alter water quality outside of the Kirk Lake watershed of the lower Lockhart River watershed (Figure 2-8). The Tundra Mine is currently not expected to alter water quality outside of a localized area (INAC 2009; Figure 2-8). Current monitoring results suggest that discharges from the mine are localized to the Sandy Lake and Matthews Lake area (INAC 2009; AANDC 2013); this does not overlap with Snap Lake effluent (Figure 2-8).

Operation of the Tibbitt-to-Contwoyto winter road is not expected to contribute TDS to the watershed. The extent of activities associated with a potential East Arm National Park (Thaidene Nene) or within the wider area of interest (see Wright et al. 2013 for an updated mineral and energy resource assessment in the area of interest; Figure 3-1) is not known, but it is not anticipated for the foreseeable future to include releases of TDS and its development is anticipated to be positive for the watershed in terms of protection for the area (De Beers 2010).

There is no overlap between the Mine and developments releasing or having the potential to release TDS to the environment and, as such, the development's contribution to cumulative effects in the Lockhart River watershed is nil (Figure 2-8).

3.4 Conclusion

What potential cumulative effects will the discharge of treated effluent with TDS concentrations equal to the SSWQO of 684 mg/L (i.e., the proposed average monthly limit) from the Snap Lake Mine have on water quality in the Lockhart River Watershed?

The discharge of treated effluent with TDS concentrations equal to the SSWQO does not overlap with discharges from other developments and as such no cumulative effects assessment is required.On the basis of a review of major developments in the Lockhart River watershed and the type and extent of the discharges from those developments, De Beers concludes that the discharge of effluent at the proposed limits will not contribute to cumulative effects on water quality within the Lockhart River Watershed..

4 ACCIDENTS AND MALFUNCTIONS

4.1 Introduction

This section consists of an assessment of the environmental consequences from accidents and malfunctions in relation to discharge of treated minewater containing elevated concentrations of TDS. On the basis of the scope of the EA outlined by the Review Board, this was assessed on the basis of an "upset in the water management system" releasing higher than permitted concentrations of TDS for a limited time duration. This section does not assess the risk of the occurrence of an accident or malfunction; operational risk management measures based on risk assessment will substantially reduce the potential occurrence of such an occurrence.

Standard policies, procedures, practices, and operating systems are integral to managing potential accidents and malfunctions. Accidents and malfunctions are unlikely to adversely impact the development or the environment due to management systems or mitigation that:

- prevent accidents and malfunctions though proper training, awareness, education, and equipment maintenance;
- assess accidents and malfunction risks during the design of the proposed project;
- continue to assess these risks through all project life cycles including detailed engineering design, construction, operation, and closure;
- incorporate inherently safe designs and effective contingency plans; and,
- implement a site environmental management plan including effective and efficient emergency response plans.

De Beers has described its policies and procedures in relation to water management in the Water Management Plan (De Beers 2013e) and outlined risks in relation to water management in the North Pile Risk Assessment in a submission to the MVLWB (De Beers 2012b).

4.2 Objective

The objective of this section is to assess the potential environmental consequences from accidents or malfunctions in relation to discharge of treated minewater containing elevated concentrations of TDS as consolidated in the following key question:

> *What impacts will a potential accident or malfunction related to discharge of treated minewater containing elevated levels of TDS at the Snap Lake Project site have on the receiving environment, specifically Snap Lake?*

4.3 Methods

Accident or malfunction scenarios or cases involving releases of TDS were developed. The water quality in the receiving environment was predicted for each case. The environmental consequence of each case was then assessed.

The assessment was conservative and assumed:

- an accident or malfunction occurs during the remaining years of operation;
- an accident or malfunction in relation to discharge of elevated TDS would persist for a maximum of 7 days before management action was effective;
- the discharge from an accident or malfunction is restricted to Snap Lake and specifically to the main basin of Snap Lake and does not affect drinking water because management actions would prevent larger-scale releases.

Water quality was predicted for accidents and malfunctions related to TDS releases as this is the most restrictive parameter of those required by the Review Board EA.

4.3.1 Accident or Malfunction Cases

Eight cases were considered for potential water quality changes related to Accidents or Malfunctions (Table 4-1). These were compared to the two Base Cases outlined in Section 2 where no accident or malfunction occurs.

For Base Cases A and B described previously in this submission, effluent was discharged from the Mine to Snap Lake with treatment for TDS such that the concentration of TDS in the effluent did not exceed the proposed AML of 684 mg/L from January 1, 2015, to January 1, 2029. For the Accident or Malfunction Cases (1A and 1B, defined below), an accident or malfunction occurs on site and effluent is discharged to Snap Lake with a TDS concentration of 1,000 mg/L at the lower and upper bound discharge rates, respectively (Table 4-1). A TDS concentration of 1,000 mg/L represents an accident or malfunction where the Mine discharges TDS concentrations approximately equal to the proposed maximum daily limit of 1,003 mg/L.

For the Accident or Malfunction Cases 2A and 2B (defined below), an accident or malfunction occurs on site and effluent is discharged to Snap Lake with a TDS concentration of 2,000 mg/L at the lower and upper bound discharge rates, respectively. A TDS concentration of 2,000 mg/L represents an accident or malfunction where the Mine discharges TDS concentrations approximately equal to the maximum TDS concentrations predicted in De Beers (2013c).

Water quality modelling of each case was completed to predict maximum concentrations of TDS in Snap Lake using the 3-D hydrodynamic and water quality model developed in the GEMSS platform. The Snap Lake model setup and model inputs were identical to those described in De Beers (2013a) with the exception of the concentration of TDS in the effluent discharged to Snap Lake (Section 2.1).

Table 4-1 Descriptions of Accident or Malfunction Cases

Timeline	Name	Effluent Discharge Rate	Effluent Discharge TDS Concentration during Malfunction (mg/L)
2017	Malfunction Case 1A	Lower Bound	1,000
	Malfunction Case 1B	Upper Bound	
	Malfunction Case 2A	Lower Bound	2,000
	Malfunction Case 2B	Upper Bound	
– 2025	Malfunction Case 1A	Lower Bound	1,000
	Malfunction Case 1B	Upper Bound	
	Malfunction Case 2A	Lower Bound	2,000
	Malfunction Case 2B	Upper Bound	

Note: Assumes that as of January 2015 the effluent AML is 684 mg/L and that accident occurs under ice in mid-March when little dilution occurs and occurs for a maximum of seven days.

mg/L = milligrams per litre; TDS = total dissolved solids; ≤ = less than or equal to; "-" = not applicable.

Predicted concentrations of TDS from the Base Cases and the Accident or Malfunction Cases are compared to the proposed site-specific water quality objective (SSWQO) of 684 mg/L. Predicted concentrations of TDS from the Accident or Malfunction Cases are compared to predictions from the Base Cases, and the spatial extent and duration of the TDS plumes resulting from each accident or malfunction are also presented. If the predicted concentration of TDS exceeded 684 mg/L, then the volume of the lake in which the exceedance occurred was calculated. It was assumed that the area immediately adjacent to the diffuser (end-of-pipe) had concentrations of TDS similar to the concentration being released.

4.3.2 Environmental Consequences

Potential environmental consequences of the discharge were assessed according to a combination of factors. Effects of an accident or malfunction on aquatic life depend on the residual volume of the accident or malfunction, its toxicity, and the volume of the lake affected by the discharge. This is consistent with the approach used in the 2002 Environmental Assessment of the Snap Lake Mine (De Beers 2002). The TDS Benchmark Study (De Beers 2013f) was reviewed to define aquatic life toxicity environmental consequences.

Environmental consequence used in this section is ranked according to four levels (Table 4-2). These levels are defined according to a combination of portion of the community affected, magnitude of the toxic effect, spatial extent, duration, and reversibility. Both lethal and sublethal effects were considered; assessment of lethal effects was more protective since lethality causes a direct effect on the population, especially for fish.

Portion of Community Affected

- Cladocerans – Effects assumed to be less important for Snap Lake because cladocerans make up a small proportion of the zooplankton community, and there is likely to be redundancy in the zooplankton community in terms of the food chain supporting fish.

- **Rest of community including zooplankton and fish** – Effects could have a more important effect overall on Snap Lake because effects on zooplankton groups that make up a larger proportion of the community (e.g., copepods) or on fish populations have a higher probability of affecting the structure and function of the ecosystem. However, this portion of the Snap Lake aquatic community is relatively tolerant to concentrations of TDS above 1,000 mg/L (De Beers 2013f).

Magnitude

- **Sublethal** – There is 20% reduction in growth, reproduction, or normal development endpoint. For cladocerans, this is 648 mg/L; for other species, this is >1,000 mg/L. Assumes that effects less than 20% are essentially indistinguishable from background variability.
- **Lethal** – There is 20% lethality in a population. This threshold cannot be defined on the basis of the TDS Benchmark Study because lethal effects were not observed in the testing. It is assumed to be at concentrations above 1,000 mg/L.

Spatial Extent

- **10% of lake volume** – When <10% of lake volume is affected, it is unlikely to affect overall populations within the lake.
- **20% of lake volume** – When the volume is in the 10% to 20% range then an effect to the lake is possible, with the degree of effect depending on what species are affected and the magnitude of effect.
- **50% of lake volume** – When volume exceeds 50%, then an effect on a particular species or group of species becomes more important and must be evaluated on a case-by-case basis.

Duration

- **One generation (7 days)** – This time corresponds to the generation time for short-lived zooplankton species (note that *Daphnia* have a longer generation time). A toxic effect lasting for one generation is non-negligible but likely of low significance for zooplankton. The duration of a water quality change that could cause this duration of a toxic effect could range from 1 to 7 days (i.e., 1 day exposure could affect the whole generation if it came at a key time). Although a toxic effect on one generation of a fish population is much more significant, the generation time for fish species is much longer (multiple months to 1 year).
- **One annual cycle of ice-off and plankton productivity (6 months to 1 year)** – An effect on zooplankton lasting an entire productivity season could start to cause a shift in the plankton community, depending on the sensitivity and significance of the species being affected.
- **Multiple annual cycles (more than 1 year)** – If the effect lasts for multiple annual cycles, a shift in the community becomes likely.

Reversibility

- An increase in TDS levels above the sublethal or lethal toxicity thresholds would typically be reversible under the cases being examined (i.e., the failure-related release would be corrected). Thus, in most cases, the water quality change and associated potential for toxicity would be reversible.
- In the event that the water quality effect was not reversible, the impacts on the structure and function of Snap Lake become more severe.

Table 4-2 Definition of Levels of Environmental Consequence

Environmental Consequence Rating (Level)	Portion of Community Affected	Magnitude (Based on Toxicity to Aquatic Life)	Spatial Extent	Duration (Duration of Toxic Effects)	Reversibility
Lethal					
Negligible	not relevant	no toxicity	not relevant	not relevant	reversible
	sensitive zooplankton (cladocerans)	acutely lethal	<10% of total lake volume	<1 day	reversible
	other species	acutely lethal	<0.04% of total lake volume[1]	<1 day	reversible
Low	other species	acutely lethal	<5% of total lake volume	<1 day	reversible
	sensitive zooplankton (cladocerans)	acutely lethal	<10% of total lake volume	>24 hours; <1 year	reversible
Moderate	sensitive zooplankton (cladocerans)	acutely lethal	>10% of total lake volume	>24 hours; <1 year	reversible
	other species	acutely lethal	>10% of total lake volume	<1 day	reversible
	other species	acutely lethal	<5% of total lake volume	>24 hours; <1 year	reversible
High	other species	acutely lethal	>10% of total lake volume	>24 hours; <1 year	reversible
	any species	acutely lethal or sub-lethal	>10% of lake volume	any duration	irreversible
Sublethal					
Negligible	not relevant	no toxicity	not relevant	not relevant	reversible
	sensitive zooplankton (cladocerans)	sublethal	not relevant	<3 days	reversible
	other species	sublethal	<0.04% of total lake volume[1]	<1 day	reversible
	sensitive zooplankton (cladocerans)	sublethal	<10% of total lake volume	>3 days	reversible
Low	sensitive zooplankton (cladocerans)	sublethal	<20% of total lake volume	>3 days	reversible
	sensitive zooplankton (cladocerans)	sublethal	<10% of total lake volume	1 year	reversible
	other species	sublethal	<10% of total lake volume	>3 days	reversible
Moderate	sensitive zooplankton (cladocerans)	sublethal	<20% of total lake volume	1 year	reversible
	sensitive zooplankton (cladocerans)	sublethal	>50% of total lake volume	>3 days	reversible
	other species	sublethal	<20% of total lake volume	>3 days	reversible
	other species	sublethal	<10% of total lake volume	1 year	reversible
High	other species	sublethal	>50% of total lake volume	1 year	reversible
	other species	sublethal	>20% of total lake volume	1 year	irreversible

Source: Table modified from De Beers (2002) with data from TDS Benchmark Study (De Beers 2013f).

Note: sublethal to sensitive zooplankton = >684 mg/L; sublethal to other plankton or fish = 1,000 mg/L; lethal to other plankton or fish >1,000 mg/L.

a) The area immediately surrounding the diffuser is <0.04 % of the volume of the lake.

< = less than; > = greater than; % = percent; TDS = total dissolved solids; mg/L = milligrams per litre.

4.4 Results

The results of the water quality predictions for accidents and malfunctions are shown in Table 4-2. Plots of the predicted concentrations in each Accident and Malfunction case are provided in Figures 4-1 through 4-4. Four of the Accident and Malfunction cases are predicted to result in water quality that is below the SSWQO and is therefore assumed to be non-toxic (either lethal or sub-lethal) to aquatic life, and the environmental consequences are rated as negligible (Table 4-3). Four of the cases are predicted to have concentrations of TDS that exceed the SSWQO (Figures 4-2 to 4-4); of these four, three are predicted to exceed the SSWQO for a limited time and to occur in a very small volume of the lake (2%) and are rated as negligible in consequence. One case is predicted to exceed the SSWQO in 14% of the lake with the corresponding environmental consequence rated as a low (Table 4-3).

Table 4-3 Prediction of water quality in Accident or Malfunction Cases

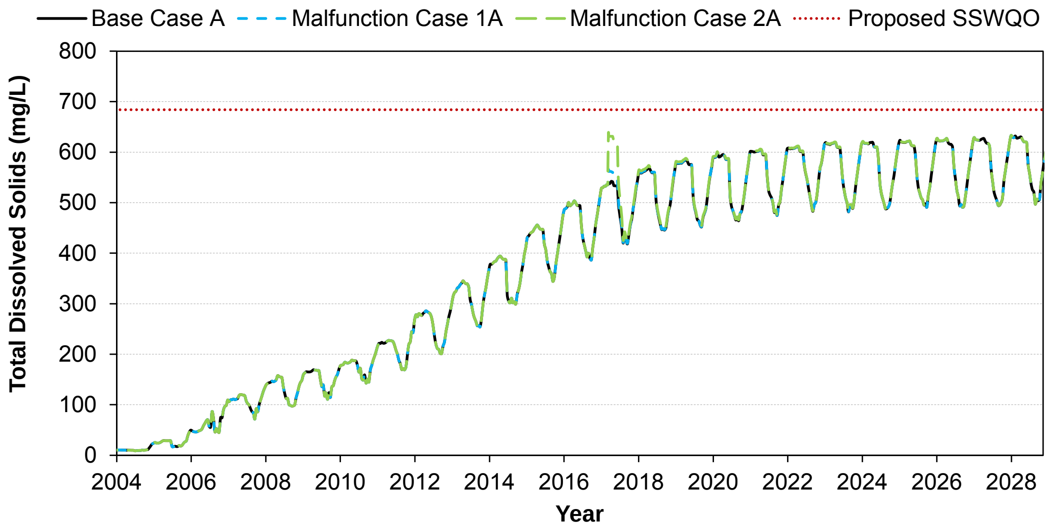
Timeline	Name	Effluent Discharge Rate	Effluent Discharge TDS Concentration during Malfunction (mg/L)	Exceedance of the SSWQO in Snap Lake?	Volume of Lake Affected by Exceedance	Predicted Environmental Consequence
2017	Malfunction Case 1A	Lower Bound	1,000	No (Figure 4-1 a,b)	None	Negligible
	Malfunction Case 1B	Upper Bound		No (Figure 4-3 a,b)	None	Negligible
	Malfunction Case 2A	Lower Bound	2,000	No (Figure 4-1 a,b)	None	Negligible
	Malfunction Case 2B	Upper Bound		Yes (Figure 4-3 a,b)	<2% of lake (Figure 4-3c)	Negligible
2025	Malfunction Case 1A	Lower Bound	1,000	No (Figure 4-2 a,b)	None	Negligible
	Malfunction Case 1B	Upper Bound		Yes (Figure 4-4 a,b)	<2% of lake	Negligible
	Malfunction Case 2A	Lower Bound	2,000	Yes (Figure 4-2 a,b)	2% of lake (Figure 4-2c)	Negligible
	Malfunction Case 2B	Upper Bound		Yes (Figure 4-4 a,b)	14% of lake (Figure 4-4c)	Low

Note: Assumes that as of January 2015 the effluent AML is 684 mg/L and that accident occurs under ice in mid-March when little dilution occurs and occurs for a maximum of 7 days.

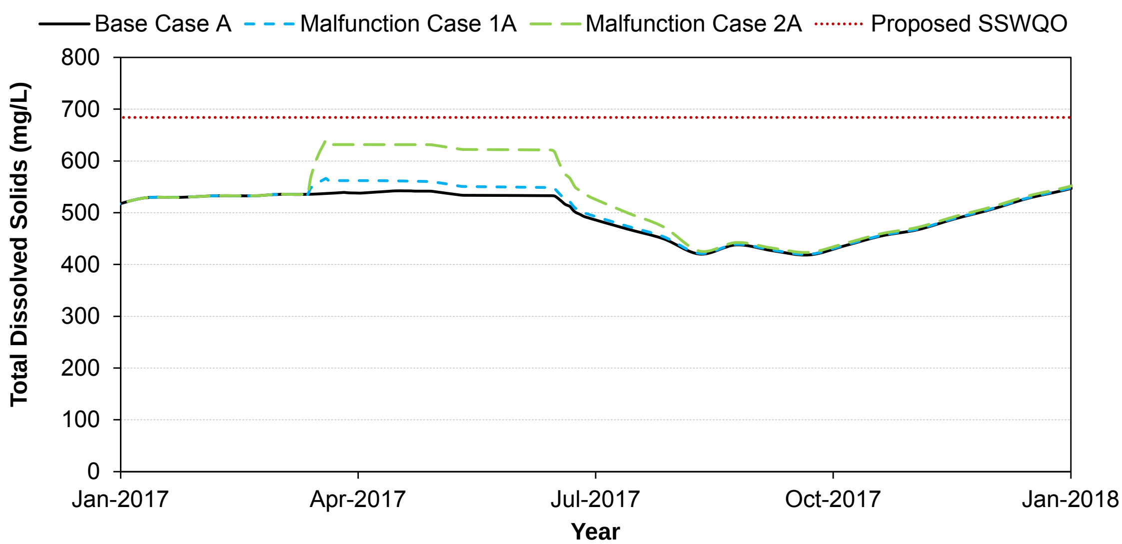
mg/L = milligrams per litre; TDS = total dissolved solids; ≤ = less than or equal to.

Figure 4-1 Maximum Predicted Total Dissolved Solids Concentrations with Accident or Malfunction in 2017 with Lower Bound Discharge Rate

(a) **Near Diffuser, SNP 02-20e, for Period of Operations**



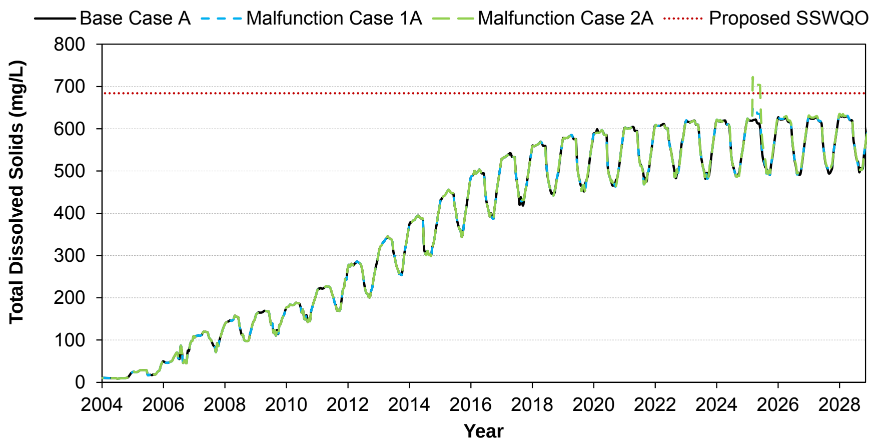
(b) **Near Diffuser, SNP 02-20e, 2017**



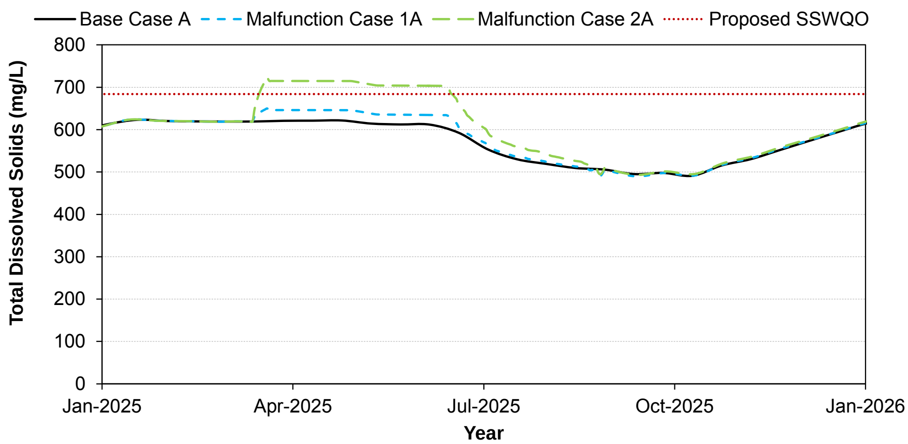
mg/L = milligrams per litre; SNP = surveillance network program; SSWQO = site-specific water quality objective.

Figure 4-2 Maximum Predicted Total Dissolved Solids Concentrations with Accident or Malfunction in 2025 with Lower Bound Discharge Rate

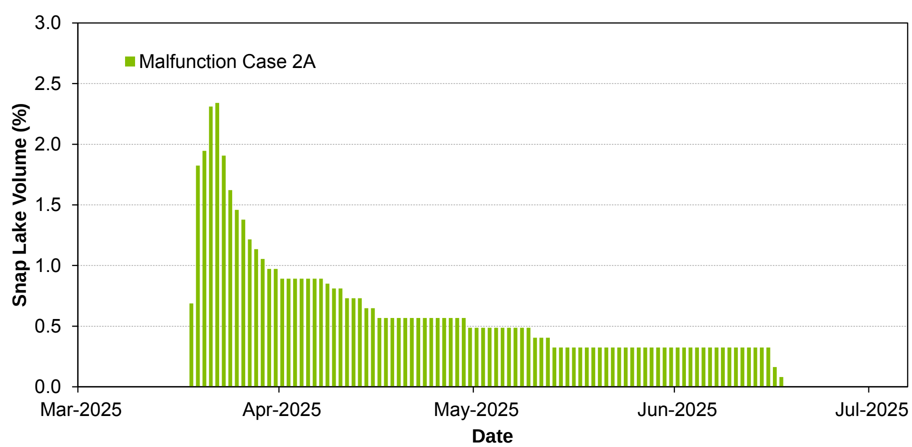
(a) Near Diffuser, SNP 02-20e, for Period of Operations



(b) Near Diffuser, SNP 02-20e, 2025



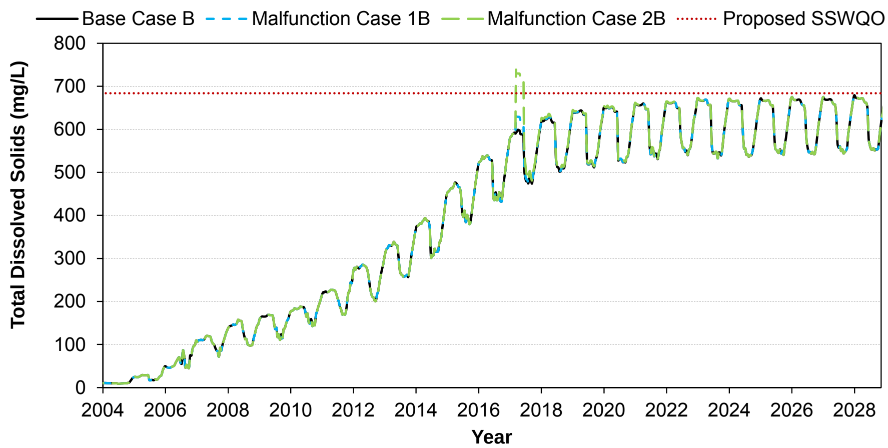
(c) Snap Lake Volume with TDS Concentration >684 mg/L



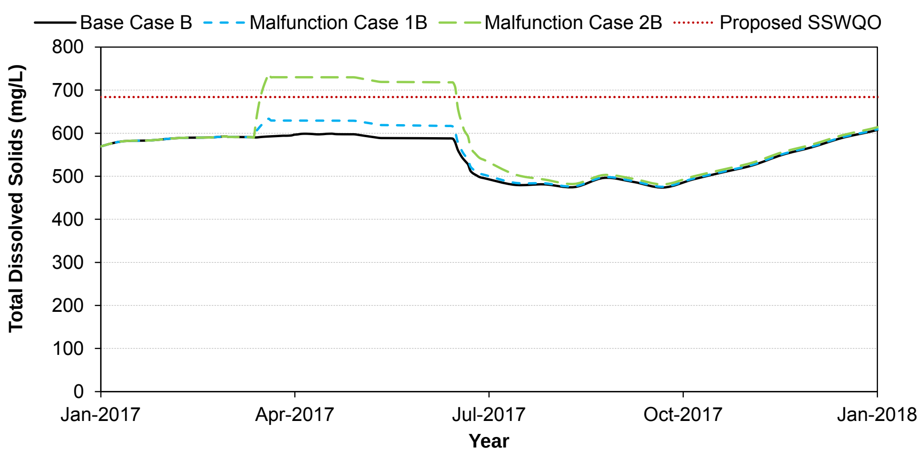
mg/L = milligrams per litre; SNP = surveillance network program; SSWQO = site-specific water quality objective; TDS = total dissolved solids; >= greater than.

Figure 4-3 Maximum Predicted Total Dissolved Solids Concentrations with Accident or Malfunction in 2017 with Upper Bound Discharge Rate

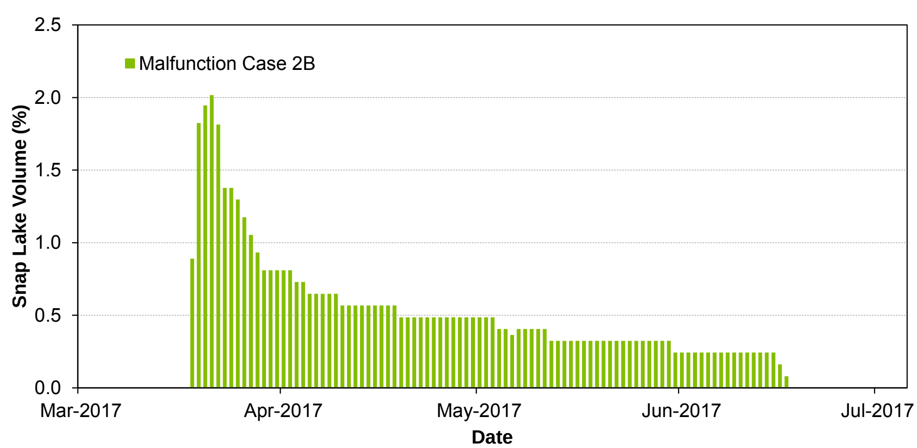
(a) Near Diffuser, SNP 02-20e



(b) Near Diffuser, SNP 02-20e



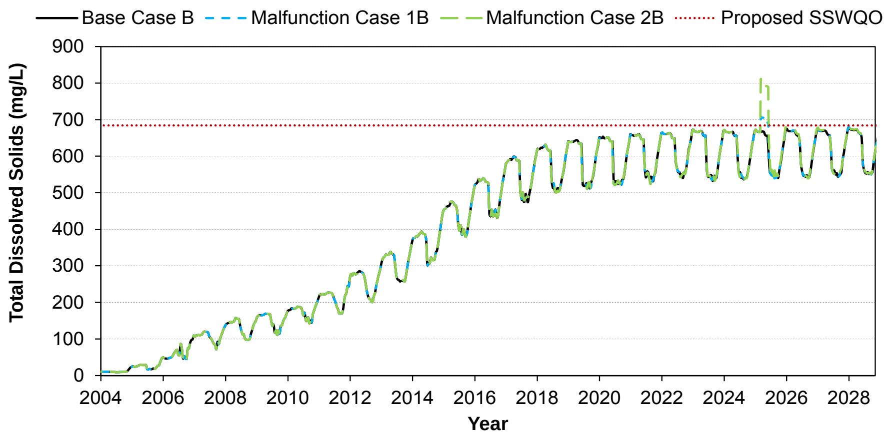
(c) Snap Lake Volume with TDS Concentration >684 mg/L



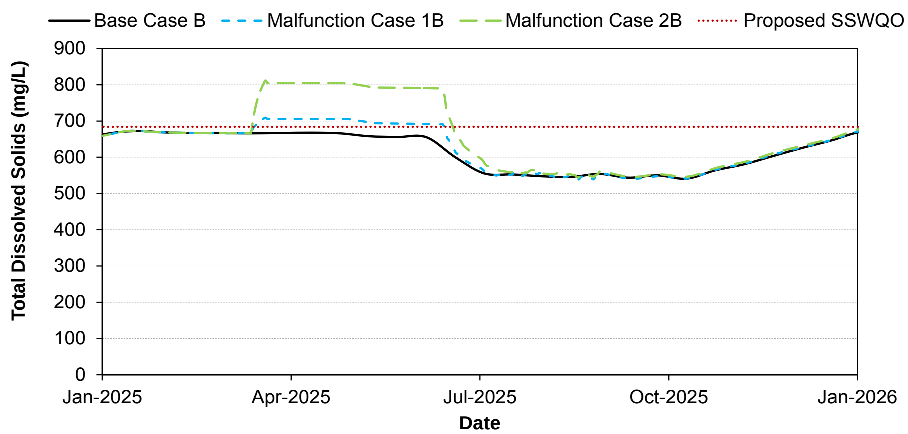
mg/L = milligrams per litre; SNP = surveillance network program; SSWQO = site-specific water quality objective; TDS = total dissolved solids; >= greater than.

Figure 4-4 Maximum Predicted Total Dissolved Solids Concentrations with Accident or Malfunction in 2025 with Upper Bound Discharge Rate

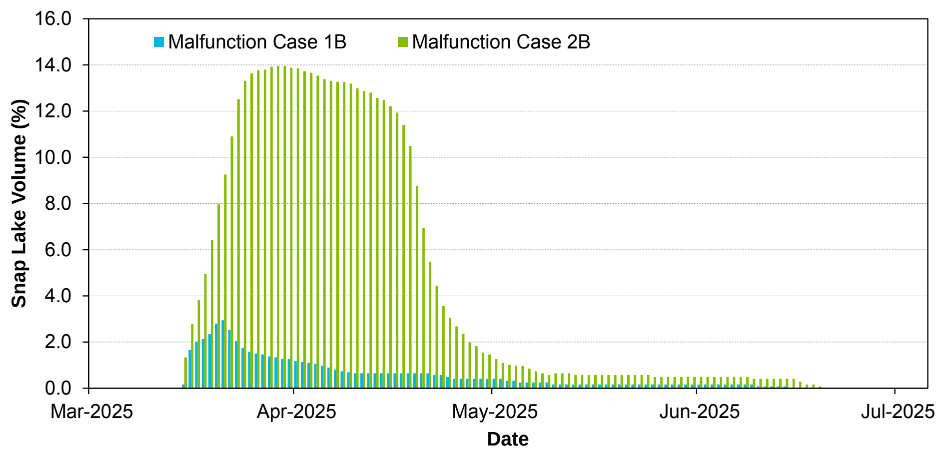
(a) Near Diffuser, SNP 02-20e



(b) Near Diffuser, SNP 02-20e



(c) Snap Lake Volume with TDS Concentration >684 mg/L



mg/L = milligrams per litre; SNP = surveillance network program; SSWQO = site-specific water quality objective; TDS = total dissolved solids; >= greater than.

4.5 Conclusions

What impacts will a potential accident or malfunction related to discharge of treated minewater containing elevated levels of TDS at the Snap Lake Project site have on the receiving environment, specifically Snap Lake?

The impacts (environmental consequence) of the modelled accidents and malfunctions cases were assessed as negligible to low. Any effects would be restricted to sensitive species of zooplankton (cladocerans) and not to the larger aquatic community. Effects would be restricted to a small volume of the lake and often would not exceed the TDS SSWQO or maximum daily limit.

5 ALTERNATIVES

De Beers has evaluated two potential alternatives to the development proposal; namely alternatives to discharging mine effluent at concentrations not exceeding AML of 684 mg/L mg/L TDS; 14 mg/L nitrate; 378 mg/L chloride; 2.43 mg/L fluoride; 1 mg/L nitrite and 427 mg/L sulphate. Both alternatives are currently not considered economically feasible.

Alternative 1: Effluent Quality Criteria Unchanged

De Beers is seeking higher EQCs based on the results of site-specific chronic effects benchmark studies, which recommend SSWQOs that are protective of the aquatic environment of Snap Lake. Prior to applying for revised EQCs, De Beers evaluated the results of predicted life-of-mine water quality (De Beers 2013a) to determine the feasibility of continuing current mine operations under current EQC limits. The water quality models have indicated that the licence limits for TDS, chloride and nitrate (effective January 1, 2015) are not realistically achievable with current mine practices, and will be exceeded within the next 1 to 5 years. De Beers' evaluation of treatment technologies, as reported in the TDS Response Plan (De Beers 2013g) indicate that the cost to implement treatment of the whole effluent to achieve current licence limits using available technology is estimated at $188M.

De Beers believes that the current proposed SSWQOs and associated EQCs are protective of the environment, and are achievable based on review of pre-feasibility studies.

Alternative 2: Reduction of Footwall Development

The greatest contributor to TDS loadings to Snap Lake is mine effluent which generates from release of connate water during mine operations, specifically during the advancement of the footwall. The increases in TDS in mine effluent as reported in Itasca (2013) are directly related to continued mining as proposed in the mine plan. Slowing advancement of the footwall would decrease the rate of TDS loading to the environment. However, since footwall development is essential to the current methods for mining the ore deposit, slowing footwall development also directly affects the rate of ore development.

Reduction in footwall development is not achievable to support the current mine plan and results in the mine becoming not economically viable in the long term.

Alternative 3: Reducing Water Flows

The investigation of options for reducing flows in the underground, are discussed in the TDS Response Plan (De Beers 2013g).

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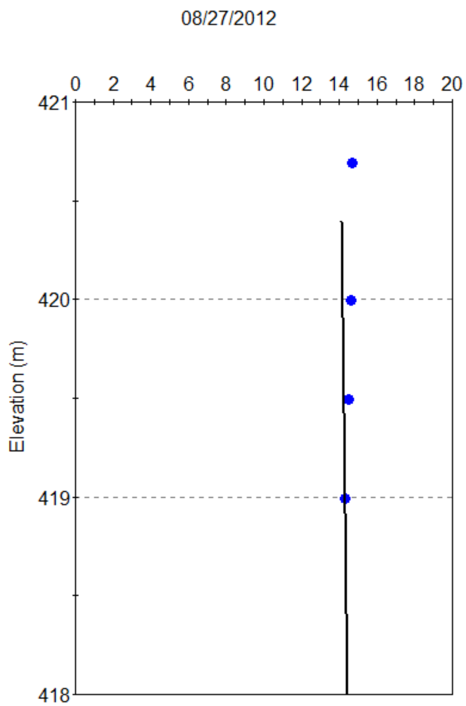
ATTACHMENT I

WATER TEMPERATURE AND TOTAL DISSOLVED SOLIDS PROFILE CALIBRATION RESULTS

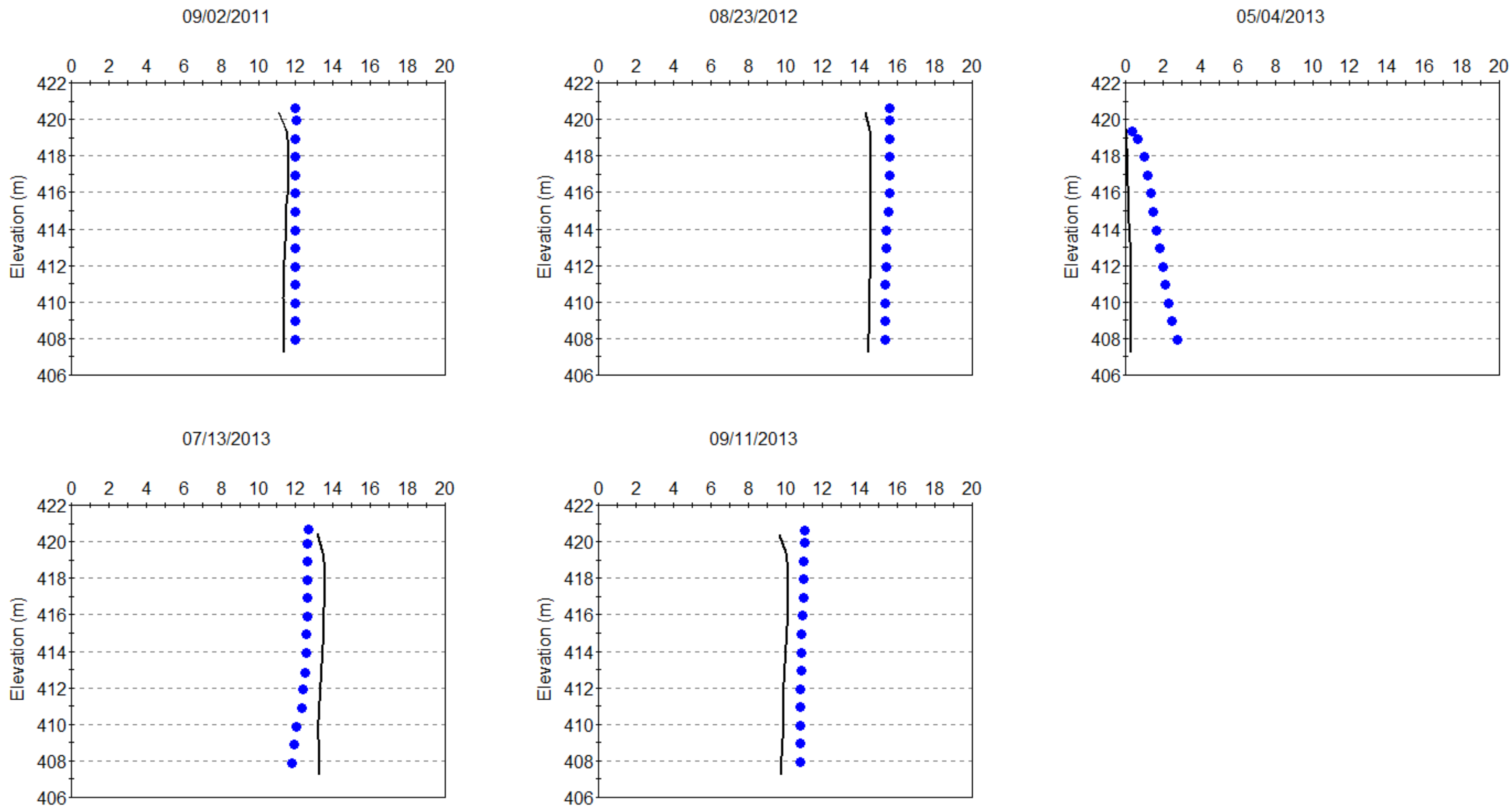
Figure I-1 Water Temperature (°C) Profile Calibration Plots at LCB Inlet.



Note: Solid line represents model results; dots represent measured water temperatures.

°C = degrees Celsius; m = metre.

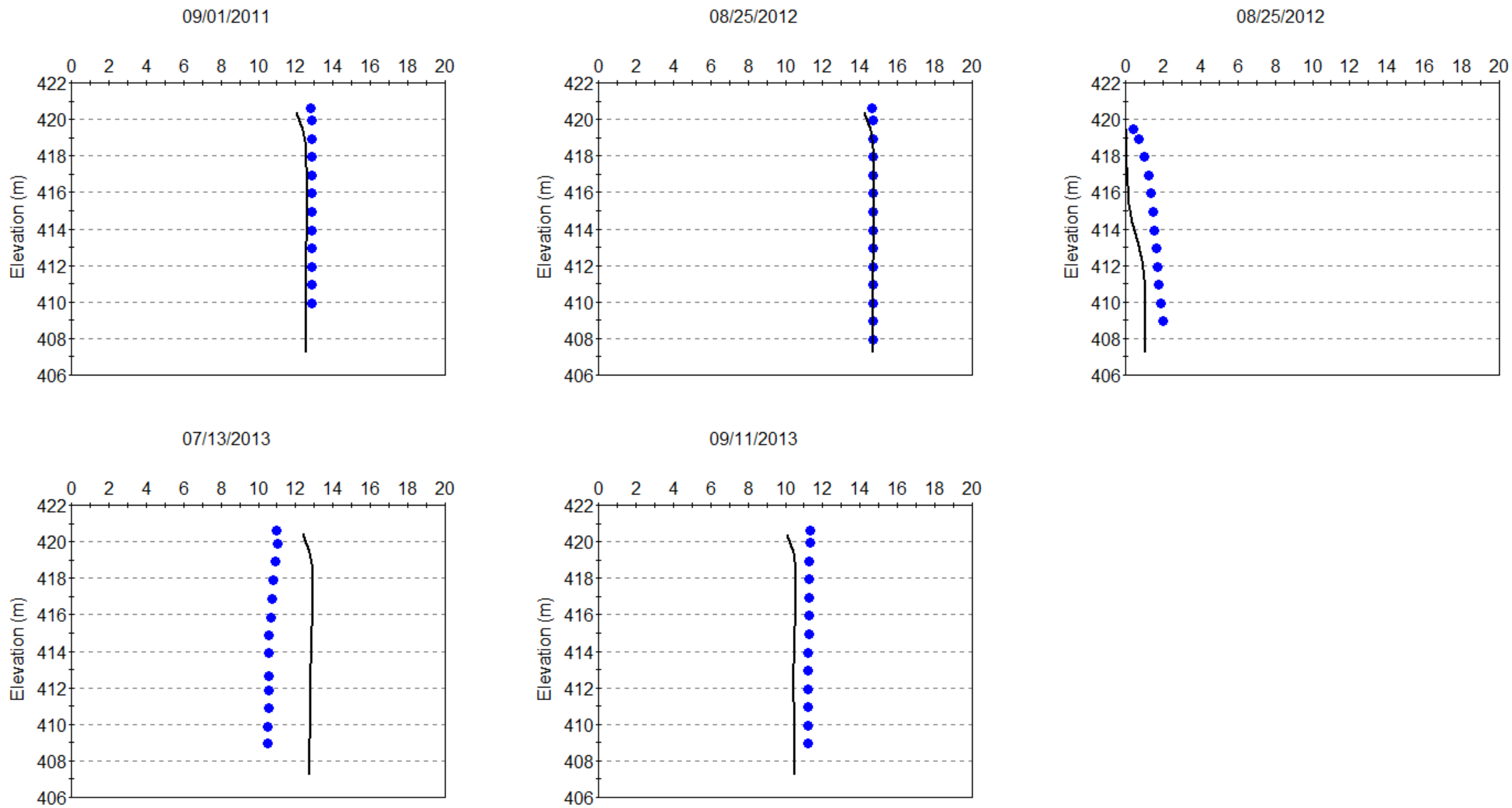
Figure I-2 Water Temperature (°C) Profile Calibration Plots at LCB-1



Note: Solid line represents model results; dots represent measured water temperatures.

°C = degrees Celsius; m = metre.

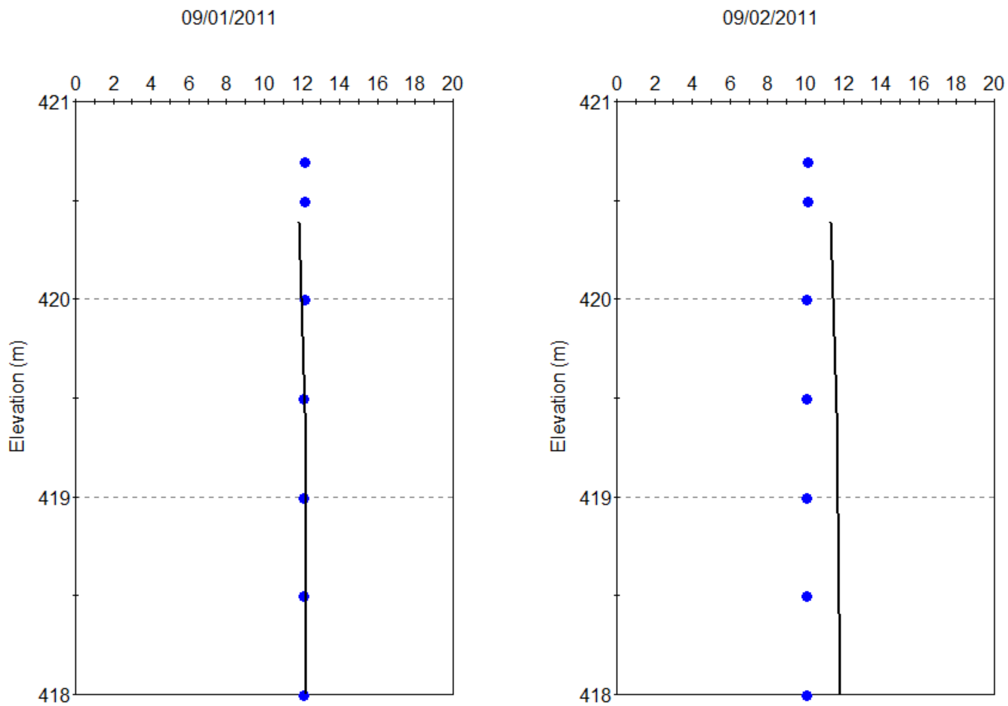
Figure I-3 Water Temperature (°C) Profile Calibration Plots at LCB-3



Note: Solid line represents model results; dots represent measured water temperatures.

°C = degrees Celsius; m = metre.

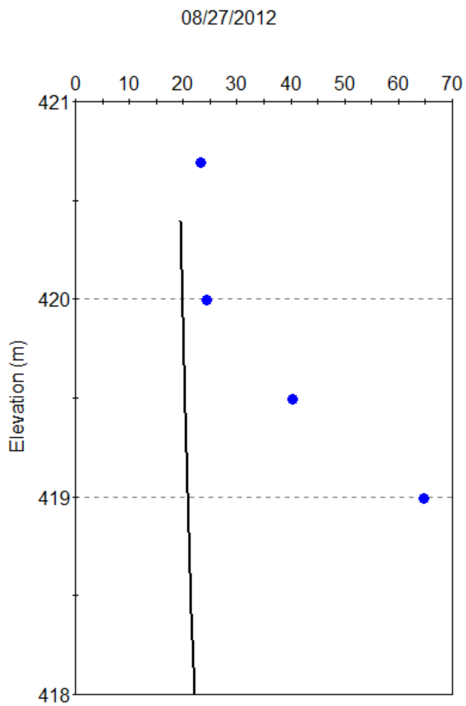
Figure I-4 Water Temperature (°C) Profile Calibration Plots at LCB Outlet



Note: Solid line represents model results; dots represent measured water temperatures.

°C = degrees Celsius; m = metre.

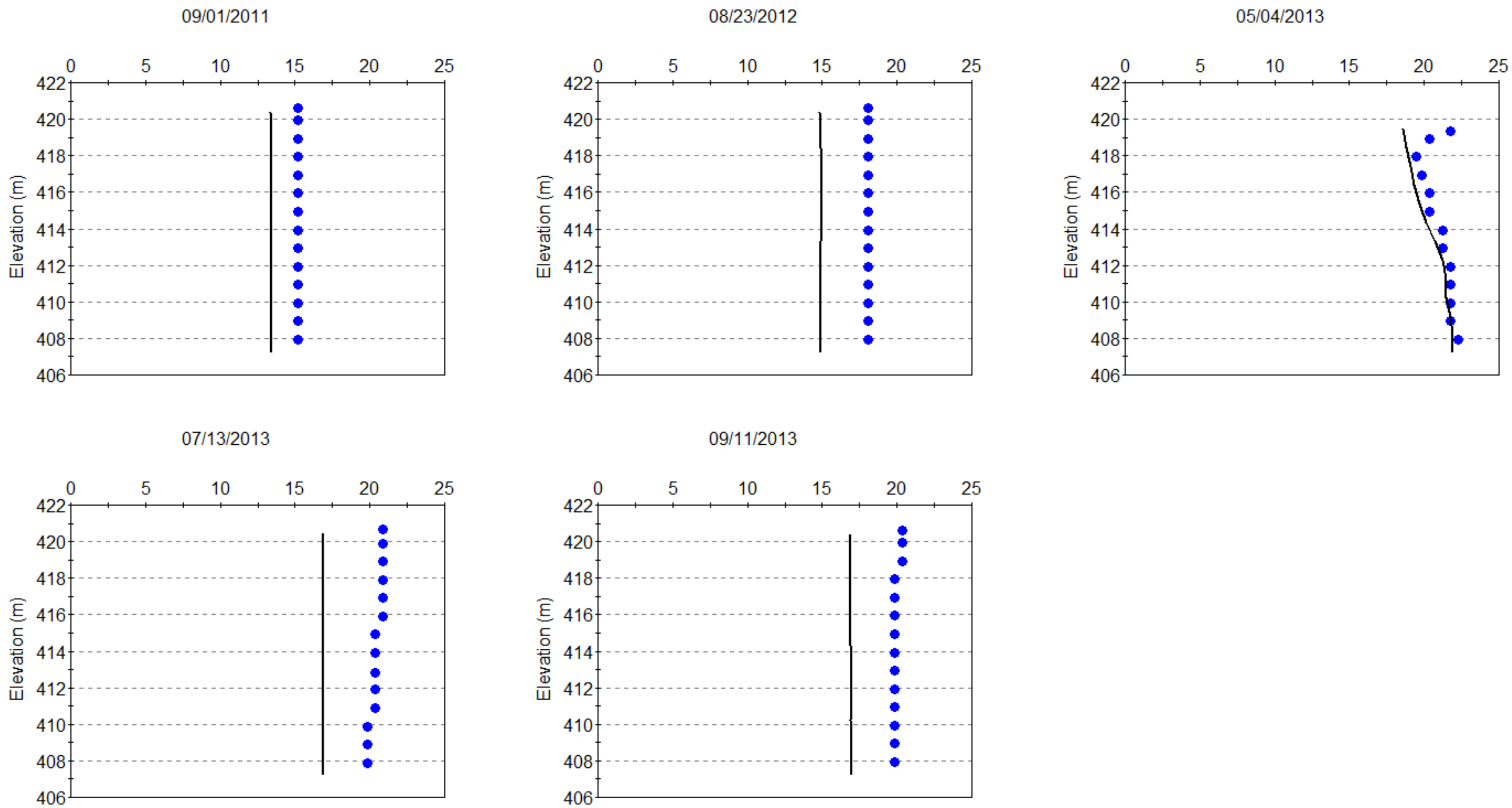
Figure I-5 Total Dissolved Solids (mg/L) Profile Calibration Plots at LCB Inlet



Note: Solid line represents model results; dots represent calculated total dissolved solids concentrations.

mg/L = milligrams per litre; m = metre.

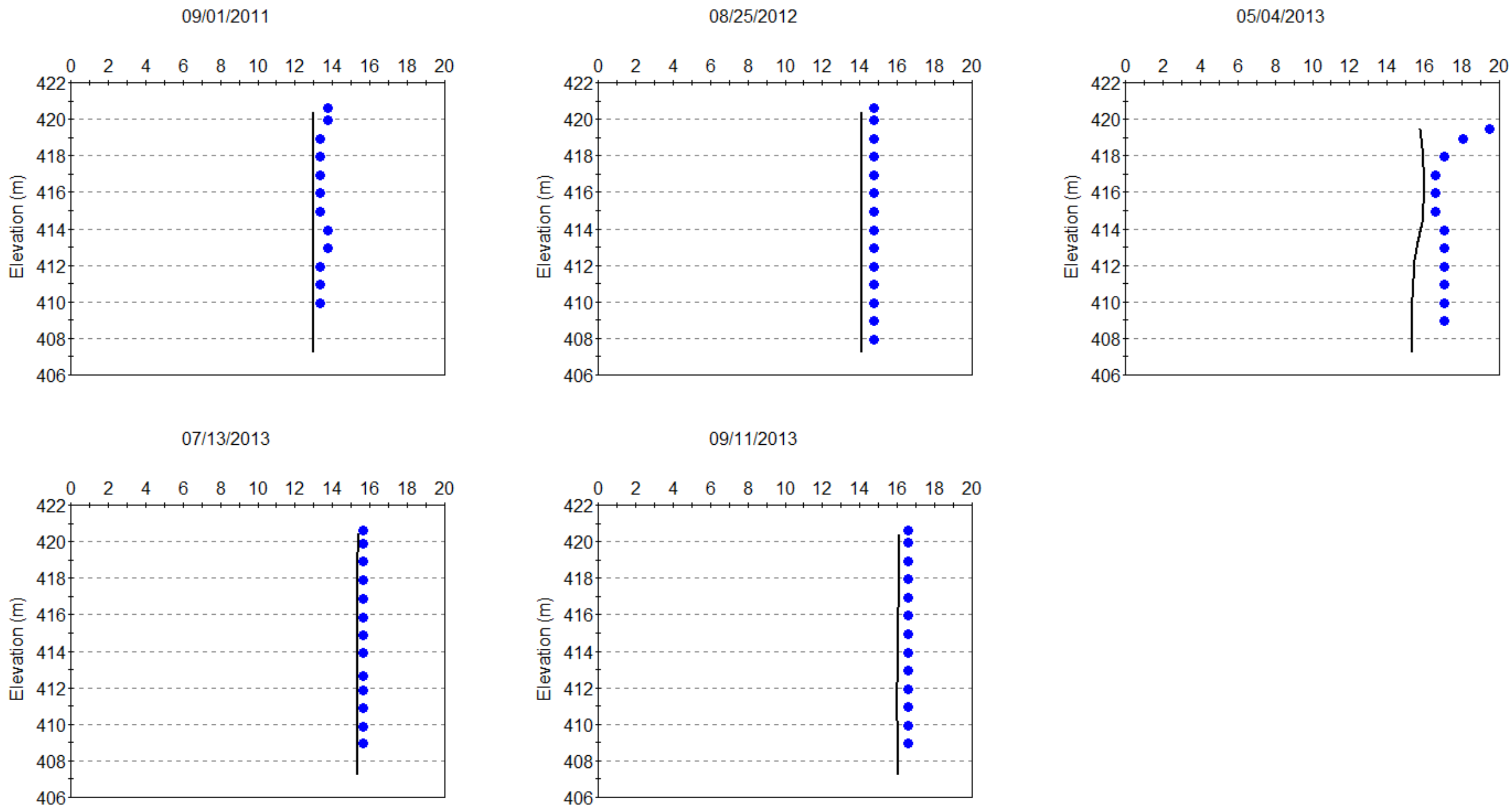
Figure I-6 Total Dissolved Solids (mg/L) Profile Calibration Plots at LCB-1



Note: Solid line represents model results; dots represent calculated total dissolved solids concentrations.

mg/L = milligrams per litre; m = metre.

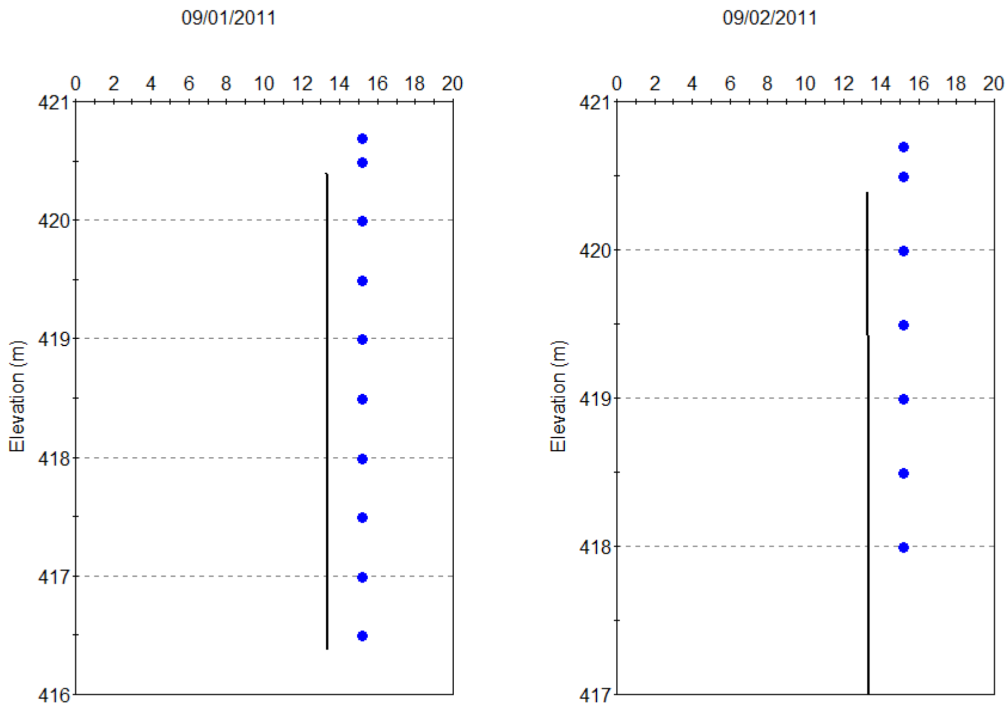
Figure I-7 Total Dissolved Solids (mg/L) Profile Calibration Plots at LCB-3



Note: Solid line represents model results; dots represent calculated total dissolved solids concentrations.

mg/L = milligrams per litre; m = metre.

Figure I-8 Total Dissolved Solids (mg/L) Profile Calibration Plots at LCB Outlet



Note: Solid line represents model results; dots represent calculated total dissolved solids concentrations.

mg/L = milligrams per litre; m = metre.

Second *Daphnia magma* 21-Day TDS Toxicity Test Results

TECHNICAL MEMORANDUM

DATE April 11, 2014 **PROJECT No.** 14-1349-0003/1500/1503

TO Erica Bonhomme, Snap Lake Environmental Manager
De Beers Canada Inc.(DBCI)

CC Tasha Hall and Alison Snow (Golder); Alexandra Hood (DBCI)

FROM Peter M. Chapman **EMAIL** pmchapman@golder.com

SECOND *DAPHNIA MAGNA* 21-DAY TDS TOXICITY TEST RESULTS

1.0 BACKGROUND AND INTRODUCTION

Golder Associates Ltd (Golder 2013) developed a total dissolved solids (TDS) benchmark for aquatic life for Snap Lake based on a literature review, problem formulation, and site-specific toxicity tests with phytoplankton, zooplankton, benthic invertebrates, and fish species representative of aquatic receptors in Snap Lake. Most species tested showed no adverse effects at TDS concentrations greater than (>) 1,400 milligrams per litre (mg/L); however, two daphnid species were more sensitive to TDS and showed adverse effects at lower TDS concentrations. Although daphnids comprise on average of approximately 2 percent (%) of the zooplankton community in Snap Lake, a conservative site-specific water quality objective (SSWQO) of 684 mg /L was proposed based on *Daphnia magna* 21-day (d) toxicity tests reported in Golder (2013).

The results of the TDS testing, including the proposed TDS SSWQO, were presented to interested parties, including regulatory agencies and representatives of Aboriginal communities, on January 6, 2014 in Yellowknife, Northwest Territories (NWT). There was discussion following the presentation regarding the repeatability of the tests.

As a result of the discussion regarding test repeatability, De Beers Canada Inc (De Beers) requested that Golder repeat the 21-day *D. magna* test that provides the basis for the proposed TDS SSWQO. The present technical memorandum provides the methods and results from this repeat testing and discusses the results relative to the proposed SSWQO.

2.0 METHODS

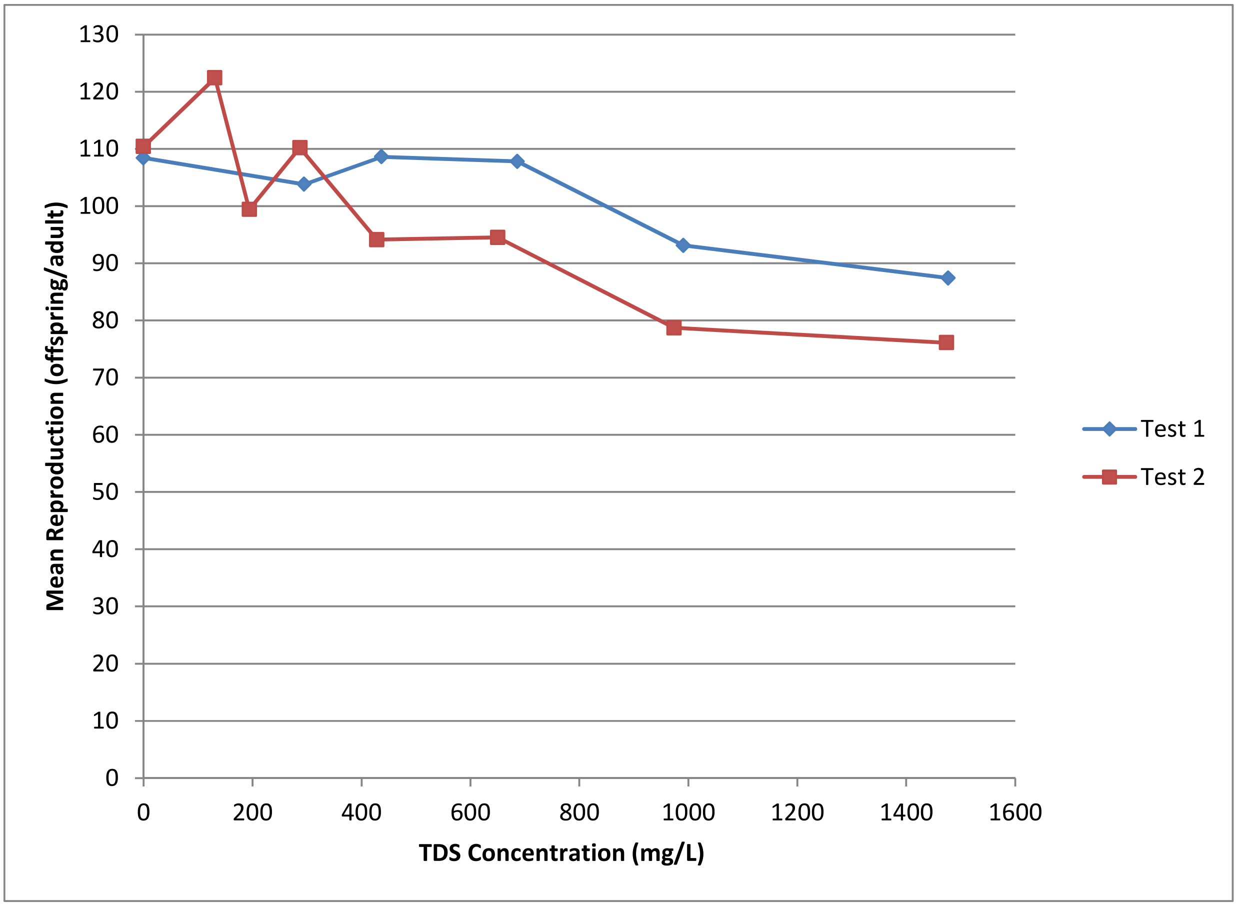
A synthetic lake water sample was prepared, with the same ratio of major ions in Snap Lake but at a nominal TDS concentration of 1,500 mg/L. The sample was prepared by Nautilus Environmental, the same laboratory that prepared samples for previous TDS testing reported in Golder (2013). The synthetic lake water was analysed for its ionic composition to assess concentrations of the major ions and to calculate TDS concentrations. Results of those analyses determined that the calculated TDS concentration for the synthetic lake water sample was 1,477 mg/L, which was very close to the target nominal concentration of 1,500 mg/L.

A 21-d *D. magna* survival and reproduction toxicity test was conducted by Nautilus Environmental following American Society for Testing and Materials (ASTM 2004) procedures. Daphnids were exposed to the following calculated TDS concentrations in a dilution series that also included a negative (clean) control: 295, 437, 686, 991, and 1477 mg/L. The Nautilus Environmental Data Report is provided as Attachment 1 and includes the chemical analyses of the TDS test solutions.

3.0 RESULTS

As is app arent from Figure 1, the *D. magna* toxicity test reporte d herein (Test 2) produced a similar dose-response as the previous *D. magna* toxicity te st (Test 1) reported in Golder (2013). However, the 20% inhibition concentration (IC20) for the p resent test (Test 2) was >1,477 mg/L compared to the first test (Test 1), where the IC20 wa s 684 mg/L. The flatness of the dose-response explains these differen ces, which are not unreasonably large (Cherr et al. 1994).

Figure 1 Concentration-Response for Two Daphnia magna Snap Lake TDS Toxicity Tests



TDS= total dissolved solids; mg/L= milligrams per litre.

4.0 RELEVANCE TO THE SNAP LAKE TDS SSWQO

The Canadian Council of Ministers of the Environment (CCME 2007; Part II, Section 1-10 and 1-11) states "Multiple comparable records for the same endpoint are to be combined by the geometric mean of these records to represent the averaged species effects endpoint." CCME (2007, Part II, Section 3.1-2) similarly states, twice, "If there is more than one comparable record for a preferred endpoint, then the species effects endpoint is to be represented by the geometric mean of these records."

Previous SSWQOs developed for the Ekati Diamond Mine followed the above approach. Specifically, in cases where more than one acceptable value was available for an individual species endpoint, the values were combined using the geometric mean to produce a single value for each species (Elphick et al. 2011; Ekati 2012a,b,c). This approach was specifically applied to daphnid toxicity data in Elphick et al. (2011) and Ekati (2012c)

The geometric mean of the two IC20 values (Tests 1 and 2) for *D. magna* is 1,005 mg/L TDS. Based on CCME (2007) and previous precedent in the NWT, this value could reasonably replace the Snap Lake TDS SSWQO of 684 mg/L previously proposed by Golder (2013) in reference to the De Beers Water Licence Amendment Application.

5.0 CLOSURE

We trust that this technical memorandum provides you with the information you require at this time. Should you have any questions, or require further information, please contact the undersigned.

GOLDER ASSOCIATES LTD.

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Senior Environmental Scientist

PMC/CAM/me

Att.

6.0 REFERENCES CITED

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ATTACHMENT 1

NAUTILUS ENVIRONMENTAL DATA REPORT

Review of Site-Specific Water Quality Objective for Strontium

Golder Associates

TECHNICAL MEMORANDUM

DATE April 11, 2014 **PROJECT No.** 1413490003/2200/2201

TO Erica Bonhomme and Alex Hood
De Beers Canada Inc

FROM Peter M Chapman **EMAIL** pmchapman@golder.com

REVISION OF SITE-SPECIFIC WATER QUALITY OBJECTIVE FOR STRONTIUM

The purpose of this technical memorandum is to detail why Golder Associates Ltd. (Golder) has revised the site-specific water quality objective (SSWQO) for strontium based on external peer review during preparation for peer reviewed publication. Specifically, three studies have been removed from the SSWQO derivation as discussed below.

Jones (1939) conducted toxicity tests with Three-spined Stickleback (*Gasterosteus aculeatus*) to determine a survival curve for strontium. The test duration was 10 d, and test solutions were renewed daily. The author reported a “lethal concentration limit” of 1,200,000 µg/L strontium, which Golder interpreted as being a measure of median lethal time (LT50, or time to 50% mortality). Jones (1939) defined the lethal concentration limit as being the level to which the concentration of test material must be reduced before definite toxic effect disappears, but did not specify what percent mortality was considered a definite toxic effect. The author reported mean or average survival times, but upon further review it was not clear what percent mortality was associated with those survival times. Testing was conducted for 2.5 x longer than the standard 4-d acute toxicity test; however, the endpoint was survival. Because this study only measured survival and not sublethal endpoints, and because the actual percentage effect being reported was unclear, it was removed from the SSWQO derivation.

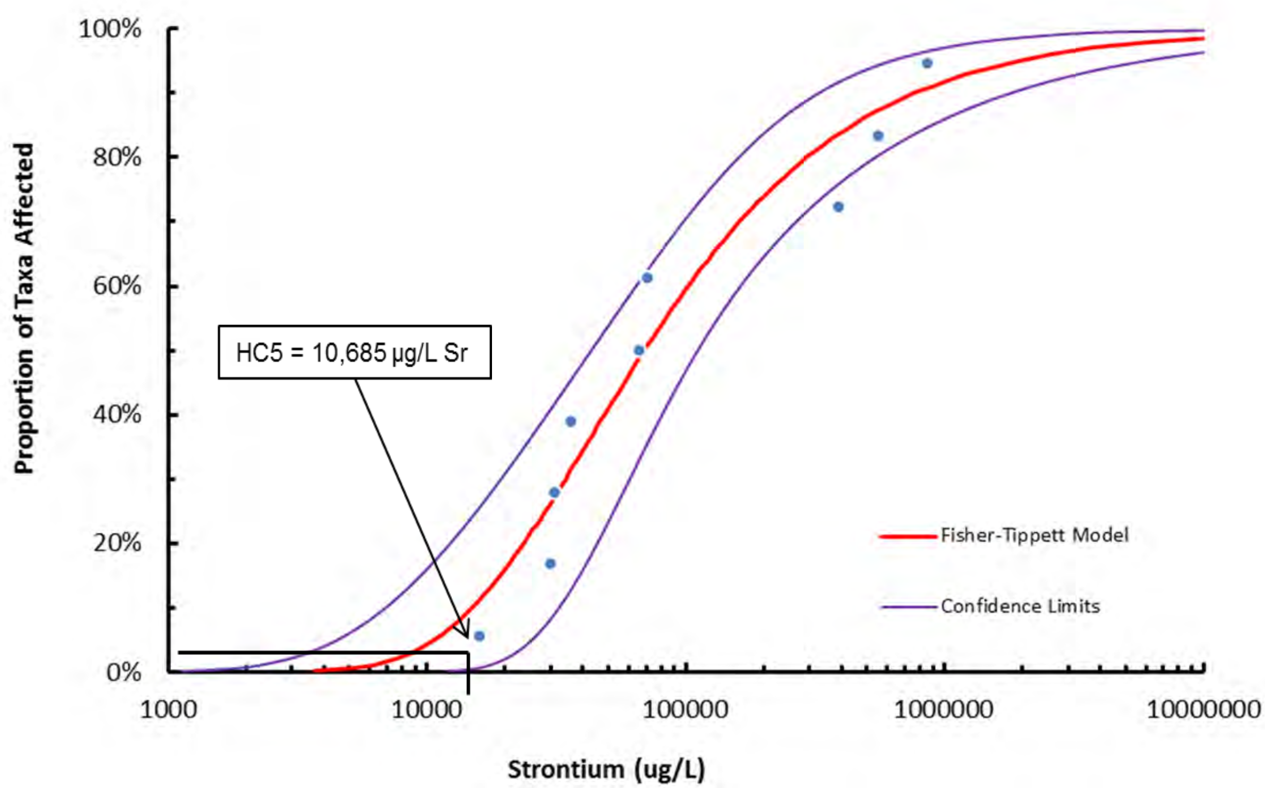
Jones (1940) also conducted 48-h tests with the planarian, *Polycelis nigra*, and reported “lethal concentration limits” of 3,500,000 and 6,000,000 µg/L for two different strontium salts. With only a slight dilution, survival was extended considerably. This study was removed from the SSWQO derivation for the same reason as this author’s earlier study with Stickleback.

Schroder et al. (1995) reported that a 24-h immersion in a strontium chloride solution is used for marking Chum Salmon (*Oncorhynchus keta*) and Sockeye Salmon (*O. nerka*) fry prior to their release in the wild. Chum Salmon fry were exposed to three strontium concentrations (120,000, or 1,200,000, or 9,000,000 µg/L) for 24 h, and then reared for 34 d on a standard hatchery diet. Control mortality was 1%; mortality in the 1,200,000 µg/L treatment was 2%; and, mortality in the 9,000,000 µg/L treatment was 7%. Sockeye Salmon fry were immersed in a 5,000,000 µg/L strontium solution for 24 h and then reared for 21 months on a standard hatchery diet to determine how long the marked fish could be distinguished from unmarked fish. The Sockeye Salmon data were not used in the original SSWQO as the authors did not provide detailed mortality data. The Chum Salmon data were used in the original SSWQO because, although this was an acute 24-h exposure to strontium, there was a

34-d follow up in clean water. However, the highest effect was only 7% and the endpoint was unbounded, thus it was removed from the SSWQO derivation.

The remaining data continue to meet the requirements of CCME (2007) for species representation to produce a Type A water quality guideline using a species sensitivity distribution (SSD). The Fisher-Tippett distribution produced the lowest Anderson Darling statistic, indicating the best fit to the data in the tails of the distribution, and was selected for deriving the HC5 of 10,685 mg/L, with confidence limits of 4,499 to 25,373 mg/L (Figure 1). All of the species mean chronic values utilized in deriving the SSWQO exceeded this value, indicating that the objective was protective.

Figure 1: Species Sensitivity Distribution for Strontium



If you have any questions please do not hesitate to contact the undersigned.

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Development of Strontium Chronic Effects Benchmark for Aquatic Life in Snap Lake

DE BEERS
GROUP OF COMPANIES

DE BEERS CANADA INC.

SNAP LAKE MINE

DEVELOPMENT OF STRONTIUM CHRONIC EFFECTS BENCHMARK FOR AQUATIC LIFE IN SNAP LAKE

December 2013

EXECUTIVE SUMMARY

Strontium concentrations in Snap Lake water have been increasing since Mine operations began in 2005. In 2012, total strontium concentrations were above 700 micrograms per litre (µg/L) in the diffuser area and approximately 600 µg/L elsewhere in the main basin. In contrast, baseline (2004) concentrations in Snap Lake and background concentrations in the area around Snap Lake were less than 15 µg/L. Modeling predictions suggest that strontium concentrations in Snap Lake could increase to approximately 4,000 µg/L by the end of Mine operations.

Concentrations of total strontium measured in treated Mine effluent peaked at 4,320 µg/L in June 2006, and have since decreased to approximately 1,600 µg/L in 2012. Although measured concentrations have decreased in recent years, modeling predictions suggest that strontium concentrations in treated mine effluent could increase to approximately 4,700 µg/L by the end of mine operations.

There are no national water quality guidelines (WQGs) for strontium for protection of freshwater aquatic life in Canada or the United States, and no benchmark was established as part of the 2002 Environmental Assessment Report (EAR). Ecometrix (2011) proposed 500 µg/L as both a site-specific water quality objective (SSWQO) for Snap Lake and an effluent quality criterion (EQC) for treated mine effluent; this made no allowance for effluent mixing and was calculated based on potentially flawed data. As part of the *Strontium Response Plan* that De Beers is required to submit to the McKenzie Valley Land and Water Board (MVLWB) in December 2013, a benchmark for strontium in Snap Lake is to be recommended.

Available data on the acute and chronic toxicity of strontium to freshwater aquatic life were compiled and reviewed. Acute toxicity was reported to occur at concentrations ranging from 75,000 to 15,000,000 µg/L. The majority of chronic effects occurred at concentrations above 11,000 µg/L; however, calculation of a representative benchmark was confounded by results from three studies indicating that chronic effects occurred at lower concentrations. One of these studies, with a goldfish, was not applicable to Snap Lake as goldfish are not found there. The other two studies were repeated to determine whether their findings, which have been questioned, were correct. In fact, these new studies showed that chronic effects occurred at considerably higher strontium concentrations. The goldfish study, although not repeated, had been conducted by the authors of one of the two studies that were repeated and shown to be non-reproducible; it is also thus likely that repeating this study would also have resulted in considerably higher strontium effects concentrations.

A chronic effects benchmark of 14,130 µg/L is recommended for strontium in Snap Lake. The burden of evidence (tissue burdens of strontium in Snap Lake and reference lake fish; toxicology of strontium) does not indicate that there is a present or future risk of strontium toxicity to the aquatic biota of Snap Lake.

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LIST OF ACRONYMS

Term	Definition
AEMP	Aquatic Effects Monitoring Program
AMV	aquatic maximum value
$CaCO_3$	calcium carbonate
CEB	chronic effects benchmark
CCME	Canadian Council of Ministers of the Environment
dw	dry weight
EAR	Environmental Assessment Report
EC	effect concentration
EC50	median effective concentration
ELS	early life stage
EQC	effluent quality criterion
FAV	final acute value
FCV	final chronic value
GMAV	genus mean acute value
HC5	hazardous concentration to 5% of species
IC	inhibitory concentration
IC10	concentration that is an inhibition to 10% of organisms
IC20	concentration that is an inhibition to 20% of organisms
IC50	concentration that is an inhibition to 50% of organisms
IDEM	Indiana Department of Environmental Management
IR	Information Request
LC	lethal concentraion
LC20	concentration that is lethal to 20% of organisms
LC50	concentration that is lethal to 50% of organisms
LOEC	lowest observed effect concentration
LT50	the leathal time to 50% mortality of organisms
MATC	maximum acceptable toxicant concentration
MDEQ	Michigan Department of Environmental Quality
MVLWB	McKenzie Valley Land and Water Board
NOEC	no observed effect concentration
SD	standard deviation
SMCV	species mean chronic value
SNP	Surveillance Network Program
SSD	species sensitivity distribution
SSWQO	site-specific water quality objective
TDS	total dissolved solids
USEPA	United States Environmental Protection Agency
WQG	water quality guideline
ww	wet weight
WHO	World Health Organization
YCT	yeast, cerophyl, trout chow

UNITS OF MEASURE

Term	Definition
°C	degrees Celsius
%	percent
d	day
h	hour
km	kilometre
L	litre
µg/L	micrograms per litre
mg/kg	milligrams per kilogram
mg/L	milligrams per litre

1 INTRODUCTION

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (Mine), an underground diamond mine located approximately 220 kilometres northeast of Yellowknife, Northwest Territories. The Mine began construction in 2004, became operational in late 2005, and is expected to be in operation until 2026. To comply with the Mine's Water Licence (Water Licence MV2001L2-0002, renewed as MV2011L2-0004 in 2012), De Beers is required to undertake a water quality monitoring component as part of a larger Aquatic Effects Monitoring Program (AEMP) that also includes monitoring of sediment quality, plankton, benthic invertebrates, and fish in Snap Lake. The AEMP water quality component includes monitoring of total and dissolved strontium concentrations in Snap Lake, along with other metals, and these results are submitted in annual AEMP reports (e.g., De Beers 2013a). In addition, De Beers is required to monitor the quality of its treated effluent discharge as part of its Surveillance Network Program (SNP), results of which are also submitted to the Mackenzie Valley Land and Water Board (MVLWB).

Strontium is present in the kimberlite and processed kimberlite. A benchmark for strontium was not established as part of the Environmental Assessment Report (EAR; De Beers 2002) and there are no Canadian WQGs for strontium for protection of freshwater aquatic life or for drinking water.

At the September 14 to 16, 2011 MVLWB Technical Sessions pertaining to the Mine's Water Licence renewal application, it was noted that strontium concentrations have increased in Snap Lake water relative to baseline conditions. An Information Request (IR) was made to De Beers to provide readily available information on strontium to the MVLWB, and such information was provided in 2011. The MVLWB also retained Ecometrix Inc. to propose site-specific water quality objectives (SSWQO) for Snap Lake and effluent quality criteria (EQC) for the treated Mine effluent for a number of parameters, one of which was strontium (Ecometrix 2011).

The current Water Licence requires that a *Strontium Response Plan* be submitted to the MVLWB by December 31, 2013. One component of that *Strontium Response Plan* is to provide recommendations and supporting rationale for a SSWQO for strontium in Snap Lake, derived from toxicity tests conducted by De Beers and/or published toxicology studies. The purpose of this report is to address that requirement of the *Strontium Response Plan*. This report provides an overview of environmental concentrations of strontium associated with Snap Lake, a compilation and review of available information on the toxicity of strontium to freshwater aquatic life, results of additional chronic toxicity testing undertaken to reduce uncertainty associated with the existing chronic toxicity data, and proposes a chronic effects benchmark (CEB) for strontium in Snap Lake.

2 WATER QUALITY BENCHMARKS FOR STRONTIUM

There are currently no national water quality guidelines (WQGs) for strontium for protection of freshwater aquatic life in Canada or the United States.

Ecometrix (2011) proposed a SSWQO for strontium in Snap Lake of 500 micrograms per litre (µg/L); the same value was also proposed as an EQC for treated Mine effluent, making no allowance for effluent mixing and dilution following discharge. This value was calculated as the geometric mean of the two lowest lethal concentration to 50% mortality (LC50)[1] values in their database: a 28-day (d) LC50 for Rainbow Trout (*Oncorhynchus mykiss*) of 250 µg/L (Birge et al. 1980) and a 7-d LC50 for the amphipod *Hyalella azteca* of 1,000 µg/L (Borgmann et al. 2005). Ecometrix (2011) identified issues with both these test results, which are discussed in Sections 4.0 and 6.0 of this report.

Hull (2008) provided a collection of worksheets showing calculations used to develop acute and chronic values for strontium for the Michigan Department of Environmental Quality (MDEQ 2008), although it was not clear whether these had been formally adopted as state water quality standards. Development of these water quality benchmarks for strontium involved rejecting all of the data available in the literature at the time, and relying on data from six unpublished studies (see Appendix A). A Tier I final acute value (FAV) of 80,600 µg/L was calculated using acute data from six studies; the FAV was divided by two to obtain an acute benchmark, the aquatic maximum value (AMV), of 40,300 µg/L. Chronic toxicity data from one test with *Ceriodaphnia dubia* and one test with Fathead Minnow, *Pimephales promelas* (Cook 2008, cited in Hull 2008), plus acute-to-chronic ratios, were used to calculate a Tier II final chronic value (FCV) of 21,000 µg/L as a chronic benchmark for strontium. According to Chowdhury and Blust (2012), that chronic threshold was also adopted by Ohio (Ohio EPA 2009) and Quebec.

The Indiana Department of Environmental Management (IDEM 2001) calculated Tier II acute and chronic values for strontium using acute data from two studies with *Daphnia magna* and *Tubifex tubifex* (Khangarot 1991; Khangarot and Ray 1989). It appears that the genus mean acute value (GMAV) for *Daphnia magna* was calculated incorrectly because it used 24-hour (h) and 48-h LC50s from the same test. Calculation of the acute and chronic values involved use of application factors and a default acute-to-chronic ratio because of the lack of data, resulting in a Tier II acute value of 4,800 µg/L and chronic value of 530 µg/L.

[1] The LC*p* is the concentration of test material estimated to be lethal to a specific percentage ("*p*") of the test organisms. The LC50, or median lethal concentration, is the concentration estimated to be lethal to 50% of the test organisms.

3 ENVIRONMENTAL CONCENTRATIONS OF STRONTIUM IN SNAP LAKE

Information on strontium concentrations measured in treated Mine effluent and in water, sediment, and fish tissue samples collected from Snap Lake and associated reference lakes, is briefly summarized below. These data have previously been provided to the MVLWB as part of the EAR, and/or in AEMP and SNP monitoring reports. Data from approximately October 2012 were the most recent data available[2] for inclusion herein. Total and dissolved concentrations of strontium were generally similar in water samples, so for simplicity only total strontium concentrations are presented here.

3.1 Treated Mine Effluent

Concentrations of total strontium measured in treated mine water at Stations SNP02-17 and SNP02-17B between 2004 and 2012 are shown in Figure 1. Strontium concentrations fluctuated between 734 and 2,560 µg/L in 2004 and 2005, increased to a maximum of 4,320 µg/L in June 2006, then decreased gradually such that the flow-weighted average concentration for 2012 was 1,563 µg/L. Although measured concentrations have decreased in recent years as less areas of kimberlite are open relative to the amount of inflow and are on a downward trend, modelling completed in 2013 (De Beers 2013b) indicated that maximum total strontium concentrations in the treated effluent discharge were predicted to range between 2,400 and 3,800 µg/L under Lower Bound Scenarios and between 2,900 and 4,700 µg/L under Upper Bound Scenarios.

3.2 Lake Water

Concentrations of total strontium measured in Snap Lake water between 2004 and 2012 are shown in Figure 2 for the five different areas of the lake: diffuser; near-field; mid-field; far-field; and, northwest arm. Concentrations measured in the Northeast Lake and Lake 13 reference lakes are also included.

Baseline water quality of Snap Lake was characterized through analyses of water samples collected between 1998 and 2001; results from these analyses were reported in the EAR (De Beers 2002). The baseline lake-wide mean concentration of total strontium in Snap Lake was 5.7 µg/L, and the range was 7.3 to 13.3 µg/L. Similarly, baseline concentrations of total strontium measured in two reference lakes in 1999 ranged from 7.0 to 11.6 µg/L (De Beers 2002). Additional sampling was conducted in five candidate reference lakes in 2005, where total strontium concentrations ranged from 5.1 to 9.9 µg/L (Golder 2005).

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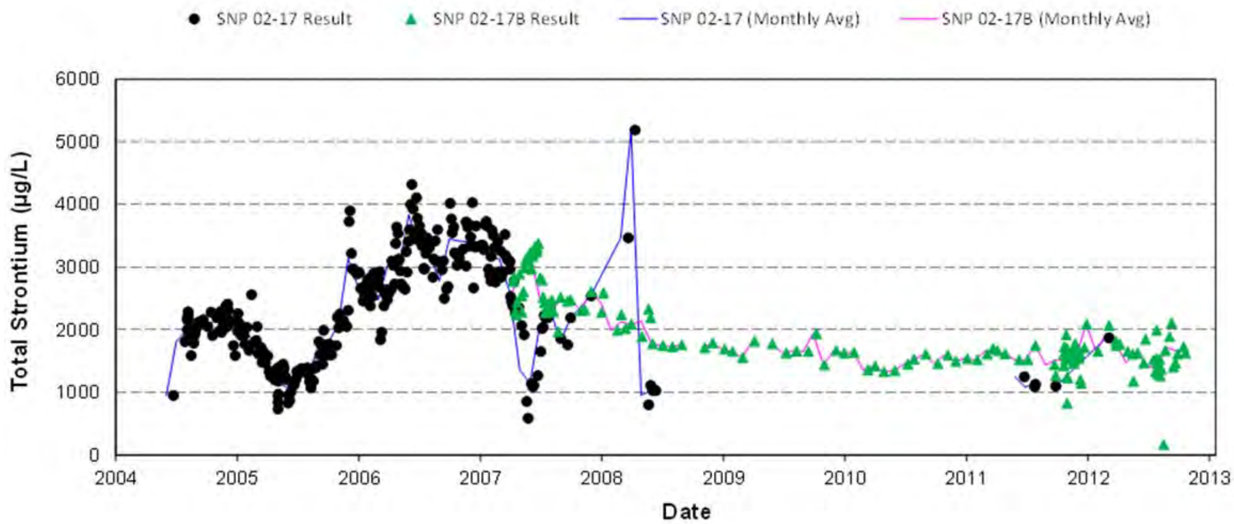
[2] Data collected in 2013 are undergoing analysis and interpretation as part of preparation of the 2013 AEMP report and were therefore not available for inclusion.

Figure 1 Concentrations of Total Strontium Measured in Treated Mine Effluent from Snap Lake Mine, June 2004 to October 2012

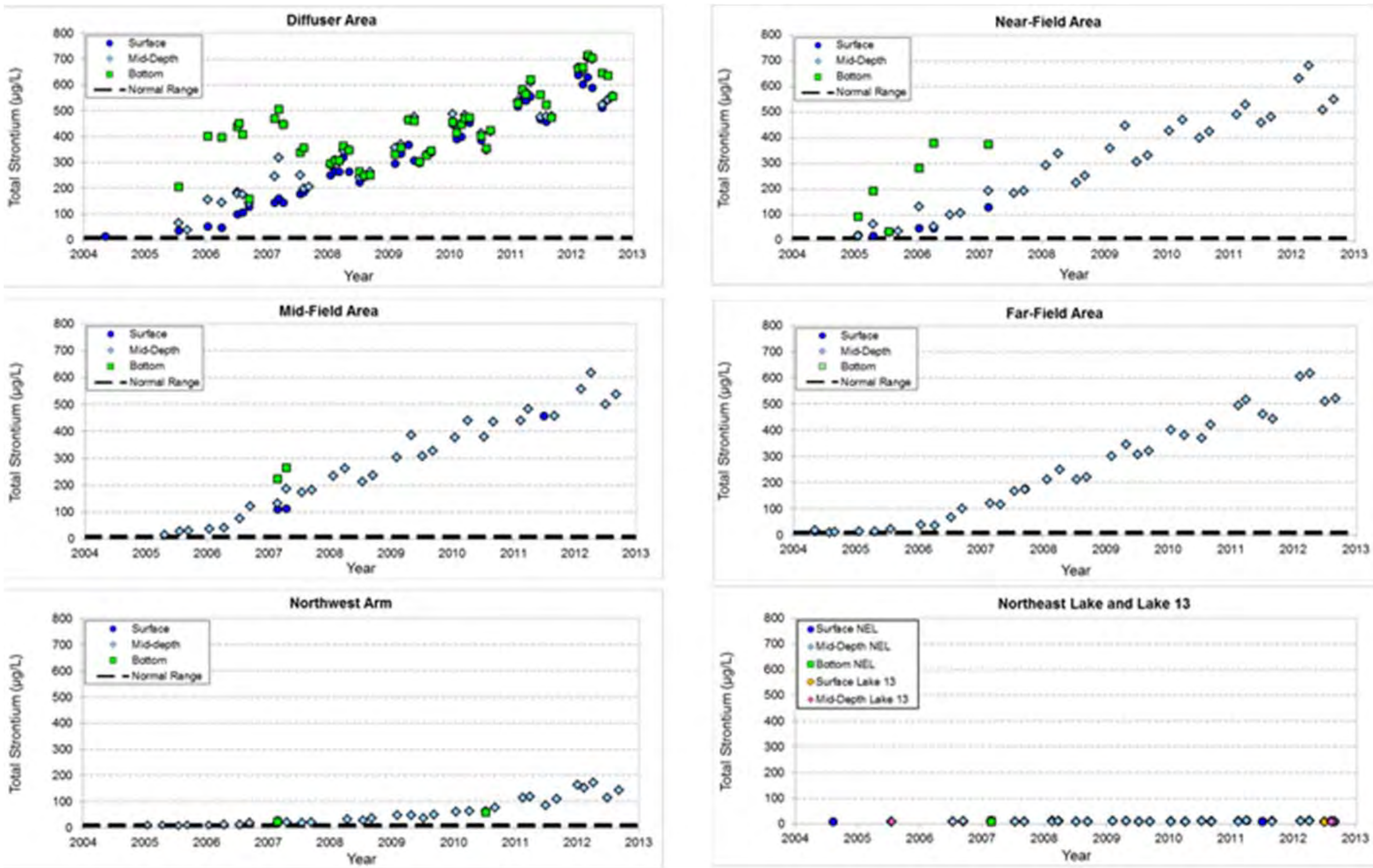


Monthly Avg = monthly average; SNP 02-17 = treated effluent from the temporary water treatment plant; SNP 02-17B = treated effluent from the permanent water treatment plant; SNP = Surveillance Network Program; µg/L = micrograms per litre.

Figure 2 shows that total strontium concentrations have increased steadily in Snap Lake since 2005, such that in 2012 they peaked at 716 µg/L in the diffuser area, and were approximately 500 to 700 µg/L in the near-field, mid-field, and far-field areas. Modelling completed in 2013 (De Beers 2013c) indicated that total strontium concentrations in Snap Lake were predicted to range from an average of 2,000 to 3,000 µg/L under Lower Bound Scenarios and from an average of 2,500 to 4,000 µg/L under Upper Bound Scenarios (Figure 3). In contrast, total strontium concentrations in the reference lakes in 2012 ranged from 10 to 13 µg/L in Northeast Lake, and from 9 to 10 µg/L in Lake 13, consistent with pre-mining conditions.

Background strontium water concentrations in the area around Snap Lake are typically less than (<) 15 µg/L. In contrast, the World Health Organization (WHO 2010) reported that natural strontium concentrations ranged from 1 to 13,600 µg/L in European rivers (median concentration of 110 µg/L), and from 400 to 1,500 µg/L in surface waters in the United States.

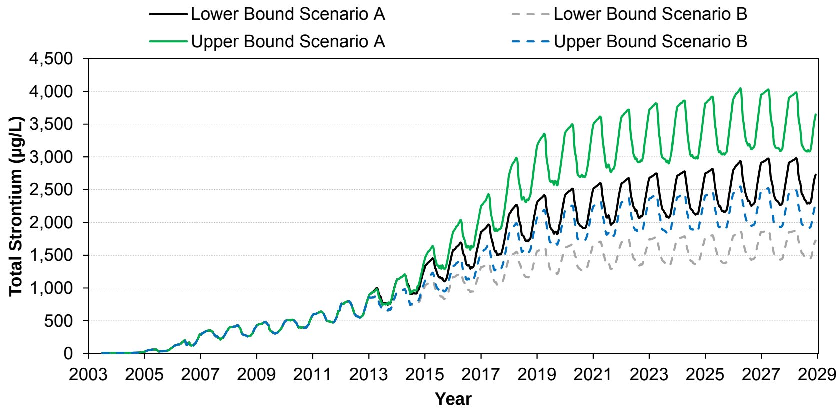
Figure 2 **Concentrations of Total Strontium in Water at Stations Located in Five Areas of Snap Lake, and in the Northeast Lake Reference Lake, from 2004 to 2012**



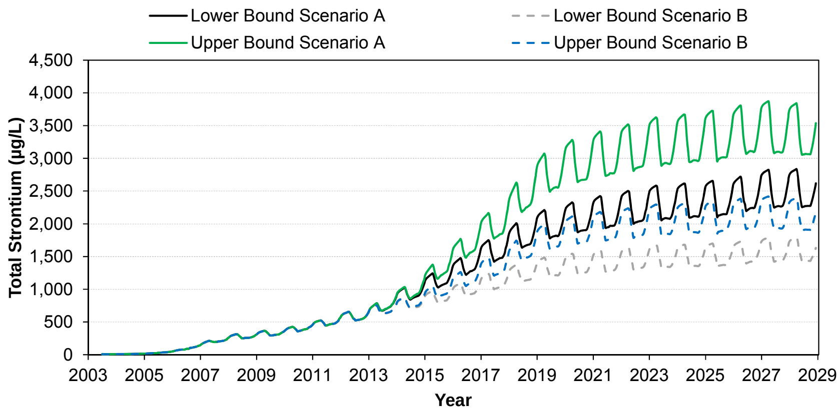
Note: µg/L = micrograms per litre; normal range is based on data collected prior to 2004, with the upper and lower range calculated as the mean ± 2 standard deviations.

Figure 3 Predicted Total Strontium Concentrations in Snap Lake, 2004 to 2029

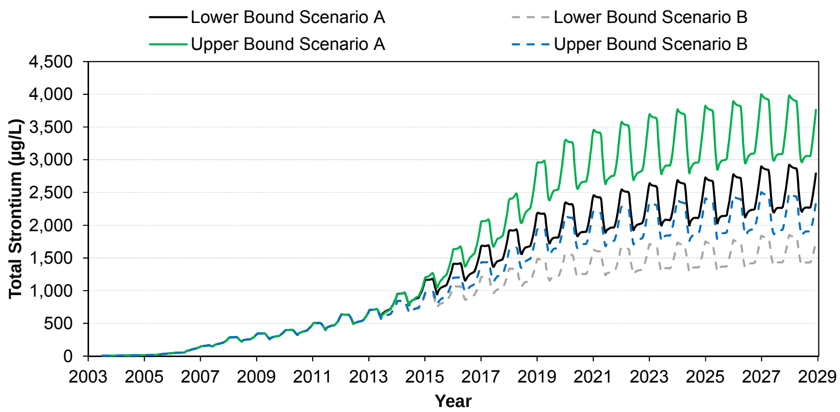
a. Diffuser Area



b. Main Basin



c. Outlet



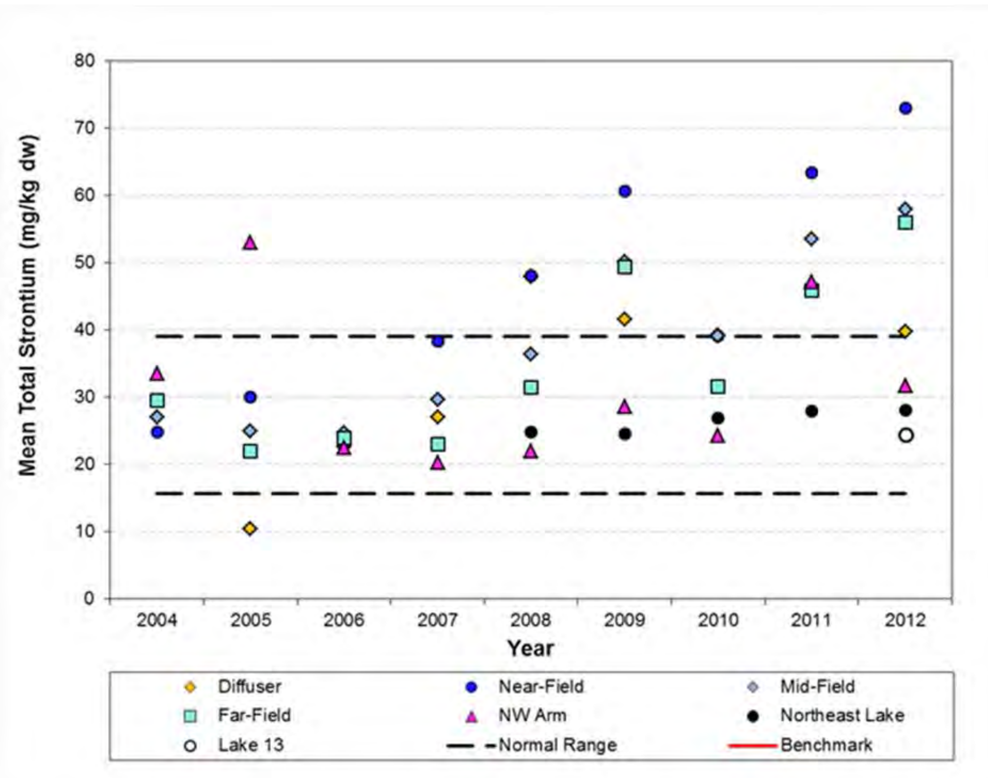
Note: µg/L = micrograms per litre. Data shown are from representative stations within Snap Lake: Diffuser Area = SNAP13 (2004 to April 2006) and SNP 02-20e (July 2006 to 2012); Main Basin = SNAP09; Outlet = SNAP08.

3.3 Sediment

Mean concentrations of strontium measured annually in sediments from five areas of Snap Lake between 2004 and 2012 are shown in Figure 4. For comparison purposes, mean concentrations measured in sediments from the Northeast Lake reference lake from 2008 to 2012, and from Lake 13 in 2012, are also included. Sediment concentrations are reported as dry weight (dw).

The baseline lake-wide mean strontium concentration in Snap Lake sediments sampled in 1999 and 2004 was 27.2 mg/kg (dw), and individual stations ranged from 21.0 to 42.0 mg/kg (dw) (De Beers 2012). Since 2006, mean sediment concentrations have increased in the diffuser, near-field, mid-field, and far-field areas. Mean concentrations in northwest arm sediments were initially higher than other areas of Snap Lake in 2004 and 2005, then decreased in 2006 and had only modest increases through 2012 apart from a peak in 2011. In 2012, the lake-wide mean strontium concentration in Snap Lake sediments was 58.2 mg/kg (dw), and individual stations ranged from 24.2 to 84.4 mg/kg (dw). In contrast, strontium concentrations in Northeast Lake sediments showed little change from 2008 to 2012 and have remained similar to baseline Snap Lake sediment concentrations with a mean of 28.0 mg/kg (dw) and a range of 27.4 to 33.3 mg/kg (dw) in 2012.

Figure 4 Mean Concentrations of Strontium in Sediments Annually at Stations Located in Five Areas of Snap Lake from 2004 to 2012, in Northeast Lake from 2008 to 2011, and in Lake 13 in 2012



Note: mg/kg (dw) = milligrams per kilogram dry weight; normal range is based on baseline data collected in 2004, with the upper and lower range calculated as the mean ± 2 standard deviations.

3.4 Fish Tissue

Mean concentrations of strontium measured in muscle tissue from Lake Trout (*Salvelinus namaycush*) and Round Whitefish (*Prosopium cylindraceum*) captured from Snap Lake and two reference lakes in large-bodied fish surveys conducted in 1999, 2004, and 2009 are shown in Figure 5. Mean concentrations were determined from samples of four to eight male or female fish from each sampling event.

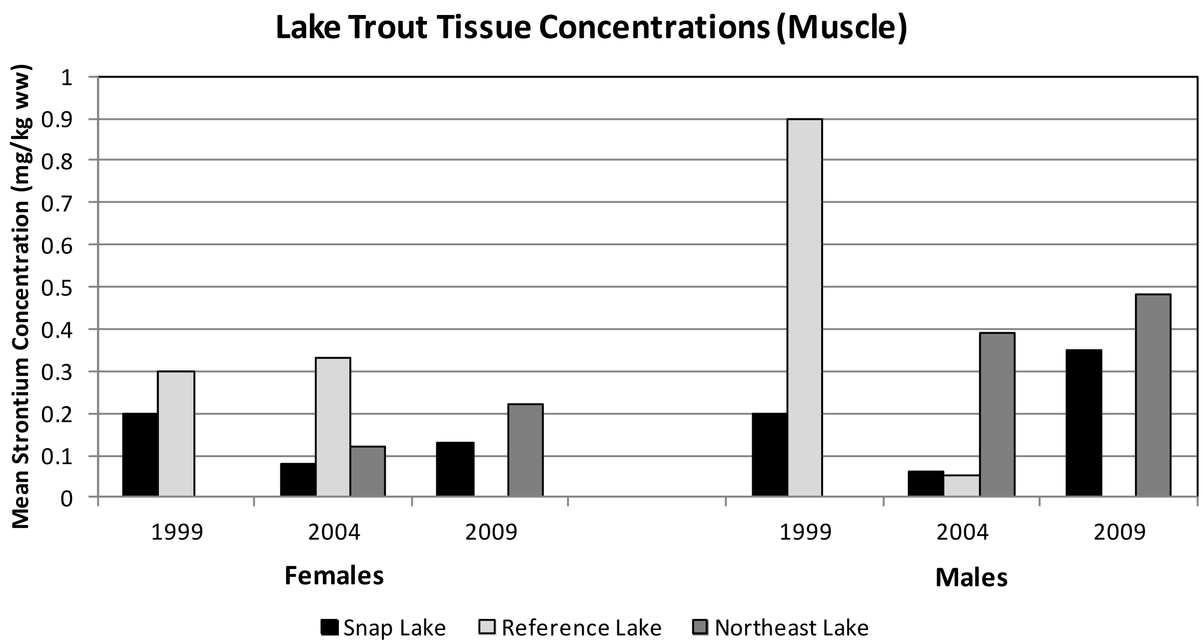
Lake Trout were sampled from Snap Lake in each of the three years, from Reference Lake in 1999 and 2004, and from Northeast Lake in 2004 and 2009. Strontium concentrations in Snap Lake fish were lower in 2004 than in 1999 and then increased in 2009, but were not as high as strontium concentrations in fish from the reference lakes.

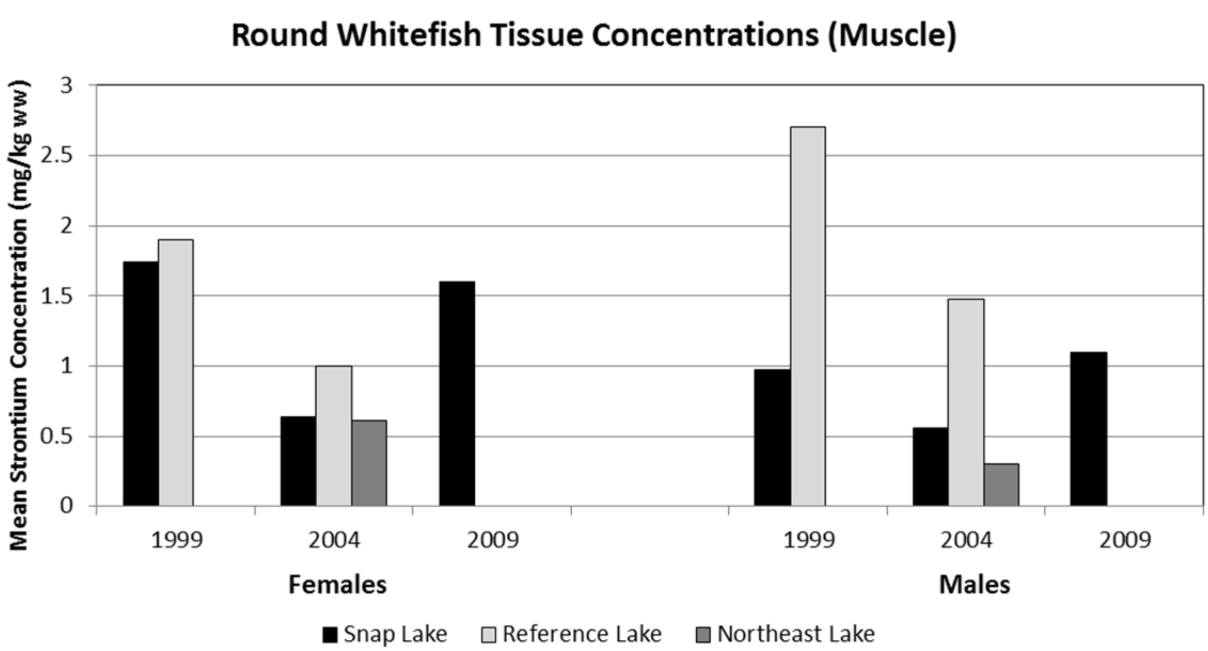
Round Whitefish were sampled from Snap Lake in 1999, 2004, and 2009, from Reference Lake in 1999 and 2004, and from Northeast Lake in 2004. Strontium concentrations in Snap Lake fish were similar in 1999 and 2009, but lower in 2004; no Northeast Lake fish data were available from 2009 for comparison, but the concentrations measured in 1999 and 2004 Reference Lake fish were higher than fish from Snap Lake in both those years.

Mean concentrations of strontium were measured in carcasses[3] of Lake Chub (*Couesius plumbeus*) captured from Snap Lake and two reference lakes in a small-bodied fish survey conducted in 2012; this was the first year that tissue concentrations were monitored in Lake Chub. Mean tissue strontium concentrations were 49.6 mg/kg ww (wet weight) for fish from Snap Lake, as compared to mean concentrations of 39.6 and 33.3 mg/kg ww for Northeast Lake and Lake 13, respectively. The mean concentration for Snap Lake fish was within the normal range calculated based on reference lake concentrations.

[3] Carcasses consisted of flesh and bone, but not viscera, liver, or gonad tissues.

Figure 5 **Mean Concentrations of Strontium in Muscle Tissue of Lake Trout (top panel) and Round Whitefish (bottom panel) in Snap Lake and Two Reference Lakes in 1999, 2004, and 2009**





Note: mg/kg ww = milligrams per kilogram wet weight

4 LITERATURE REVIEW ON TOXICITY OF STRONTIUM TO FRESHWATER AQUATIC LIFE

Available acute and chronic toxicity data for freshwater fish, invertebrates, algae, and amphibians are tabulated in Appendix A. The LC50s from acute toxicity tests with strontium ranged from a 48-h LC50 of 75,000 µg/L for the water flea *Daphnia hyalina* (Baudouin and Scoppa 1974) to a 24-h LC50 of 15,000,000 µg/L for the nematode *Caenorhabditis elegans* (Tatara et al. 1998). Fish and invertebrates exhibited similar acute toxicity to strontium. Because the objective of this review was to develop a CEB for strontium, only the chronic toxicity studies are summarized below. Test endpoints are expressed in terms of the concentration of strontium, not the metal salt. No studies on the toxicity of strontium in sediments were identified.

4.1 Fish

Pacholski (2009) conducted a 21-d test with juvenile Rainbow Trout; additional details of the test procedures and endpoint calculations were provided in HydroQual (2009, 2013)[4]. Test fish were approximately 0.3 to 0.5 g ww at test initiation, and the exposure system was static-renewal with weekly replacement of test solutions. Control survival after 21 d was 90 percent (%), and the results were corrected for control responses. Survival was the only endpoint measured, and the endpoints reported were an LC10 of 67,000 µg/L, an LC20 of 110,000 µg/L, and an LC50 of 286,000 µg/L. The LC10 of 67,000 µg/L was considered to be an acceptable low-effect concentration and was therefore used for the CEB determination (see Section 6.0).

Birge (1978) conducted a 28-d test with Rainbow Trout, from fertilization through to four days post-hatch; results of this study were also reported in Birge et al. (1979). The exposure system was static-renewal, with replacement of test solutions every 12 hours. Control performance was not reported, but the results were corrected for control responses. Survival was the only endpoint measured; an LC01 of 6.0 µg/L and an LC50 of 200 µg/L were reported. The LC01 was considered to be too conservative an estimate of a no-effect concentration for the CEB, as the Canadian Council of Ministers of the Environment (CCME 2007) methodology allows for up to a 10% effect for that estimate, and was also problematic because it was within the range of baseline and/or background strontium concentrations associated with Snap Lake and nearby reference lakes. Conversely, the LC50 was considered to be insensitive and therefore unsuitable for the CEB; CCME (2007) notes that if lethal endpoints are used as low-effect concentrations for the CEB, their effect level should be between 11 and 25%. A maximum acceptable toxicant concentration (MATC) of 35 µg/L was calculated as the geometric mean of the LC01 and LC50 concentrations. This MATC was still only three times higher than baseline/background Snap Lake concentrations, and was lower than background concentrations reported for European and US streams.

[4] HydroQual (2009) conducted toxicity tests with freshwater algae, invertebrates, and fish in support of Pacholski (2009), but only reported point estimates based on 25% and 50% effect levels for each test. For the purpose of developing the strontium CEB proposed in this report, HydroQual was subsequently requested to provide point estimates based on the 10% and 20% effect levels for each those tests (HydroQual 2013).

Results from this study were also over 1,000 times more sensitive than reported by Pacholski (2009) for juveniles of the same species.

Birge et al. (1980) reported results for a 28-d test with Rainbow Trout, conducted from fertilization through to four days post-hatch; results of this study were also reported in Birge et al. (1981). The exposure system was static-renewal, with replacement of test solutions every 12 hours. Control survival was 83 to 96%, which was acceptable for this type of test, and the results were corrected for control responses. Survival was the only endpoint measured, and the endpoints reported were an LC01 of 13 µg/L, an LC10 of 49 µg/L, and an LC50 of 250 µg/L. Results from this study were consistent with those reported by Birge (1978), but were also close to baseline/background concentrations associated with Snap Lake and lower than background concentrations reported for European and US streams.

Birge et al. (1980) noted that their point estimates were calculated by a different method than used in previous studies. Given the similarity in results reported by Birge (1978) and Birge et al. (1980) for the 28-d Rainbow Trout test, and the lack of details about test methodologies, there is uncertainty as to whether these represent results from two separate tests or results from a single test calculated by different methods. To provide a conservative approach to developing the strontium CEB, it has been assumed that they represent two separate tests. Because the results from the Birge (1978) and Birge et al. (1980) Rainbow Trout tests indicated a much greater sensitivity to strontium than reflected in other toxicity test results, additional Rainbow Trout early life stage (ELS) tests were conducted to determine whether these results could be relied upon, in other words, whether their findings could be reproduced (see Section 5.0).

Birge (1978) conducted a 7-d test with Goldfish, *Carassius auratus*, from fertilization through to four days post-hatch; results of this study were also reported in Birge et al. (1979). The exposure system was static-renewal, with replacement of test solutions every 12 hours. Control performance was not reported, but the results were corrected for control responses. Survival was the only endpoint measured; an LC01 of 45.3 µg/L and an LC50 of 8,580 µg/L were reported. For reasons previously described, an MATC of 623 µg/L was calculated as the geometric mean of the LC01 and LC50. Although the MATC from this study was well above the baseline/background strontium concentrations associated with Snap Lake, it was within the range of background concentrations reported for European and US streams. Also, Goldfish are not native to North America and are not found in Snap Lake.

Pacholski (2009) conducted a standard 7-d survival and growth test with larval (<24-h old) Fathead Minnow; additional testing details and endpoint calculations were provided in HydroQual (2009, 2013). Control performance was acceptable, and the results were corrected for the control responses. For survival, the endpoints reported were an LC10 of 255,000 µg/L, an LC20 of 276,000 µg/L, and an LC50 of 354,000 µg/L. For growth (expressed as increased dw), the endpoints were reported as an IC10[5] of 263,000 µg/L and an IC20 of 304,000 µg/L. The IC10 of 263,000 µg/L was used for the CEB determination.

[5] The IC*p* is the inhibiting concentration for a specified percentage ("*p*") effect on a continuous endpoint such as growth or reproduction. For example, the IC10 is the concentration of test material estimated to cause a 10% reduction in growth or reproduction of the test species.

Hull (2008) provided a collection of worksheets showing calculations used to develop acute and chronic values for strontium for the Michigan Department of Environmental Quality, including tabulated toxicity data from a number of unpublished reports. Hull (2008) used survival data from a 7-d Fathead Minnow test conducted by Cook (2008), but only reported the no observed effect concentration[6] (NOEC; 92,870 µg/L) and lowest observed effect concentration (LOEC; 188,750 µg/L) that were used to calculate an MATC of 132,390 µg/L. We were able to obtain copies of summary tables and bench sheets (Cook 2013) in order to confirm testing details and calculate point estimates that would be more suitable for use in the CEB determination. The Cook (2008) Fathead Minnow test was a standard 7-d larval survival and growth test; control performance was acceptable and the results were corrected for control responses. For survival, the LC20 and LC50 were greater than (>) 92,870 µg/L. For growth (expressed as increased dry weight), the IC10 was <13,440 µg/L and the IC20 was 17,420 µg/L. Because the IC10 for growth was lower than the lowest test concentration, and therefore could not be estimated accurately, the IC20 of 17,420 µg/L was included in the CEB determination. Survival and growth results from the Cook (2008) 7-d Fathead Minnow test were more sensitive than the Pacholski (2009) 7-d Fathead Minnow results. However, survival results from Cook (2008) were similar to the Pacholski (2009) results for juvenile Rainbow Trout, and also consistent with results from three acute 96-h LC50s for Fathead Minnow that ranged from 140,180 to 228,470 µg/L (Hull 2008).

Jones (1939) conducted toxicity tests with Stickleback (*Gasterosteus aculeatus*), to determine a survival curve for strontium. The test duration was 10 d, and test solutions were renewed daily. The lethal time to 50% mortality (LT50) for strontium was 1,200,000 µg/L for this 10-d exposure; this result was included in the CEB determination.

Schroder et al. (1995) reported that a 24-h immersion in a strontium chloride solution is used for marking Chum Salmon (*Oncorhynchus keta*) and Sockeye Salmon (*O. nerka*) fry prior to their release in the wild. The strontium is deposited in calcified tissues and can easily be detected in otoliths when the fish are older. For that study, Chum Salmon fry were exposed to three strontium concentrations (120,000, or 1,200,000, or 9,000,000 µg/L) for 24 h, reared for 34 d on a standard hatchery diet, then sacrificed for analyses. Control mortality was 1%; mortality in the 1,200,000 µg/L treatment was 2%, and mortality in the 9,000,000 µg/L treatment was 7%. The geometric mean of these two results was used for the CEB determination. In a second experiment, Sockeye Salmon were immersed in a 5,000,000 µg/L strontium solution for 24 h and then reared for 21 months on a standard hatchery diet to determine how long the marked fish could be distinguished from unmarked fish. Although mortality data were not provided for the second experiment, it was presumed that survival was sufficiently high during the 21-month rearing period to provide meaningful test results. However, this information was not used in the CEB determination.

4.2 Invertebrates

Biesinger and Christensen (1972) conducted 21-d tests with the water flea, *Daphnia magna*, to determine effects of strontium exposure on survival and reproduction. They reported a 21-d LC50 of 86,000 µg/L for

[6] The NOEC is the highest test concentration where there is no statistically significant difference in mean response relative to the control. The LOEC is the lowest test concentration where there is a statistically significant difference in mean response relative to the control.

survival and a 21-d median effective concentration (EC50)[7] of 60,000 µg/L for reproduction. In addition, an EC16 of 42,000 µg/L was calculated for reproduction, to represent the lowest effect size that could be distinguished from variability associated with the control responses. This EC16 was used for the CEB determination.

Pacholski (2009) conducted a 21-d survival and reproduction test with *Daphnia magna*, and reported an LC50 of 122,000 µg/L for survival; the IC (inhibitory concentration)10 was 23,000 µg/L and the IC20 was 35,000 µg/L for reproduction. Control performance was acceptable, and results were corrected for control responses. Additional details regarding testing and endpoint calculations were provided in HydroQual (2009, 2013). The IC10 and IC20 for reproduction were lower than the EC16 from the Biesinger and Christensen (1972) study; the IC10 was included for the CEB determination.

Cook (2008; cited in Hull 2008) conducted a 6-d survival and reproduction test with the water flea, *Ceriodaphnia dubia*. Hull (2008) only reported the NOEC and LOEC for reproduction as 24,570 and 45,890 µg/L, respectively, and used those values to calculate an MATC of 33,578 µg/L. Point estimates more suitable for use in the strontium CEB determination were determined using data provided by Cook (2013). The LC50 for survival was 92,870 µg/L, and the IC10 and IC20 for reproduction were 22,920 µg/L and an IC20 of 33,610 µg/L, respectively. The IC10 for reproduction was included for the CEB determination.

Pacholski (2009) conducted a 6-d survival and reproduction test with *Ceriodaphnia dubia*, and reported an LC50 of 206,000 µg/L for survival, and an IC10 of 2,866 µg/L and an IC20 of 11,160 µg/L for reproduction. Additional details regarding testing and endpoint calculations were provided in HydroQual (2009, 2013). Control performance was acceptable, and results were corrected for control responses. Mean reproduction fluctuated among the lower test concentrations, and therefore the IC20 of 11,160 µg/L was considered to be a more representative endpoint for use in the CEB determination.

Borgmann et al. (2005) conducted 7-d tests with the amphipod, *Hyalella azteca*, to determine the effects of strontium on survival. The primary objective of this study was to assess the toxicity of 63 elements in waters at two different hardness concentrations, and therefore a number of elements were only tested at a few concentrations, starting at 1,000 µg/L and then testing at higher or lower concentrations depending on the initial result. This was the case for strontium, which was not tested at a full dilution series that would have allowed for determination of LC20 or LC50 values. In soft water, the 7-d LC50 was >1,000 µg/L; there was 18% mortality at 315 µg/L but only 12% mortality at 1,000 µg/L. In higher-hardness water, the 7-d LC50 was >3,150 µg/L, and there was only 7% mortality at 1,000 µg/L. The authors reported that control survival was at least 80%, which is reasonable for this test method. However, the results were not corrected for the control responses and, given that the survival results that were reported for strontium were all at least 80% it is possible that, with correction for the control responses, these effect sizes would have been smaller or even non-existent. This is supported by the fact that Hull (2008) reported a 48-h LC50 of 198,011 µg/L from an acute *Hyalella azteca* test, a concentration almost 200 times higher than that reported by Borgmann et al. (2005). In order to address the uncertainty regarding these results, additional toxicity testing was conducted with *Hyalella azteca* (see Section 5.0).

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[7] The EC*p* is the concentration of test material estimated to cause an adverse effect other than lethality to a specific percentage ("*p*") of the test organisms. The EC50, or median effective concentration, is the concentration estimated to cause an effect to 50% of the test organisms.

Boutet and Chaisemartin (1973) reported a 30-d LC50 of 390,000 µg/L for white clawed crayfish, *Austropolmobius pallipes pallipes*, and a 30-d LC50 of 860,000 µg/L for spinycheek crayfish, *Orconectes limonus*. Both these results were included for the CEB determination.

Suzuki (1959) conducted 10-d tests with mosquito larvae, *Culex pipiens paliens*, to determine the time required to reach 50% effect levels using different concentrations of strontium. The EC50 for emergence occurred at approximately 6.9 days and was 553,000 µg/L. The EC50 for pupation occurred at approximately 4.1 days and was 5,530 µg/L, but the time required to reach this endpoint was inconsistent for the range of test concentrations. The EC50 of 553,000 µg/L for emergence was considered to be more representative and was therefore included for the CEB determination.

Jones (1940) conducted 48-h tests with the planarian, *Polycelis nigra*, and reported LT50s of 3,500,000 and 6,000,000 µg/L for two different strontium salts. The author considered this endpoint to be the threshold of toxicity because with only a slight dilution survival was extended considerably. Both of these results were included for the CEB determination.

4.3 Algae / Plants

Pacholski (2009) conducted a standard 72-h algal growth test with the alga *Pseudokirchneriella subcapitata*; additional testing details and endpoint calculations were provided in Hydro Qual (2009, 2013). Control performance was acceptable, and the results were corrected for the control responses. The 72-h IC10 was 36,000 µg/L and the IC20 was 47,000 µg/L; the IC10 was used for the CEB determination. The algae demonstrated a hormetic response, with growth stimulation occurring at strontium concentrations up to 23,000 µg/L, but inhibition of growth at higher concentrations.

4.4 Amphibians

Birge (1978) conducted a 7-d test with the narrow-mouthed toad, *Gastrophryne carolinensis*, from fertilization through to four days post-hatch; results of this study were also reported in Birge et al. (1979). The exposure system was static-renewal, with replacement of test solutions every 12 hours. Control performance was not reported, but the results were corrected for control responses. Survival was the only endpoint measured; an LC01 of 2.4 µg/L and an LC50 of 160 µg/L were reported. The LC01 was considered to be too conservative for use as a no-effect concentration, and the LC50 was not conservative enough as a low-effect concentration. An MATC of 20 µg/L was calculated as the geometric mean of the LC01 and LC50; this MATC was only two times higher than baseline/background strontium concentrations associated with Snap Lake. Apart from one possible sighting of an unknown frog species near Snap Lake in 2005, there has been no evidence that amphibians are present in Snap Lake, which is located north of the treeline. This study was excluded from the CEB determination, based on the absence of amphibians in Snap Lake and the fact that the test endpoints were close to baseline/background strontium concentrations associated with Snap Lake and lower than background concentrations associated with European and US streams.

5 RESULTS OF NEW TOXICITY STUDIES

Results of the chronic toxicity studies summarized in Section 4.0 showed that there were two sets of studies contributing uncertainty to the strontium CEB determination. The 28-d Rainbow Trout test results reported by Birge (1978) and Birge et al. (1980) were orders of magnitude lower than other test results performed with a range of aquatic species, so additional Rainbow Trout ELS tests were conducted to determine whether those test results were reproducible. The 7-d *Hyalella azteca* tests conducted by Borgmann et al. (2005) did not include high enough strontium concentrations to calculate point estimates, and therefore additional testing with *Hyalella azteca* was performed to determine sensitivity to higher strontium concentrations. Results from these additional toxicity tests were added to the chronic toxicity data set (Appendix A) used for the strontium CEB determination.

5.1 Rainbow Trout Early Life Stage Toxicity Tests

Nautilus (2013) conducted two Rainbow Trout ELS tests to repeat the tests reported in Birge (1978) and Birge et al. (1980), in order to establish whether those results were repeatable, and to determine the relative sensitivity of Rainbow Trout to strontium. The tests were conducted under two water quality regimes: one with water hardness similar to that used by Birge and colleagues (approximately 100 milligrams per liter [mg/L] as calcium carbonate [$CaCO_3$]); and, a second test in water with a lower hardness (approximately 12 mg/L as $CaCO_3$). Testing was conducted under these two hardness regimes because it was anticipated that sensitivity to strontium may change in response to calcium concentrations in the water. The proximity of calcium and strontium to each other on the periodic table suggests that they may share similar properties that could result in interactions by competitive exclusion at uptake sites on the fish gill.

Test conditions are summarized in Table 1, and additional details are provided in the Nautilus laboratory report (Appendix B). Test methods were intended to match those used by Birge (1978), with the following exceptions:

- Test solutions were renewed every 24 h, rather than every 12 h;
- The number of eggs exposed per concentration was 120, rather than 150;
- The test temperature was 14 ± 1 degrees Celsius (°C), rather than 13 ± 0.5°C; and,
- The test ended seven days after 50% of the control fish had hatched (32-d exposure overall), rather than four days following hatch (28-d exposure overall).

Table 1 Summary of Test Conditions for Nautilus (2013) Rainbow Trout Early Life Stage Toxicity Tests

Parameter	Test Condition
Test organism	Rainbow Trout (*Oncorhynchus mykiss*)
Test organism source	Fraser Valley Trout Hatchery, BC, Canada
Test organism age	Fertilized eggs
Test type	Static-renewal (daily)
Test duration	32 d
Test vessel	2-L plastic jars
Test volume	2 L
Test replicates	4 replicates per treatment
No. of organisms	30 per replicate
Dilution water	Low hardness test: dechlorinated municipal water (11 to 12 mg/L as $CaCO_3$) High hardness test: moderately hard reconstituted water (98 to 100 mg/L as $CaCO_3$)
Test temperature	14 ± 1°C
Feeding	None
Photoperiod	24 hours dark
Aeration	Gentle aeration throughout test
Test protocol	Environment Canada (1998)
Test endpoints	Survival and normal development
Test acceptability criterion for controls	65% normal surviving fry
Reference toxicant	Sodium dodecyl sulphate (7 d embryo exposure)

d= days; L= litres; mg/L= milligrams per litre; $CaCO_3$= calcium carbonate; °C= degrees Celsius; %= percent

These procedural differences were implemented to provide consistency with the standard Environment Canada (1998) test protocol. They were considered minor and not be anticipated to result in any difference in sensitivity between the tests. If anything, the use of a slightly higher test temperature and longer test duration would have been expected to result in lower (more sensitive) test endpoints than those reported by Birge and colleagues but this was not the case.

Results of the toxicity tests performed at two different water hardness concentrations are summarized in Table 2 (very soft water) and Table 3 (moderately hard water). Control performance was acceptable for both tests, and results were corrected for mean control responses. The endpoints measured were survival to hatching, and normal development of surviving fry. There was very little difference between these two endpoints, as almost all of the surviving fish developed normally. Because of small differences in the concentration-response patterns for each test endpoint, the point estimates for survival were slightly lower than those for normal development and were therefore given priority for the CEB determination.

Rainbow Trout were more sensitive to strontium in very soft water, when exposed at the embryo-larval stage. In the test with very soft water, the survival endpoints were an LC10 of 75,200 µg/L, an LC20 of 98,500 µg/L, and an LC50 of >157,500 µg/L. In contrast, the corresponding survival endpoints for the test performed with moderately hard water were all >151,100 µg/L. These point estimates were more than

1,000 times higher than those reported by Birge (1978) and Birge et al. (1980), but were similar to the results reported by Pacholski (2009) for a 21-d test with Rainbow Trout fry. The LC10 of 75,200 µg/L in very soft water was used for the CEB determination; this was a conservative approach because Snap Lake water has a higher hardness.

Table 2 Results of the Nautilus (2013) Rainbow Trout Early Life Stage Test Using Strontium in Very Soft Water

Strontium Concentration (µg/L)		Survival to Hatch (%)	Normally Developed Surviving Fry (%)
Nominal	**Measured**	**Mean ± SD**	**Mean ± SD**
Control	16	72.2 ± 12.5	70.6 ± 12.7
5,000	4,700	71.3 ± 12.0	68.7 ± 15.0
10,000	10,300	74.8 ± 9.7	67.2 ± 7.2
20,000	20,800	74.2 ± 5.5	71.6 ± 6.5
40,000	42,400	76.7 ± 10.5	75.0 ± 11.4
80,000	79,900	63.8 ± 6.3	61.4 ± 3.6
160,000	157,500	39.8 ± 2.4	38.9 ± 2.3
Point Estimates (µg/L measured Sr)	EC50	>157,500	>157,500
	EC20	98,500	101,400
	EC10	75,200	77,800

µg/L= milligrams per litre; %= percent; EC= effective concentration; > = greater than; SD = standard deviation

Table 3 Results of Nautilus (2013) Rainbow Trout Early Life Stage Test Using Strontium in Moderately Hard Water

Strontium Concentration (µg/L)		Survival to Hatch (%)	Normally Developed Surviving Fry (%)
Nominal	**Measured**	**Mean ± SD**	**Mean ± SD**
Control	163	83.9 ± 11.3	81.3 ± 13.3
5,000	4,000	67.4 ± 6.6	63.2 ± 7.0
10,000	10,700	79.4 ± 4.7	74.5 ± 6.2
20,000	20,100	78.6 ± 7.2	72.5 ± 8.3
40,000	39,500	76.6 ± 3.6	76.6 ± 3.6
80,000	78,400	76.5 ± 7.2	72.0 ± 8.3
160,000	151,100	79.0 ± 4.6	72.8 ± 4.9
Point Estimates (µg/L measured Sr)	EC50	>151,100	>151,100
	EC20	>151,100	>151,100
	EC10	>151,100	>151,100

µg/L= milligrams per litre; %= percent; EC= effective concentration; > = greater than; SD = standard deviation

5.2 *Hyalella azteca* Survival and Growth Test

Nautilus (2012) conducted a toxicity test with the amphipod, *Hyalella azteca*, to obtain more clearly defined point estimates than those reported by Borgmann et al. (2005). Whereas Borgmann et al. (2005)

conducted 7-d tests with survival as the only test endpoint, this additional testing was conducted using a 14-d test duration in order to measure effects on both survival and growth (Environment Canada 1997). The amphipods were exposed to strontium-spiked test solutions in test containers with a clean sediment substrate. Test conditions are summarized in Table 4, and additional details are provided in the Nautilus laboratory report (Appendix C).

Results of the toxicity test are summarized in Table 5. Control performance was acceptable, and results were corrected for mean control responses. The endpoints measured were survival and growth (dry weight). For survival, the LC50 was 176,800 µg/L. For growth, the IC10 was 31,200 µg/L and the IC20 was 43,000 µg/L. These point estimates were at least an order of magnitude higher than those previously reported by Borgmann et al. (2005). The IC10 of 31,200 µg/L was included for the CEB determination.

Table 4 Summary of Test Conditions for the Nautilus (2012) *Hyalella azteca* Toxicity Test with Strontium

Parameter	Test Condition
Test organism	Amphipod (*Hyalella azteca*)
Test organism source	Aquatic BioSystems, Fort Collins, CO, USA
Test organism age	7 - 8 d old
Test type	Static-renewal (three times per week)
Test duration	14 d
Test vessel	375 mL glass jars
Test treatment	100 mL control sediment; 175 mL overlying water
Test replicates	3 replicates per treatment
No. of organisms	10 per replicate
Test temperature	23 ± 1°C
Dilution water	Moderately hard reconstituted water (80 to 100 mg/L as $CaCO_3$), prepared as per Environment Canada (1997)
Feeding	1.5 mL of yeast, cerophyl, trout chow (YCT) per replicate daily
Photoperiod	16 hours light/8 hours dark
Aeration	Gentle aeration throughout test
Test protocol	Environment Canada (1997)
Test endpoints	Survival and biomass
Test acceptability criterion for controls	Mean control survival of ≥80% and ≥0.1 mg/amphipod dw
Reference toxicant	Sodium chloride (NaCl)

d= day; mL= millilitre; °C= degrees Celsius; mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate; ≥ = greater than or equal to; % = percent; mg= milligram; dw= dry weight

Table 5 Results of Nautilus (2012) 14-d *Hyalella azteca* Toxicity Test with Strontium

Strontium Concentration (µg/L)		Survival (%) Mean ± SD	Biomass (mg/ind) Mean ± SD
Nominal	Measured		
Control	56	100 ± 0	0.41 ± 0.03
30,000	30,100	100 ± 0	0.38 ± 0.05
60,000	61,200	100 ± 0	0.25 ± 0.05
120,000	125,000	100 ± 0	0.13 ± 0.01
240,000	242,000	0	Not applicable
480,000	469,000	0	Not applicable
Point Estimates (mg/L measured Sr)	LC50	176,800	Not applicable
	IC50	Not applicable	79,600
	IC20	Not applicable	43,000
	IC10	Not applicable	31,200

d = day; LC= lethal concentration; IC= inhibitory concentration; µg/L= micrograms per litre; %= percent; SD = standard deviation; mg/L= milligrams per litre

6 PROPOSED CHRONIC EFFECTS BENCHMARK FOR STRONTIUM

6.1 Overview of Benchmark Calculation Methodology

Toxicity test endpoints calculated from chronic studies were compiled using a species sensitivity distribution (SSD) approach; no-effect and low-effect endpoints were given preference. When more than one endpoint was available from a particular study, only the most suitable endpoint was used in accordance with the CCME (2007) ranking system. For example, if both an EC10 and EC20 were reported for an endpoint then the EC10 was selected, and if both lethal and sublethal effects were assessed then only the more sensitive sublethal endpoint was selected. If endpoints from multiple studies were available for a particular species, then a species mean chronic value (SMCV) was calculated as the geometric mean of the most suitable endpoint from each study. The geometric mean, as opposed to the arithmetic mean, was used to minimize bias toward high test results. The resulting SMCV was used in the SSD so that there was only one data entry for each available species. SMCVs were then ranked from lowest to highest, and the percent of species affected was calculated using the following equation:

$$\text{Percent Affected} = (X - 0.5) / N$$

where X is the species rank, with 1 being the most sensitive species, and N is the total number of species in the database. The correction factor of 0.5 was used (Hazen plotting position [Aldenberg et al. 2002]) to create symmetry in cumulative probability (*i.e.*, median ranked species will be associated with 50% affected) and to acknowledge that the concentration affecting the highest ranked species is not necessarily associated with adverse effects to the entire aquatic community.

SigmaPlot software was used to fit the SMCV data to a curve for the SSD, using a logistic four-parameter model. The CCME (2007) approach for WQG derivation is to use the intercept of the fifth (5th) percentile of the SSD as the WQG, with the intent that this hazardous concentration to 5% of species (HC5) will provide protection to 95% of the aquatic species. This approach was adopted to determine the strontium CEB for Snap Lake.

6.2 Calculation of Strontium Chronic Effects Benchmarks

Tests with three species were excluded from the CEB calculation: Goldfish (Birge 1978; Birge et al. 1979); Rainbow Trout (Birge 1978; Birge et al. 1979); and, *Hyalella azteca* (Borgmann et al. 2005). Goldfish are not found in Snap Lake, are not native to North America, and the tests by Birge and colleagues produced results that overlapped with background strontium concentrations (i.e., were questionable).

The tests conducted by Birge and colleagues with Rainbow Trout were not reproducible, also overlapped background concentrations, and had previously been considered unreliable. These two studies by Birge and colleagues also reported results for testing of a number of other metals, in addition to strontium. A review of the US Environmental Protection Agency's (USEPA) water quality criteria for aluminum, arsenic, cadmium, chromium, copper, and selenium revealed that the corresponding data from these two studies were listed as 'other data' but were not included in the datasets used for criteria derivation; no reason was given for this exclusion. Ecometrix (2011) stated: "There is evidence for other metals that the Birge et al. tests are not reproducible…confidence in the trout result is low." Thus, the more recent data for Rainbow Trout were used instead in the CEB calculation.

The *Hyalella azteca* tests by Borgmann et al. (2005), when redone using additional test concentrations and an additional endpoint, provided less uncertain data for this amphipod. The study design and data processing used by Borgmann et al. (2005) were such that clearly defined point estimates could not be determined and the responses that were reported were likely overly conservative because they were not corrected for potentially similar control responses. Ecometrix (2011) stated that these results, like the results of the studies by Birge and colleagues discussed above, were low outliers in the literature. In contrast, Nautilus (2012) reported that effects on *Hyalella* occurred at concentrations at least 30 times higher than those reported by Borgmann et al. (2005). These more recent data were used in the CEB calculation.

Table 6 summarizes the endpoints that were used to generate the SSD for strontium, with the data from the Birge (1978), Birge et al. (1980), and Borgmann et al. (2005) studies replaced by the Rainbow Trout studies by Pacholski (2009) and Nautilus (2013), and the *Hyalella azteca* study by Nautilus (2012). Data from 10 chronic studies with 12 species (representing 4 fish, 7 invertebrates, and 1 algal species) were used for this calculation. Figure 6 shows the SSD curve for this dataset, and the associated HC5 of 14,130 µg/L.

The HC5 of 14,130 µg/L is a more realistic chronic threshold than the WQO for Snap Lake of 500 µg/L calculated by Ecometrix (2011) using the geometric mean of the unreliable (as demonstrated in repeat testing) Birge et al. (1980) and Borgmann et al. (2005) studies. This chronic threshold of 14,130 µg/L is also conservative when considered relative to the endpoints used to generate it. The six lowest SMCVs used to generate this chronic threshold ranged from approximately 16,000 to 71,000 µg/L and were calculated from point estimates that represented effect levels between 10 and 20%, with the majority being 10% effect levels.

The above chronic threshold of 14,130 µg/L is lower than the chronic threshold adopted for strontium by the US states of Michigan and Ohio (Hull 2008; MDEQ 2008; Ohio EPA 2009) and subsequently by Quebec (Chowdhury and Blust 2012): 21,000 µg/L.

A recent review of the homeostasis and toxicology of strontium (Chowdhury and Blust 2012) found that "Sr in the environment is not generally considered a concern to aquatic organisms. The only known case is the Kola region of Russia, where many lakes are heavily contaminated with Sr from nearby metal mines, and the fish living in the lakes are characterized by high concentrations of tissue Sr in association with skeletal abnormalities (Moiseenko and Kudryavtseva 2001)." As is apparent from Figure 5, large-bodied fish in Snap Lake have lower strontium tissue concentrations than reference lakes despite increasing strontium concentrations in the waters of Snap Lake (Figure 2). However, the opposite was true for a small-bodied fish, Lake Chub.

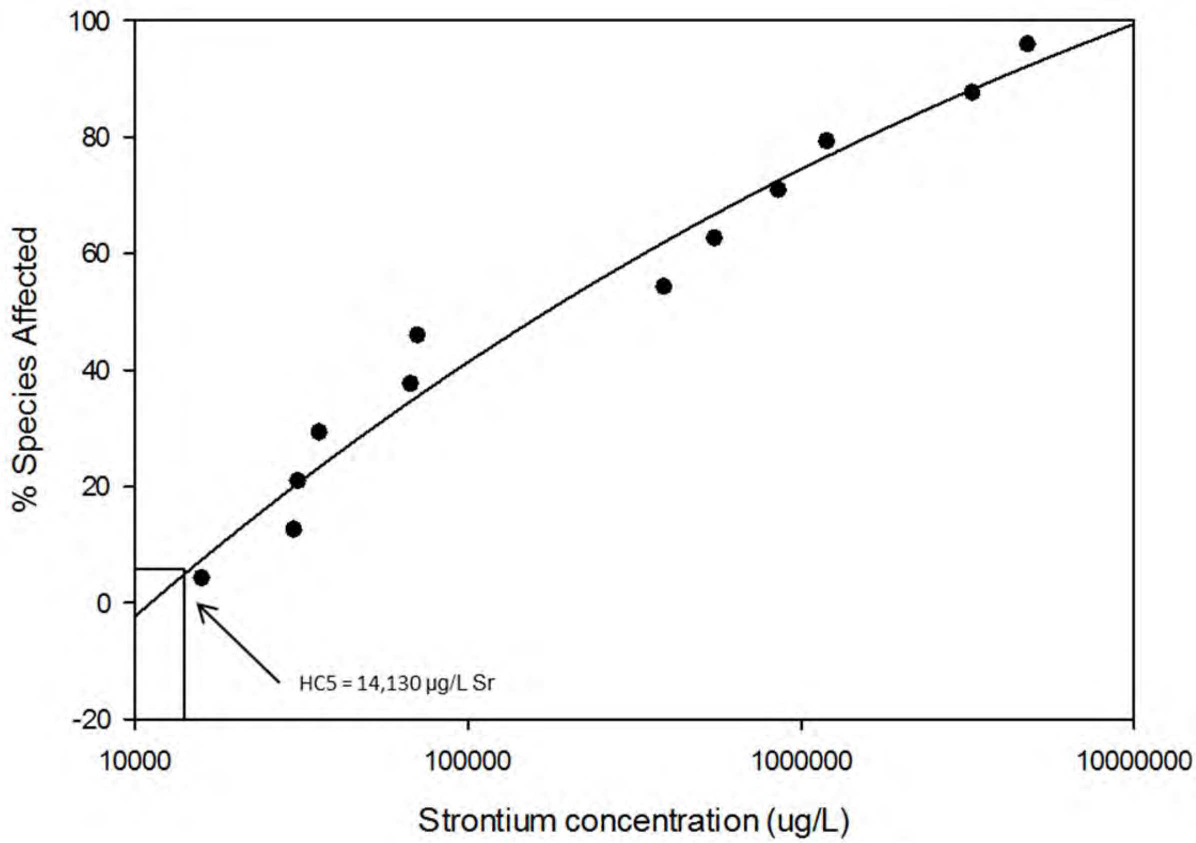
Calcium and strontium share many common pathways; strontium uptake and toxicity decrease as calcium concentrations increase (Blust 2011; Chowdhury and Blust 2012). This was evident in the results reported by Nautilus (2013) for Rainbow Trout ELS tests at two different water hardness concentrations; strontium was less toxic at the higher hardness. Calcium concentrations, as a major component of total dissolved solids (TDS), are increasing in Snap Lake. Thus, it is considered unlikely that there is an imminent or future hazard to aquatic life in Snap Lake from strontium toxicity.

Table 6 Chronic Toxicity Data Used to Generate Species Sensitivity Distribution for Strontium

Citation	Test Species	Common Name	Endpoint	Strontium Concentration (µg/L)	Species Mean Chronic Value (µg/L)	Rank	Percent Affected
Pacholski (2009); HydroQual (2009, 2013)	*Ceriodaphnia dubia*	water flea	IC_{20}	11,160	15,993	1	4%
Cook (2008) as cited in Hull (2008); Cook (2013)	*Ceriodaphnia dubia*	water flea	IC_{10}	22,920			
Nautilus (2012)	*Hyalella azteca*	amphipod	IC_{10}	30,240	30,240	2	13%
Pacholski (2009); HydroQual (2009, 2013)	*Daphnia magna*	water flea	IC_{10}	23,000	31,081	3	21%
Biesinger and Christensen (1972)	*Daphnia magna*	water flea	EC_{16}	42,000			
Pacholski (2009); HydroQual (2009, 2013)	*Pseudokirchneriella subcapitata*	green algae	IC_{10}	36,000	36,000	4	29%
Cook (2008) as cited in Hull (2008); Cook (2013)	*Pimephales promelas*	Fathead Minnow	IC_{20}	17,420	67,686	5	38%
Pacholski (2009); HydroQual (2009, 2013)	*Pimephales promelas*	Fathead Minnow	IC_{10}	263,000			
Pacholski (2009); HydroQual (2009, 2013)	*Oncorhynchus mykiss*	Rainbow Trout	LC_{10}	67,000	70,982	6	46%
Nautilus (2013)	*Oncorhynchus mykiss*	Rainbow Trout	LC_{10}	75,200			
Boutet and Chaisemartin (1973)	*Austropotamobius pallipes pallipes*	white-clawed crayfish	LC_{50}	390,000	390,000	7	54%
Suzuki (1959)	*Culex pipiens paliens*	mosquito	EC_{50}	553,000	553,000	8	63%
Boutet and Chaisemartin (1973)	*Orconectes limosus*	spinycheek crayfish	LC_{50}	860,000	860,000	9	71%
Jones (1939)	*Gasterosteus aculeatus L.*	Threespine Stickleback	LT_{50}	1,200,000	1,200,000	10	79%
Schroder et al. (1994)	*Oncorhynchus keta*	Chum Salmon	NOEC	1,200,000	3,286,335	11	88%
Schroder et al. (1994)	*Oncorhynchus keta*	Chum Salmon	LC_{06}	9,000,000			
Jones (1940)	*Polycelis nigra*	planarian	LT_{50}	3,500,000	4,806,246	12	96%
Jones (1940)	*Polycelis nigra*	planarian	LT_{50}	6,600,000			

µg/L- micrograms per litre; %=percent; IC= inhibitory concentration; EC= effective concentration; LC= lethal concentration; NOEC = no observed effect concentration

Figure 6 Species Sensitivity Distribution for Strontium



µg/L= micrograms per litre; % = percent; HC5 = hazardous concentration to 5% of species; Sr = strontium.

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Appendix A

Strontium Toxicity Data

Appendix A. Acute and Chronic Toxicity Data for Strontium

Endpoint Type[1]	Trophic Group	Test Species	Common Name	Life Stage	Chemical Species	pH	Hardness (mg/L $CaCO_3$)	Conductivity/ Alkalinity	Duration	Biological Measurement	Endpoint	Strontium Concentration (µg/L)	Included/ Excluded for SSD	Citation
Acute Toxicity Data														
acute	Fish	*Gasterosteus aculeatus L.*	Threespine Stickleback	juveniles (3-5 cm)	$Sr(NO_3)_2$	6.0 - 6.8	NR	NR	2 d	survival	LT_{50}	6,500,000	excluded	Jones (1939)
acute	Fish	*Lepomis macrochirus*	Bluegill Sunfish	NR	$SrCl_2$	NR	NR	NR	4 d	survival	LC_{50}	6,316,556	excluded	ESE (2000) as cited in Hull (2008)
acute	Fish	*Morone saxatilis*	Striped Bass	juveniles	$SrCl_2 \cdot 6H_2O$	8.12	4,430	36 mmhos/cm / 88 mg/L	4 d	survival	LC_{50}	>92,800	excluded	Dwyer et al (1992)
acute	Fish	*Oncorhynchus mykiss*	Rainbow Trout	juveniles	$SrCl_2$	NR	82	NR	4 d	survival	LC_{50}	2,348,110	excluded	Harding ESE (2001) as cited in Hull (2008)
acute	Fish	*Oncorhynchus nerka*	Sockeye Salmon	emergent fry	$SrCl_2 \cdot 6H_2O$	NR	NR	NR	24 h	survival / stress	NOEC	3,000,000	excluded	Oxman et al (2004)
acute	Fish	*Pimephales promelas*	Fathead Minnow	10 d old	$SrCl_2$	NR	100 - 616	NR	4 d	survival	LC_{50}	144,610	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
acute	Fish	*Pimephales promelas*	Fathead Minnow	NR	$SrCl_2$	NR	82	NR	4 d	immobilization	EC_{50}	140,180	excluded	Owusu-Yaw (1998) as cited in Hull (2008)
acute	Fish	*Pimephales promelas*	Fathead Minnow	NR	$Sr(NO_3)_2$	NR	100	NR	4 d	survival	LC_{50}	228,470	excluded	SFALBL (1998) as cited in Hull (2008)
acute	Invertebrate	*Austropotamobius pallipes pallipes*	white-clawed crayfish	19-32 mm	$SrCrO_4$	7	NR	NR	4 d	survival	LC_{50}	440,000	excluded	Boutet and Chaisemartin (1973)
acute	Invertebrate	*Caenorhabditis elegans*	nematode	young adult (3 to 4 d old)	$Sr(NO_3)_2$	NR	NR	NR	4 d	survival	LC_{50}	465,000	excluded	Williams and Dusenbury (1990)
acute	Invertebrate	*Caenorhabdituis elegans*	nematode	adult	$Sr(NO_3)_2$	NR	NR	NR	24 h	survival	LC_{50}	15,000,000	excluded	Tatara (1998)
acute	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2$	NR	100 - 616	NR	48 h	survival	LC_{50}	96,030	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
acute	Invertebrate	*Chironomus tentans*	midge	NR	$SrCl_2$	NR	NR	NR	48 h	survival	LC_{50}	424,456	excluded	ESE (2000) as cited in Hull (2008)
acute	Invertebrate	*Culex pipiens paliens*	mosquito	fourth stage	$SrCl_2 \cdot 6H_2O$	NR	NR	NR	8.2 d	survival	LC_{50}	5,530,000	excluded	Suzuki (1959)
acute	Invertebrate	*Cyclops abyssorum prealpinus*	copepod	adult (0.62 mm)	$SrCl_2 \cdot 6H_2O$	7.2	NR	75 µS / 0.58 meq/L	48 h	survival	LC_{50}	300,000	excluded	Baudouin and Scoppa (1974)
acute	Invertebrate	*Daphnia hyalina*	water flea	adult (1.27 mm)	$SrCl_2 \cdot 6H_2O$	7.2	NR	75 µS / 0.58 meq/L	48 h	survival	LC_{50}	75,000	excluded	Baudouin and Scoppa (1974)
acute	Invertebrate	*Daphnia magna*	water flea	<24 h old	$SrCl_2$	7.7	45.3	NR / 42.3 mg/L	48 h	survival	LC_{50}	125,000	excluded	Biesinger and Christensen (1972)
acute	Invertebrate	*Daphnia magna*	water flea	<24 hr old	$SrCl_2 \cdot 6H_2O$	several	several	several	48 h	immobilization	EC_{50}	<2,300	excluded	Dwyer et al (1992)
acute	Invertebrate	*Daphnia magna*	water flea	NR	$SrCl_2$	7.2 - 7.8	235 - 260	NR / 390-415 mg/L	48 h	immobilization	EC_{50}	94,000	excluded	Khangarot and Ray (1989)
acute	Invertebrate	*Daphnia magna*	water flea	NR	$SrCl_2$	NR	150	NR	4 d	immobilization	EC_{50}	227,070	excluded	Owusu-Yaw (1998) as cited in Hull (2008)
acute	Invertebrate	*Daphnia magna*	water flea	NR	$Sr(NO_3)_2$	NR	100	NR	4 d	survival	LC_{50}	140,770	excluded	SFALBL (1998) as cited in Hull (2008)
acute	Invertebrate	*Dugesia tigrina*	brown planarian	NR	$SrCl_2 \cdot 6H_2O$	7.8 - 8.2	84 - 870	NR	4 d	survival	LC_{50}	129,550	excluded	Hull (2008)
acute	Invertebrate	*Dugesia tigrina*	brown planarian	NR	$SrCl_2 \cdot 6H_2O$	7.8 - 8.2	84 - 870	NR	4 d	survival	LC_{100}	239,100	excluded	Hull (2008)
acute	Invertebrate	*Dugesia tigrina*	brown planarian	NR	$SrCl_2 \cdot 6H_2O$	7.8 - 8.2	84 - 870	NR	4 d	survival	LC_0	86,080	excluded	Hull (2008)
acute	Invertebrate	*Dugesia tigrina*	brown planarian	NR	$SrCl_2 \cdot 6H_2O$	7.8 - 8.2	84 - 870	NR	4 d	survival	MATC	111,180	excluded	Hull (2008)
acute	Invertebrate	*Eudiaptmous padanus padanus*	copepod	adult (0.43 mm)	$SrCl_2 \cdot 6H_2O$	7.2	NR	75 µS / 0.58 meq/L	48 h	survival	LC_{50}	180,000	excluded	Baudouin and Scoppa (1974)
acute	Invertebrate	*Hyalella azteca*	amphipod	NR	$SrCl_2$	NR	NR	NR	48 h	survival	LC_{50}	198,011	excluded	ESE (2000) as cited in Hull (2008)
acute	Invertebrate	*Hyalella azteca*	amphipod	juveniles	$SrCl_2$	NR	80 - 100	NR	4 d	survival	LC_{50}	396,000	excluded	Lee et al (2012)
acute	Invertebrate	*Orconectes limosus*	spinycheek crayfish	19-32 mm	$SrCrO_4$	7	NR	NR	4 d	survival	LC_{50}	910,000	excluded	Boutet and Chaisemartin (1973)
acute	Invertebrate	*Physa integra*	snail	NR	$SrCl_2$	NR	NR	NR	4 d	survival	LC_{50}	537,504	excluded	ESE (2000) as cited in Hull (2008)
acute	Invertebrate	*Tubifex tubifex*	annelid	mixed age	$SrCl_2 \cdot 6H_2O$	7.6	245	NR / 400 mg/L	4 d	immobilization	EC_{50}	240,800	excluded	Khangarot (1991)

Appendix A. Acute and Chronic Toxicity Data for Strontium

Endpoint Type[1]	Trophic Group	Test Species	Common Name	Life Stage	Chemical Species	pH	Hardness (mg/L $CaCO_3$)	Conductivity/ Alkalinity	Duration	Biological Measurement	Endpoint	Strontium Concentration (µg/L)	Included/ Excluded for SSD	Citation
Chronic Toxicity Data														
chronic	Fish	*Carassius auratus*	Goldfish	eggs	$SrCl_2$	7.4	195	NR	7 d	survival	LC_{01}	45.3	excluded	Birge (1978); Birge et al (1979)
chronic	Fish	*Carassius auratus*	Goldfish	eggs	$SrCl_2$	7.4	195	NR	7 d	survival	LC_{50}	8,580	excluded	Birge (1978); Birge et al (1979)
chronic	Fish	*Carassius auratus*	Goldfish	eggs	$SrCl_2$	7.4	195	NR	7 d	survival	MATC	623	included	Birge (1978); Birge et al (1979)
chronic	Fish	*Gasterosteus aculeatus L.*	Threespine Stickleback	juveniles (3-5 cm)	$Sr(NO_3)_2$	6.0 - 6.8	NR	NR	10 d	survival	LT_{50}	1,200,000	included	Jones (1939)
subchronic	Fish	*Oncorhynchus keta*	Chum Salmon	emergent fry	$SrCl_2$	7.7	38 - 57	NR	35 d*	survival	LC_{06}	9,000,000	included	Schroder et al. (1994)
subchronic	Fish	*Oncorhynchus keta*	Chum Salmon	emergent fry	$SrCl_2$	7.7	38 - 57	NR	35 d*	survival	NOEC	1,200,000	included	Schroder et al. (1994)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	eggs	$SrCl_2$	7.4	104	NR	28 d	survival	LC_{01}	6	excluded	Birge (1978); Birge et al (1979)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	eggs	$SrCl_2$	7.4	104	NR	28 d	survival	LC_{50}	200	excluded	Birge (1978); Birge et al (1979)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	eggs	$SrCl_2$	7.4	104	NR	28 d	survival	MATC	35	included	Birge (1978); Birge et al (1979)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.9 - 7.8	92 - 110	NR	28 d	survival	LC_{01}	13	excluded	Birge et al (1980); Birge et al (1981)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.9 - 7.8	92 - 110	NR	28 d	survival	LC_{10}	49	included	Birge et al (1980); Birge et al (1981)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.9 - 7.8	92 - 110	NR	28 d	survival	LC_{50}	250	excluded	Birge et al (1980); Birge et al (1981)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.5-7.3	Soft (11 - 12)	31-54 µS / 7-11 mg/L	32 d	normal development	EC_{10}	77,800	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.5-7.3	Soft (11 - 12)	31-54 µS / 7-11 mg/L	32 d	normal development	EC_{20}	101,400	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.5-7.3	Soft (11 - 12)	31-54 µS / 7-11 mg/L	32 d	normal development	EC_{50}	>157,500	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.5-7.3	Soft (11 - 12)	31-54 µS / 7-11 mg/L	32 d	survival	LC_{10}	75,200	included	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.5-7.3	Soft (11 - 12)	31-54 µS / 7-11 mg/L	32 d	survival	LC_{20}	98,500	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	6.5-7.3	Soft (11 - 12)	31-54 µS / 7-11 mg/L	32 d	survival	LC_{50}	>157,500	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	7.5-7.9	Moderately hard (80 - 100)	299-348 µS / 58-64 mg/L	32 d	normal development	EC_{10}	3,048	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	7.5-7.9	Moderately hard (80 - 100)	299-348 µS / 58-64 mg/L	32 d	normal development	EC_{20}	>151,100	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	embryo-larval	$SrCl_2$	7.5-7.9	Moderately hard (80 - 100)	299-348 µS / 58-64 mg/L	32 d	survival	LC_{10}	>151,100	excluded	Nautilus (2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	fry (0.5 g wet wt)	$SrCl_2 \cdot 6H_2O$	7.7	NR	432 µS/cm / NR	21 d	survival	LC_{10}	67,000	included	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	fry (0.5 g wet wt)	$SrCl_2 \cdot 6H_2O$	7.7	NR	432 µS/cm / NR	21 d	survival	LC_{20}	110,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Oncorhynchus mykiss*	Rainbow Trout	fry (0.5 g wet wt)	$SrCl_2 \cdot 6H_2O$	7.7	NR	432 µS/cm / NR	21 d	survival	LC_{50}	286,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2$	NR	100 - 348	NR	7 d	growth	IC_{10}	<13,440	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2$	NR	100 - 348	NR	7 d	growth	IC_{20}	17,420	included	Cook (2008) as cited in Hull (2008); Cook (2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2$	NR	100 - 348	NR	7 d	survival	LC_{20}	>92,870	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2$	NR	100 - 348	NR	7 d	survival	LC_{50}	>92,870	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2 \cdot 6H_2O$	7.3	199	471 µS/cm / 130 mg/L	7 d	growth	IC_{10}	263,000	included	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2 \cdot 6H_2O$	7.3	199	471 µS/cm / 130 mg/L	7 d	growth	IC_{20}	304,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2 \cdot 6H_2O$	7.3	199	471 µS/cm / 130 mg/L	7 d	survival	LC_{10}	255,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2 \cdot 6H_2O$	7.3	199	471 µS/cm / 130 mg/L	7 d	survival	LC_{20}	276,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Fish	*Pimephales promelas*	Fathead Minnow	<24 h old	$SrCl_2 \cdot 6H_2O$	7.3	199	471 µS/cm / 130 mg/L	7 d	survival	LC_{50}	354,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Austropotamobius pallipes pallipes*	white-clawed crayfish	19-32 mm	$SrCrO_4$	7	NR	NR	30 d	survival	LC_{50}	390,000	included	Boutet and Chaisemartin (1973)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2$	NR	100 - 348	NR	6 d	reproduction	IC_{10}	22,920	included	Cook (2008) as cited in Hull (2008); Cook (2013)

Appendix A. Acute and Chronic Toxicity Data for Strontium

Endpoint Type[1]	Trophic Group	Test Species	Common Name	Life Stage	Chemical Species	pH	Hardness (mg/L $CaCO_3$)	Conductivity/ Alkalinity	Duration	Biological Measurement	Endpoint	Strontium Concentration (µg/L)	Included/ Excluded for SSD	Citation
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2$	NR	100 - 348	NR	6 d	reproduction	IC_{20}	33,610	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2$	NR	100 - 348	NR	6 d	survival	LC_{50}	92,870	excluded	Cook (2008) as cited in Hull (2008); Cook (2013)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	8.2	149	417 µS/cm / 113 mg/L	6 d	reproduction	IC_{10}	2,866	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	8.2	149	417 µS/cm / 113 mg/L	6 d	reproduction	IC_{20}	11,160	included	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	8.2	149	417 µS/cm / 113 mg/L	6 d	survival	LC_{10}	137,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	8.2	149	417 µS/cm / 113 mg/L	6 d	survival	LC_{20}	149,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Ceriodaphnia dubia*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	8.2	149	417 µS/cm / 113 mg/L	6 d	survival	LC_{50}	206,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Culex pipiens paliens*	mosquito	fourth stage	$SrCl_2 \cdot 6H_2O$	NR	NR	NR	6.9 d	emergence	EC_{50}	553,000	included	Suzuki (1959)
chronic	Invertebrate	*Culex pipiens paliens*	mosquito	fourth stage	$SrCl_2 \cdot 6H_2O$	NR	NR	NR	4.1 d	pupation	EC_{50}	5,530	excluded	Suzuki (1959)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 hr old	$SrCl_2$	7.7	45.3	NR / 42.3 mg/L	21 d	reproduction	EC_{16}	42,000	included	Biesinger and Christensen (1972)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 hr old	$SrCl_2$	7.7	45.3	NR / 42.3 mg/L	21 d	reproduction	EC_{50}	60,000	excluded	Biesinger and Christensen (1972)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 hr old	$SrCl_2$	7.7	45.3	NR / 42.3 mg/L	21 d	survival	LC_{50}	86,000	excluded	Biesinger and Christensen (1972)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 hr old	$SrCl_2$	7.7	45.3	NR / 42.3 mg/L	21 d	growth	IC_{24}	99,900	excluded	Biesinger and Christensen (1972)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	7.8	139 - 171	380 µS/cm / NR	21 d	reproduction	IC_{10}	23,000	included	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	7.8	139 - 171	380 µS/cm / NR	21 d	reproduction	IC_{20}	35,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	7.8	139 - 171	380 µS/cm / NR	21 d	survival	LC_{10}	72,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	7.8	139 - 171	380 µS/cm / NR	21 d	survival	LC_{20}	86,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Daphnia magna*	water flea	<24 h old	$SrCl_2 \cdot 6H_2O$	7.8	139 - 171	380 µS/cm / NR	21 d	survival	LC_{50}	122,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Invertebrate	*Hyalella azteca*	amphipod	juveniles	Sr atomic absorption standards (fully dissolved)	7.4	18	46 µS / 14 mg/L	7 d	survival	LC_{18}	315	included	Borgmann et al (2005)
chronic	Invertebrate	*Hyalella azteca*	amphipod	juveniles	Sr atomic absorption standards (fully dissolved)	7.4	18	46 µS / 14 mg/L	7 d	survival	LC_{13}	1000	included	Borgmann et al (2005)
chronic	Invertebrate	*Hyalella azteca*	amphipod	juveniles	Sr atomic absorption standards (fully dissolved)	7.4	18	46 µS / 14 mg/L	7 d	survival	LC_{50}	>1000	excluded	Borgmann et al (2005)
chronic	Invertebrate	*Hyalella azteca*	amphipod	juveniles	Sr atomic absorption standards (fully dissolved)	8.4	124	311 µS / 84 mg/L	7 d	survival	LC_{07}	1000	included	Borgmann et al (2005)
chronic	Invertebrate	*Hyalella azteca*	amphipod	juveniles	Sr atomic absorption standards (fully dissolved)	8.4	124	311 µS / 84 mg/L	7 d	survival	LC_{50}	>3150	excluded	Borgmann et al (2005)
chronic	Invertebrate	*Hyalella azteca*	amphipod	7-8 d old	$SrCl_2$	7.6-8.2	100	343-454 µS / 58 mg/L	14 d	growth	IC_{10}	30,240	included	Nautilus (2012)
chronic	Invertebrate	*Hyalella azteca*	amphipod	7-8 d old	$SrCl_2$	7.6-8.2	100	343-454 µS / 58 mg/L	14 d	growth	IC_{20}	43,150	excluded	Nautilus (2012)
chronic	Invertebrate	*Hyalella azteca*	amphipod	7-8 d old	$SrCl_2$	7.6-8.2	100	343-454 µS / 58 mg/L	14 d	growth	IC_{50}	79,240	excluded	Nautilus (2012)
chronic	Invertebrate	*Hyalella azteca*	amphipod	7-8 d old	$SrCl_2$	7.6-8.2	100	343-454 µS / 58 mg/L	14 d	survival	LC_{50}	176,800	excluded	Nautilus (2012)
chronic	Invertebrate	*Orconectes limosus*	spinycheek crayfish	19-32 mm	$SrCrO_4$	7	NR	NR	30 d	survival	LC_{50}	860,000	included	Boutet and Chaisemartin (1973)
subchronic	Invertebrate	*Polycelis nigra*	planarian	NR	$SrCl_2$	6.6	NR	NR	48 h	survival	LT_{50}	6,600,000	included	Jones 1940
subchronic	Invertebrate	*Polycelis nigra*	planarian	NR	$Sr(NO_3)_2$	6.6	NR	NR	48 h	survival	LT_{50}	3,500,000	included	Jones 1940
chronic	Algae / Plants	*Pseudokirchneriella subcapitata*	green algae	7 d old culture	$SrCl_2 \cdot 6H_2O$	6.5	NR	NR	3 d	growth	IC_{10}	36,000	included	Pacholski (2009); HydroQual (2009, 2013)
chronic	Algae / Plants	*Pseudokirchneriella subcapitata*	green algae	7 d old culture	$SrCl_2 \cdot 6H_2O$	6.5	NR	NR	3 d	growth	IC_{20}	47,000	excluded	Pacholski (2009); HydroQual (2009, 2013)
chronic	Amphibian	*Gastrophryne carolinensis*	narrow-mouthed toad	eggs	$SrCl_2$	7.4	195	NR	7 d	survival	LC_{01}	2.4	excluded	Birge (1978); Birge et al (1979)
chronic	Amphibian	*Gastrophryne carolinensis*	narrow-mouthed toad	eggs	$SrCl_2$	7.4	195	NR	7 d	survival	LC_{50}	160	excluded	Birge (1978); Birge et al (1979)
chronic	Amphibian	*Gastrophryne carolinensis*	narrow-mouthed toad	eggs	$SrCl_2$	7.4	195	NR	7 d	survival	MATC	20	excluded	Birge (1978); Birge et al (1979)

[1] Chronic tests based on CCME (2007) definition that chronic benchmarks in the aquatic ecosystem that are intended to protect all forms of aquatic life for indefinite exposure periods (≥7d exposures for fish and invertebrates, ≥24h exposures for aquatic plants and algae).

NR = No data reported

Appendix B

Nautilus Laboratory Report - Rainbow Trout Early Life Stage (ELS) Toxicity Tests

Evaluation of the chronic toxicity of strontium to early life stages of rainbow trout

Final Report

Report date:
February 20, 2013

Submitted to:

Golder Associates
Burnaby, BC

8664 Commerce Court
Burnaby, BC
V5A 4N7

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1.0 INTRODUCTION

Strontium is an alkaline earth metal that occurs in the Periodic Table immediately above barium and below calcium. This metal is highly reactive in water and typically occurs in aqueous solution as a divalent cation (Sr^{2+}) or as a hydroxide, $Sr(OH)^{+}$. It occurs naturally in rocks, either as the sulfate mineral celestite ($SrSO_4$) or the carbonate strontianite ($SrCO_3$) and is released into the environment during coal and oil combustion.

There are currently no Canadian or USEPA water quality benchmarks for strontium. The Indiana Department of Environmental Management has established a benchmark based on limited data; a Secondary Acute Value (SAV) was calculated based on application of a 13-fold safety factor to the lowest Genus Mean Acute Value, which was an LC50 of 123.8 mg/L for *Daphnia*. The acute guideline was then calculated by dividing the SAV by two, and the chronic guideline was calculated by dividing the SAV by 18, which was a generic acute-to-chronic ratio for contaminants with no data, resulting in benchmarks of 4.8 mg/L for acute and 0.53 mg/L for chronic exposures (Kallander 2001). The Michigan Department of Environmental Quality has also developed water quality benchmarks for strontium (Hull 2008) by rejecting all of the data available in the literature at the time, and relying on data from six unpublished studies. The Final Acute Value was calculated as 81 mg/L, and acute and chronic benchmarks were established as 40 and 21 mg/L, respectively. The chronic value was calculated on the basis of an acute-to-chronic ratio of 3.83, which was the geometric mean of estimates for: 1) *Ceriodaphnia dubia*; 2) fathead minnows; and, 3) a default acute-to-chronic ratio of 18.

In general, the available data for strontium have demonstrated that it exhibits a low degree of toxicity to aquatic organisms. However, a small number of data are available that suggest that it may, in fact, exhibit toxicity at concentrations lower than those associated with the benchmarks promulgated by Indiana and Michigan. For example, Birge (1978) exposed $SrCl_2$ to rainbow trout (*Oncorhynchus mykiss*), goldfish (*Carassius auratus*), and the narrow-mouthed toad (*Gastrophryne carolinensis*) from fertilization to 4 days post hatch for each species. The rainbow trout and narrow-mouthed toad were similar in sensitivity, producing LC50s of 0.2 mg/L and 0.16 mg/L strontium, respectively. These effect levels represent the most sensitive data in the available dataset, and both fall well below the Indiana and Michigan benchmarks. Goldfish were less sensitive, with an LC50 of 8.58 mg/L, although even this value falls below the limit for chronic exposure established by Michigan State.

In a subsequent publication, Birge et al. (1980) reported similar results for development of rainbow trout to four days post hatch, with an LC50 of 0.25 mg/L; an LC10 of 0.049 mg/L was also reported in this subsequent publication. However, it appears likely that the data from Birge (1978) and Birge et al. (1980) reflect the results of differing statistical analyses of the same dataset, rather than being results from two discrete tests.

The toxicity tests performed in the present study were conducted to repeat the tests reported in Birge (1978) and Birge et al. (1980), in order to establish whether those results were anomalous, or whether rainbow trout are indeed relatively sensitive to strontium. The tests were conducted under two water quality regimes: one with water hardness similar to that used by Birge and co-authors (approximately 100 mg/L as $CaCO_3$); and, a second test in water with a lower hardness (approximately 12 mg/L as $CaCO_3$). Tests were conducted under two hardness regimes since it was anticipated that sensitivity to strontium may change in response to calcium concentration in the water because the proximity of these two elements on the periodic table suggests that they might share similar properties that could result in interactions between them by competitive exclusion at uptake sites on the gill.

2.0 METHODS

The toxicity tests were conducted according to procedures summarized in Table 1, which are based on Environment Canada (1998) test methods for embryo-alevin lifestages of rainbow trout.

Eggs and milt were obtained from four female and three male fish from the Fraser Valley Trout Hatchery (Abbotsford, BC). Milt was inspected under a microscope for motility following mixing with water; milt with highly motile sperm was pooled and used for fertilization. The eggs were pooled and fertilized in the absence of water. After allowing approximately 20 minutes for fertilization, the eggs were transferred to their test solutions.

The control waters used in the two tests were: 1) dechlorinated Metro Vancouver municipal tapwater; and, 2) dechlorinated tapwater supplemented with salts to approximately 100 mg/L hardness, according to the proportions outlined by USEPA for moderately hard water (USEPA 2002). Strontium was introduced to the test solutions as strontium chloride. Test solutions were renewed daily with freshly-prepared solutions throughout exposure, at which point pH, temperature, and dissolved oxygen were measured on both the 24-hr old and freshly prepared solutions, and mortalities were recorded and removed.

The test was ended seven days following the time that 50% of the fish in the controls had hatched, which resulted in a 32-day exposure. At the end of the test, percent surviving hatched fish and survival of normally-developed fish were evaluated as test endpoints.

Subsamples of the test solutions were collected at the beginning and end of the test and measured for strontium by ALS Environmental. Statistical analyses were conducted using measured concentrations of strontium and using CETIS version 1.8 (Tidepool Software 2012).

The methods that were employed in these tests followed standardized procedures developed for testing of early life stages of salmonids by Environment Canada (1998). They are considered to be equivalent procedures to those used by Birge (1978), but have the following minor differences, which are not expected to have had an effect on the relative sensitivity of the procedures:

- the water renewal frequency employed here was every 24 h, compared with every 12 h;
- the number of eggs exposed per concentration was 120, compared with 150;

- the exposure temperature was 14 ± 1°C here, compared with 13 ± 0.5°C; and,
- the test ended seven days after 50% of the control fish had hatched (32 day exposure overall), compared with four days following hatch (28 day exposure overall).

These procedural differences are minor and would not be anticipated to result in any difference in sensitivity between the tests.

Table 1. Summary of test conditions: rainbow trout embryo-alevin toxicity test.

Test organism	*Oncorhynchus mykiss*
Test organism source	Fraser Valley Trout Hatchery
Test organism age	Fertilized eggs
Test type	Static-renewal (daily)
Test duration	30 days
Test vessel	2-L plastic jars
Test volume	2-L
Test replicates	4 replicates per treatment
No. of organisms	30 per replicate
Test temperature	14 ± 1°C
Feeding	None
Photoperiod	24 hours dark
Aeration	Gentle aeration throughout test
Test protocol	Environment Canada (1998), EPS 1/RM/28
Test endpoints	Survival and normal development
Test acceptability criterion for controls	65% normal surviving fry
Reference Toxicant	Sodium dodecyl sulphate (SDS)

3.0 RESULTS AND DISCUSSION

Copies of bench-sheets from the tests and printouts of statistical analyses are provided in Appendix A. Results of analytical confirmations of test solutions are provided in Appendix B.

The results of toxicity tests using rainbow trout are provided in Tables 2 and 3 for very soft water (measured as 11 to 12 mg/L as $CaCO_3$) and moderately hard water (measured as 98 to 100 mg/L as $CaCO_3$), respectively. In very soft water, the EC10 and EC20 were 75.2 and 98.5 mg/L strontium; however, no adverse effects were observed in the test in moderately hard water in any of the test solutions, resulting in point estimates of >151.1 mg/L strontium. Thus, it appears that increasing water hardness does indeed reduce the toxicity of strontium.

The test conducted in moderately hard water produced results that are in stark contrast to those reported under similar conditions by Birge (1978) and Birge et al. (1980), in which an effect on 50% of exposed test organisms was observed at 0.2 to 0.25 mg/L strontium. The results presented by these authors have been questioned for other toxicants; for example, Davies et al. (2005) reported no adverse effects on developing rainbow trout exposed to up to 400 mg/L molybdenum, whereas Birge (1978) and Birge et al. (1980) reported LC50s of 0.73 and 0.78 mg/L, respectively, for this metal. Thus, it appears that the data presented by Birge (1978) and Birge et al. (1980) are anomalous, and should not be relied upon.

The only other test reported in the literature involving exposure of salmonids to strontium was conducted by Schroder et al. (1995), in which hatchery sockeye and chum fry were marked with strontium prior to release. Exposure for 24 hours to concentrations as high as 1200 mg/L strontium resulted in no significant mortality for up to 34 days following exposure, although exposure to 9000 mg/L did induce mortalities. Although the short exposure complicates a direct comparison, these results also indicate effect levels that were orders of magnitude higher than those reported by Birge (1978).

3.1 QA/QC

Measured strontium concentrations were in good agreement with target concentrations, and measurements conducted at the end of the test were similar to those measured at test initiation, indicating that the exposure concentrations were consistent during exposure.

The performance of the control exposures met acceptance criteria specified in the test method and the water quality (pH, temperature, dissolved oxygen) remained within acceptable ranges during the tests.

Results of reference toxicant (positive control) tests are provided in Table 4. The reference toxicant test results fell within the range of historical data from the laboratory (mean ± 2 SD), indicating that the sensitivity of the test organisms was appropriate.

Table 2. Results of the rainbow trout embryo-alevin test using strontium in very soft water.

Concentration (mg/L)		Survival to hatch (%)	Normally developed surviving fry (%)
Sr (nominal)	Sr (measured)		
Control	0.0	72.2 ± 12.5	70.6 ± 12.7
5	4.7	71.3 ± 12.0	68.7 ± 15.0
10	10.3	74.8 ± 9.7	67.2 ± 7.2
20	20.8	74.2 ± 5.5	71.6 ± 6.5
40	42.4	76.7 ± 10.5	75.0 ± 11.4
80	79.9	63.8 ± 6.3	61.4 ± 3.6
160	157.5	39.8 ± 2.4	38.9 ± 2.3
Point estimates	EC50	>157.5	>157.5
(mg/L measured Sr)	EC20	98.5 (55.1 – 120.2)	101.4 (49.2 – 124.4)
	EC10	75.2 (29.1 – 98.7)	77.8 (23.5 – 103.2)

Table 3. Results of the rainbow trout embryo-alevin test using strontium in moderately hard water.

Concentration (mg/L)		Survival to hatch (%)	Normally developed surviving fry (%)
Sr (nominal)	Sr (measured)		
Control	0.1	83.9 ± 11.3	81.3 ± 13.3
5	4.0	67.4 ± 6.6	63.2 ± 7.0
10	10.7	79.4 ± 4.7	74.5 ± 6.2
20	20.1	78.6 ± 7.2	72.5 ± 8.3
40	39.5	76.6 ± 3.6	76.6 ± 3.6
80	78.4	76.5 ± 7.2	72.0 ± 8.3
160	151.1	79.0 ± 4.6	72.8 ± 4.9
Point estimates	EC50	>151.1	>151.1
(mg/L measured Sr)	EC20	>151.1	>151.1
	EC10	>151.1	>151.1

Table 4. Reference toxicant test results for early life stage tests with rainbow trout.

Endpoint	Date	Toxicant	Point estimate	Acceptable Range	CV
Embryo development	25 Oct 2012	SDS	4.2 mg/L	1.9 – 9.4 mg/L	49

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APPENDIX A – Toxicity test data

Rainbow Trout Embryo Summary Sheet

Client: Golder

Start Date/Time: Oct 25, 2012 @ 1700h

Work Order No.: 12193

Test Species: *Oncorhynchus mykiss*

Sample Information:

Sample ID: Strontium in Dechlor Water
Sample Date: n/a
Date Received: n/a
Sample Volume: n/a

Dilution Water:

Type: Dechlorinated Tap Water
Hardness (mg/L $CaCO_3$): 11-12
Alkalinity (mg/L $CaCO_3$): 7-11

Test Organism Information:

Batch No.: 102512
Source: Fraser Valley Trout Hatchery
Loading Density: n/a

SDS Reference Toxicant Results:

Reference Toxicant ID: RTE39
Stock Solution ID: 12SO2
Date Initiated: 25-Oct-12
7-d EC50 (95% CL): 2.3 (2.1 - 2.5) mg/L SDS

Reference Toxicant Mean and Range: 4.2 (1.9 - 9.4) mg/L SDS
Reference Toxicant CV (%): 49

Test Results:

	Survival	Proportion normal
EC25 (mg/L) (95% CL)	109.2 (69.4 - 130.9)	112.1 (64.5 - 135.2)
EC50 (mg/L) (95% CL)	>157.5 (n/a)	>157.5 (n/a)

Reviewed by: JGH

Date reviewed: Jan 11/13

CETIS Analytical Report

Report Date:	11 Jan-13 09:53 (p 1 of 2)	**Test Code:**	12193 | 18-5559-6750

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	11-2313-2282	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.8.4
Analyzed:	11 Jan-13 9:52	**Analysis:**	Linear Regression (MLE)	**Official Results:**	Yes
Batch ID:	14-5322-9195	**Test Type:**	Survival-Development	**Analyst:**	Karen Lee
Start Date:	25 Oct-12 17:00	**Protocol:**	EC/EPS 1/RM/28	**Diluent:**	Dechlorinated Tap Water
Ending Date:	26 Nov-12 14:00	**Species:**	Oncorhynchus mykiss	**Brine:**	
Duration:	31d 21h	**Source:**	Fraser Valley Trout Hatchery	**Age:**	
Sample ID:	02-2758-5265	**Code:**	D90ACF1	**Client:**	Golder
Sample Date:	25 Oct-12 17:00	**Material:**	Strontium	**Project:**	
Receive Date:	25 Oct-12 17:00	**Source:**	Golder		
Sample Age:	NA	**Station:**	Strontium in Dechlor Water		

Linear Regression Options

Model Function	Threshold Option	Threshold	Optimized	Pooled	Het Corr	Weighted
Log-Normal [NED=A+B*log(X)]	Control Threshold	0.276423	Yes	No	No	Yes

Regression Summary

Iters	LL	AICc	BIC	Mu	Sigma	Adj R2	F Stat	Critical	P-Value	Decision(α:5%)
16	-500.4	1008	1011	2.218	0.2672	0.612	0.2986	2.84	0.8755	Non-Significant Lack of Fit

Point Estimates

Level	mg/L	95% LCL	95% UCL
EC5	60.09	17	84.93
EC10	75.15	29.11	98.74
EC15	87.38	41.65	109.8
EC20	98.51	55.05	120.2
EC25	109.2	69.4	130.9
EC40	141.5	114.1	176.8
EC50	165.3	138.6	235.3

Regression Parameters

Parameter	Estimate	Std Error	95% LCL	95% UCL	t Stat	P-Value	Decision(α:5%)
Threshold	0.261	0.01918	0.2235	0.2986	13.61	<0.0001	Significant Parameter
Slope	3.742	1.131	1.526	5.958	3.31	0.0028	Significant Parameter
Intercept	-8.302	2.412	-13.03	-3.574	-3.442	0.0020	Significant Parameter

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Model	49.67035	49.67035	1	44.58	<0.0001	Significant
Lack of Fit	1.499102	0.374776	4	0.2986	0.8755	Non-Significant
Pure Error	26.35535	1.255017	21			
Residual	27.85445	1.114178	25			

Residual Analysis

Attribute	Method	Test Stat	Critical	P-Value	Decision(α:5%)
Goodness-of-Fit	Pearson Chi-Sq GOF	27.85	37.65	0.3146	Non-Significant Heterogenity
	Likelihood Ratio GOF	28.4	37.65	0.2896	Non-Significant Heterogenity
Variances	Bartlett Equality of Variance	8.282	12.59	0.2182	Equal Variances
	Mod Levene Equality of Variance	0.7061	2.573	0.6482	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9663	0.9264	0.4850	Normal Distribution
	Anderson-Darling A2 Normality	0.448	2.492	0.2835	Normal Distribution

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	11-2313-2282	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.8.4
Analyzed:	11 Jan-13 9:52	**Analysis:**	Linear Regression (MLE)	**Official Results:**	Yes

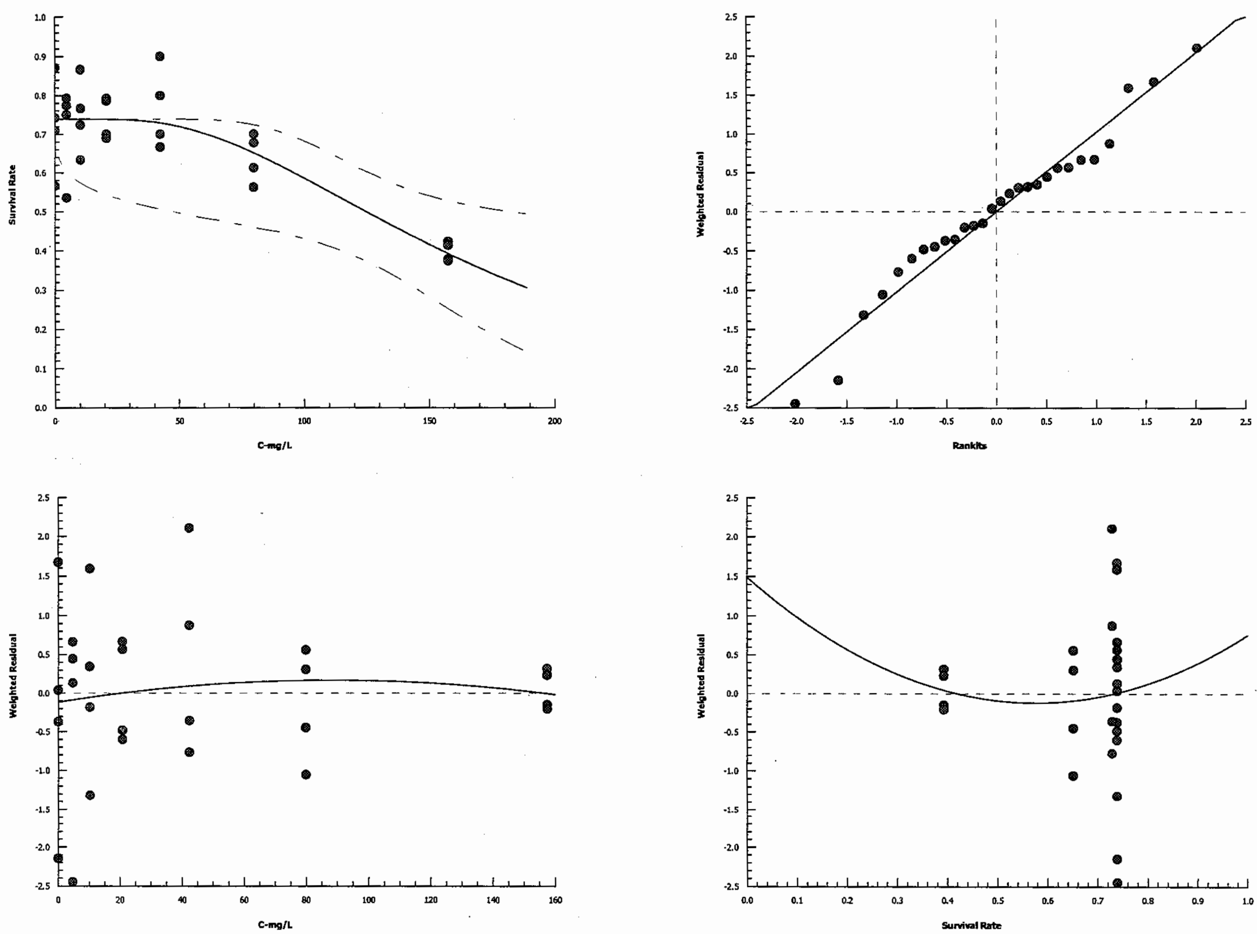
Survival Rate Summary

			Calculated Variate(A/B)								
C-mg/L	**Control Type**	**Count**	**Mean**	**Min**	**Max**	**Std Err**	**Std Dev**	**CV%**	**%Effect**	**A**	**B**
0	Negative Control	4	0.7223	0.5667	0.871	0.0625	0.125	17.3%	0.0%	89	123
4.7 ✓		4	0.7133	0.5357	0.7931	0.05983	0.1197	16.78%	1.25%	83	116
10.3 ✓		4	0.7477	0.6333	0.8667	0.04843	0.09686	12.95%	-3.52%	89	119
20.8 ✓		4	0.7421	0.6897	0.7931	0.02743	0.05485	7.39%	-2.74%	86	116
42.4 ✓		4	0.7667	0.6667	0.9	0.0527	0.1054	13.75%	-6.14%	92	120
79.9 ✓		4	0.6382	0.5625	0.7	0.03126	0.06252	9.8%	11.64%	79	124
157.5 ✓		4	0.3978	0.375	0.4231	0.0121	0.0242	6.08%	44.93%	46	116

Survival Rate Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	0.7419	0.871	0.5667	0.7097
4.7		0.5357	0.7742	0.7931	0.75
10.3		0.7667	0.6333	0.7241	0.8667
20.8		0.7	0.7931	0.6897	0.7857
42.4		0.7	0.8	0.6667	0.9
79.9		0.7	0.5625	0.6129	0.6774
157.5		0.3793	0.4231	0.375	0.4138

Graphics — Log-Normal [NED=A+B*log(X)]



CETIS Analytical Report

Report Date:	11 Jan-13 09:54 (p 1 of 2)
Test Code:	12193 | 18-5559-6750

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	08-1069-4817	**Endpoint:**	Proportion Normal	**CETIS Version:**	CETISv1.8.4
Analyzed:	11 Jan-13 9:52	**Analysis:**	Linear Regression (MLE)	**Official Results:**	Yes

Batch ID:	14-5322-9195	**Test Type:**	Survival-Development	**Analyst:**	Karen Lee
Start Date:	25 Oct-12 17:00	**Protocol:**	EC/EPS 1/RM/28	**Diluent:**	Dechlorinated Tap Water
Ending Date:	26 Nov-12 14:00	**Species:**	Oncorhynchus mykiss	**Brine:**	
Duration:	31d 21h	**Source:**	Fraser Valley Trout Hatchery	**Age:**	

Sample ID:	02-2758-5265	**Code:**	D90ACF1	**Client:**	Golder
Sample Date:	25 Oct-12 17:00	**Material:**	Strontium	**Project:**	
Receive Date:	25 Oct-12 17:00	**Source:**	Golder		
Sample Age:	NA	**Station:**	Strontium in Dechlor Water		

Linear Regression Options

Model Function	Threshold Option	Threshold	Optimized	Pooled	Het Corr	Weighted
Log-Normal [NED=A+B*log(X)]	Control Threshold	0.292683	Yes	No	No	Yes

Regression Summary

Iters	LL	AICc	BIC	Mu	Sigma	Adj R2	F Stat	Critical	P-Value	Decision(α:5%)
22	-519.7	1046	1049	2.226	0.2613	0.5526	0.4323	2.84	0.7837	Non-Significant Lack of Fit

Point Estimates

Level	mg/L	95% LCL	95% UCL
EC5	62.53	12.61	89.46
EC10	77.81	23.51	103.2
EC15	90.17	35.61	114.1
EC20	101.4	49.24	124.4
EC25	112.1	64.46	135.2
EC40	144.4	114.1	185.5
EC50	168.2	140	258

Regression Parameters

Parameter	Estimate	Std Error	95% LCL	95% UCL	t Stat	P-Value	Decision(α:5%)
Threshold	0.294	0.01976	0.2553	0.3327	14.88	<0.0001	Significant Parameter
Slope	3.827	1.279	1.321	6.334	2.993	0.0061	Significant Parameter
Intercept	-8.519	2.739	-13.89	-3.15	-3.11	0.0046	Significant Parameter

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Model	41.22927	41.22927	1	35.35	<0.0001	Significant
Lack of Fit	2.218082	0.554521	4	0.4323	0.7837	Non-Significant
Pure Error	26.93838	1.28278	21			
Residual	29.15647	1.166259	25			

Residual Analysis

Attribute	Method	Test Stat	Critical	P-Value	Decision(α:5%)
Goodness-of-Fit	Pearson Chi-Sq GOF	29.16	37.65	0.2574	Non-Significant Heterogenity
	Likelihood Ratio GOF	29.65	37.65	0.2377	Non-Significant Heterogenity
Variances	Bartlett Equality of Variance	11.81	12.59	0.0663	Equal Variances
	Mod Levene Equality of Variance	0.8354	2.573	0.5563	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9552	0.9264	0.2663	Normal Distribution
	Anderson-Darling A2 Normality	0.6369	2.492	0.0973	Normal Distribution

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	08-1069-4817	**Endpoint:**	Proportion Normal	**CETIS Version:**	CETISv1.8.4
Analyzed:	11 Jan-13 9:52	**Analysis:**	Linear Regression (MLE)	**Official Results:**	Yes

Proportion Normal Summary

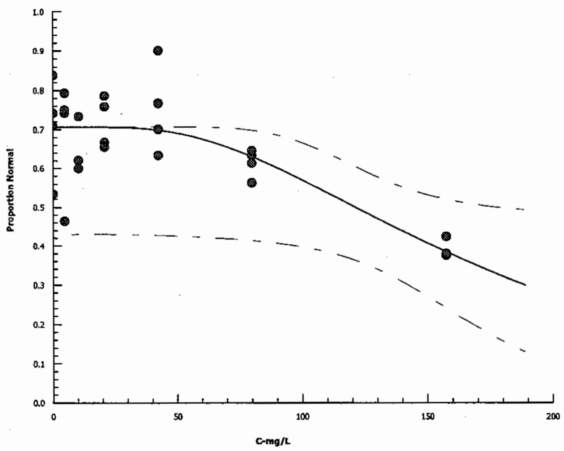
C-mg/L	Control Type	Count	Calculated Variate(A/B) Mean	Min	Max	Std Err	Std Dev	CV%	%Effect	A	B
0	Negative Control	4	0.7059	0.5333	0.8387	0.06372	0.1274	18.05%	0.0%	87	123
4.7		4	0.6873	0.4643	0.7931	0.07519	0.1504	21.88%	2.63%	80	116
10.3		4	0.6718	0.6	0.7333	0.03575	0.07151	10.64%	4.83%	80	119
20.8		4	0.7165	0.6552	0.7857	0.03267	0.06534	9.12%	-1.51%	83	116
42.4		4	0.75	0.6333	0.9	0.05693	0.1139	15.18%	-6.25%	90	120
79.9		4	0.6135	0.5625	0.6452	0.01825	0.0365	5.95%	13.1%	76	124
157.5		4	0.3892	0.375	0.4231	0.01135	0.02269	5.83%	44.87%	45	116

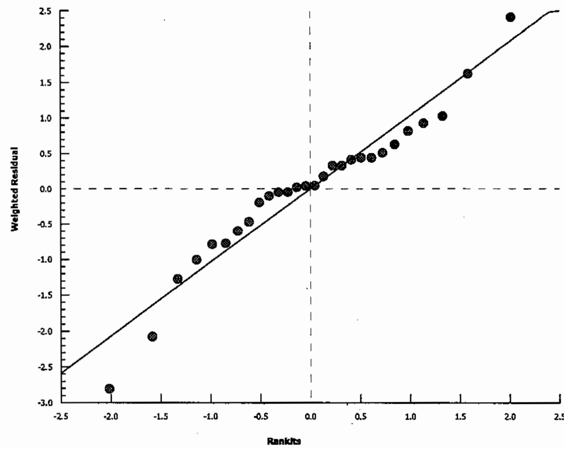
Proportion Normal Detail

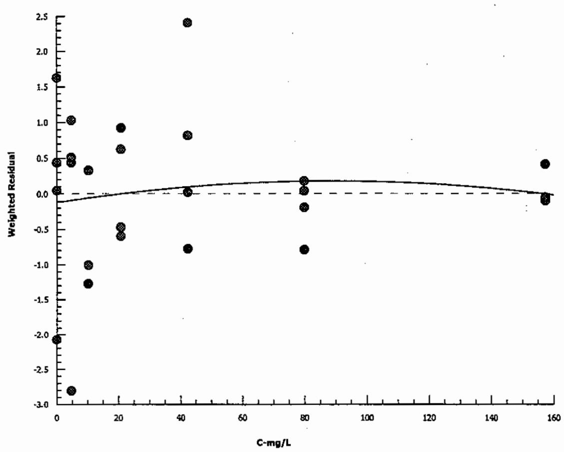
C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	0.7419	0.8387	0.5333	0.7097
4.7		0.4643	0.7419	0.7931	0.75
10.3		0.7333	0.6	0.6207	0.7333
20.8		0.6667	0.7586	0.6552	0.7857
42.4		0.7	0.7667	0.6333	0.9
79.9		0.6333	0.5625	0.6129	0.6452
157.5		0.3793	0.4231	0.375	0.3793

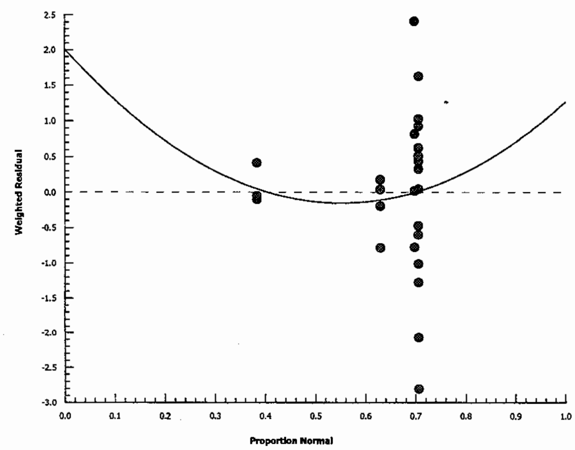
Graphics

Log-Normal [NED=A+B*log(X)]









Rainbow Trout Embryo-Alevin Toxicity Test

Client: Golder **Test Date:October 25, 2012**

WO: 12193

Test Conc.	Rep	Weekly Mortality Counts 1	2	3	4	5	Total Dead	Total Abnormal Alevins	Total Normal Alevins	Total Number Exposed
Control-Dechlor	1	1	1	1	2	3	8 ✓	0	23	31 ✓
	2	1	0	0	1	2	4 ✓	1	26	31 ✓
	3	3	2	0	4	4	13 ✓	1	16	30 ✓
	4	1	1	0	6	1	9 ✓	0	22	31 ✓
5	1	2	0	0	8	3	13 ✓	2	13	28 ✓
	2	1	1	0	3	2	7 ✓	1	23	31 ✓
	3	1	0	0	4	1	6 ✓	0	23	29 ✓
	4	1	2	0	0	4	7 ✓	0	21	28 ✓
10	1	1	1	0	2	3	7 ✓	1	22	30 ✓
	2	1	0	2	1	7	11 ✓	1	18	30 ✓
	3	3	1	0	4	0	8 ✓	3	18	29 ✓
	4	0	0	0	3	1	4 ✓	4	22	30 ✓
20	1	2	2	2	1	2	9 ✓	1	20	30 ✓
	2	0	0	0	2	4	6 ✓	1	22	29 ✓
	3	1	1	0	3	4	9 ✓	1	19	29 ✓
	4	1	0	1	4	0	6 ✓	0	22	28 ✓
40	1	1	0	0	2	6	9 ✓	0	21	30 ✓
	2	1	0	0	5	0	6 ✓	1	23	30 ✓
	3	2	1	1	5	1	10 ✓	1	19	30 ✓
	4	0	0	0	1	2	3 ✓	0	27	30 ✓
80	1	4	0	1	2	2	9 ✓	2	19	30 ✓
	2	3	1	1	5	4	14 ✓	0	18	32 ✓
	3	2	0	1	5	4	12 ✓	0	19	31 ✓
	4	5	0	0	1	4	10 ✓	1	20	31 ✓
160	1	5	0	0	5	8	18 ✓	0	11	29 ✓
	2	5	0	0	5	5	15 ✓	0	11	26 ✓
	3	4	1	0	5	10	20 ✓	0	12	32 ✓
	4	3	1	0	4	9	17 ✓	1	11	29 ✓

JGh
Jan. 10/13

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date & Time: 26-Nov-12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration Control	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.2	9.9	10.2	10.1	10.2	10.1	10.1	9.8	10.2	9.9	10.1	9.5	10.2
pH	7.3	7.2	7.3	7.2	7.1	7.1	7.1	7.1	7.2	7.2	7.0	7.2	7.2	7.0
Cond. (µS/cm)	31	54		42		42		41		46		34		31
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

Concentration 5	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.6	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.3	9.9	10.2	10.2	10.2	10.1	10.1	9.9	10.2	10.1	10.1	9.5	10.1
pH	7.2	7.2	7.1	7.2	7.1	7.1	7.1	7.1	7.2	7.0	7.0	7.3	7.1	7.0
Cond. (µS/cm)	51	57		43		50		42		76		35		33
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

Concentration 10	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.0	10.2	10.1	10.2	10.1	10.1	9.9	10.3	10.1	10.1	9.5	10.2
pH	7.1	7.2	7.1	7.2	7.1	7.1	7.2	7.1	7.1	7.0	7.0	7.3	7.0	7.0
Cond. (µS/cm)	65	83		67		69		67		78		69		66
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

Concentration 20	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.0	10.2	10.1	10.2	10.1	10.1	9.9	10.1	10.1	10.2	9.6	10.2
pH	7.1	7.0	7.0	7.2	7.1	7.1	7.2	7.2	7.0	7.0	6.9	7.3	7.0	7.0
Cond. (µS/cm)	95	115		96		102		103		114		98		91
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

DO meter: DO-1
pH meter: pH-1
Conductivity meter: C-1

	Control			
Hardness*	~~100~~ [illegible]	11-12		
Alkalinity*	~~60-64~~ 11-12	7-11		

* mg/L as CaCO3

Analysts: KLB, AWD, KJL, JW
Reviewed by: JGL
Date reviewed: Jan-10/13

Sample Description: Clear; dechlorinated water spiked with strontium

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: 26-Nov-12 @1400h
Test Species: *Oncorhynchus mykiss*

Concentration 40	Days 0	1		2		3		4		5		6		7
	Init	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.0	10.2	10.1	10.2	10.1	10.1	9.9	10.1	10.1	10.2	9.7	10.1
pH	7.0	6.8	7.0	7.2	7.1	7.1	7.1	7.1	7.0	7.2	6.9	7.2	6.9	7.0
Cond. (µS/cm)	151	153		150		148		KLB ~~161~~ 161		136		164		146
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

Concentration 80	Days 0	1		2		3		4		5		6		7
	Init	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.0	10.2	10.1	10.2	10.1	10.1	9.9	10.1	10.1	10.2	9.6	10.1
pH	7.0	6.9	6.9	7.0	7.0	7.1	7.1	7.0	7.0	~~7.1~~ ER	6.9	7.0	6.9	6.9
Cond. (µS/cm)	262	267		264		261		280		6.9 290		265		275
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

Concentration 160	Days 0	1		2		3		4		5		6		7
	Init	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	13.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.1	10.2	10.2	10.2	10.0	10.1	9.9	10.2	10.1	10.2	9.6	10.2
pH	6.9	6.9	6.8	6.5	7.0	7.0	7.1	7.0	6.9	~~7.0~~ ER	6.8	7.0	6.8	6.9
Cond. (µS/cm)	486	500		497		503		506		6.8 532		536		575
Initials	KLB	KLB		^		^		KLB		KJL		JW		KJL

Concentration	Days 0	1		2		3		4		5		6		7
	Init	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	~~110~~ 100-112			
Alkalinity*	60-64			

* mg/L as CaCO3 7-11

Analysts: KLB, AWD, KJL, JW
Reviewed by: JGL
Date reviewed: Jan-10/13

Sample Description: clear; dechlorinated water spiked with strontium

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date & Time: 26-Nov-12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration Control	7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	~~15.0~~ 14.0	14.0	14.0	14.0
DO (mg/L)	10.1	10.0	10.3	10.0	10.1	10.0	9.8	~~10.2~~ 10.1	10.0	10.1	9.7	9.6	9.7	10.0
pH	6.9	6.5	7.1	7.0	7.2	7.3	7.1	7.0	7.3	6.9	7.3	6.9	6.9	6.5
Cond. (µS/cm)	41	33		34		34		34		33		30		30
Initials	KJL	KJL		[illegible]		[illegible]		KJL		JW		JW		KJL

Concentration 5	7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	13.5	14.0	14.0
DO (mg/L)	10.1	10.0	10.2	10.0	10.1	10.0	9.9	10.0	9.9	10.3	9.8	10.0	9.9	9.7
pH	6.9	6.5	7.1	7.0	7.1	7.3	7.1	6.9	7.3	7.3	7.2	6.8	6.9	6.7
Cond. (µS/cm)	65	59		55		57		50		47		JW ~~35~~ 45		33
Initials	KJL	KJL		[illegible]		[illegible]		KJL		JW		JW		KJL

Concentration 10	7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	13.5	14.0	14.0
DO (mg/L)	10.2	10.0	10.1	10.0	10.1	10.0	9.5	10.1	9.9	10.3	9.8	10.0	9.8	9.9
pH	6.9	6.7	7.1	7.0	7.1	7.3	7.1	6.9	7.2	7.3	7.1	6.8	6.9	6.6
Cond. (µS/cm)	77	62		61		63		65		60		62		63
Initials	KJL	KJL		[illegible]		[illegible]		KJL		JW		JW		KJL

Concentration 20	7	8		9		10		11		12		13		14
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	13.5	14.0	14.0
DO (mg/L)	10.1	10.0	10.3	10.0	10.0	10.0	9.9	10.1	10.0	10.3	9.8	9.9	9.9	9.9
pH	6.9	6.8	7.1	7.0	7.1	7.3	7.0	6.9	7.1	7.3	7.1	6.8	6.8	6.7
Cond. (µS/cm)	103	98		92		90		92		90		86		93
Initials	KJL	KJL		[illegible]		[illegible]		KJL		JW		JW		KJL

DO meter: DO-1 pH meter: pH-1 Conductivity meter: C-1

	Control			
Hardness*	~~100~~ 112			
Alkalinity*	~~60~~ 64			

* mg/L as CaCO3 7-11

Analysts: KJL, AWD, JW
Reviewed by: JGu
Date reviewed: Jan. 10/13

Sample Description: Clear; dechlor water spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	Start Date & Time:	25-Oct-12 @ 1700h
Sample ID:	Strontium (Dechlor)	Stop Date & Time:	26-Nov-12 @ 1400h
Work Order #:	12193	Test Species:	*Oncorhynchus mykiss*

Concentration 40	Days 7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	13.5	14.0	14.0
DO (mg/L)	10.1	10.0	10.1	10.0	10.1	10.0	9.9	10.0	10.0	10.3	9.8	9.9	9.9	9.7
pH	6.9	6.9	7.0	7.0	7.1	7.3	7.0	6.9	7.1	7.2	7.0	6.8	6.8	6.7
Cond. (µS/cm)	161	159		155		152		148		147		153		153
Initials	KJL	KJL		~		~		KJL		JW		JW		KJL

Concentration 80	Days 7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	13.5	14.0	14.0
DO (mg/L)	10.2	10.0	10.1	10.0	10.1	10.0	9.8	10.0	10.0	10.3	9.9	10.0	9.9	10.0
pH	6.9	6.7	7.0	6.9	7.1	7.3	6.9	6.9	7.0	7.1	7.0	6.8	6.8	6.6
Cond. (µS/cm)	294	285		285		280		278		267		313		295
Initials	KJL	KJL		~		~		KJL		JW		JW		KJL

Concentration 160	Days 7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	13.5	14.0	14.0
DO (mg/L)	10.1	10.1	10.2	10.0	10.0	10.0	9.9	10.1	10.1	10.3	10.0	10.0	9.9	9.7
pH	6.9	6.7	7.0	6.8	7.1	7.3	6.9	6.8	7.0	7.1	7.0	6.8	6.8	6.6
Cond. (µS/cm)	494	473		492		490		504		483		438		499
Initials	KJL	KJL		~		~		KJL		JW		JW		KJL

Concentration	Days 7	8		9		10		11		12		13		14
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials	KJL													

DO meter: DO-1   pH meter: pH-1   Conductivity meter: C-1

	Control			
Hardness*	100 11-12			
Alkalinity*	60-64 7-11			

* mg/L as CaCO3

Analysts: KJL, AWD, JW

Reviewed by: JGL

Date reviewed: Jan. 10/13

Sample Description: Clear; Dechlor water spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date & Time: 26-Nov-12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration Control	14 old	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	~~15~~ 13.5
DO (mg/L)	10.0	10.1	10.0	10.1	10.1	10.1	10.1	10.1	10.1	9.7	9.7	10.0	10.0	10.1
pH	6.8	7.1	6.8	7.0	7.0	7.0	7.2	7.0	7.2	7.1	7.0	7.1	6.8	7.2
Cond. (µS/cm)	39	32		32		32		32		36		31		32
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 5	14 old	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.0	10.1	10.0	10.0	10.1	10.1	10.1	10.1	10.0	10.2	9.7	10.0	10.0	10.1
pH	6.8	7.3	6.8	7.0	6.9	7.0	7.1	7.0	7.2	7.2	6.9	7.2	6.8	7.0
Cond. (µS/cm)	50	47		41		43		35		36		43		47
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 10	14 old	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.0	10.2	10.0	10.0	10.1	10.1	10.1	10.1	10.1	10.3	9.7	10.0	10.0	10.1
pH	6.8	7.1	6.8	7.0	6.9	7.0	~~7.0~~ 7.1	7.0	7.1	7.2	6.9	7.1	6.8	7.0
Cond. (µS/cm)	62	62		53		58		52		65		69		64
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 20	14 Initial	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.2	9.9	10.0	10.1	10.1	10.1	10.1	10.1	10.2	9.8	10.0	10.1	10.1
pH	6.8	7.1	6.8	7.0	6.9	7.0	7.0	7.0	7.1	7.0	6.9	7.1	6.8	7.0
Cond. (µS/cm)	94	95		88		86		82		90		93		95
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	~~100~~ 112			
Alkalinity*	60-~~64~~			

* mg/L as CaCO3

7-11

Analysts: KJL, AWD, EMM
Reviewed by: JBL
Date reviewed: Jan-10/13

Sample Description: Clear; declor water spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: 26/Nov/12 @1400h
Test Species: *Oncorhynchus mykiss*

Concentration 40	Days 14	15		16		17		18		19		20		21
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.1	10.1	10.0	10.0	10.0	10.1	10.1	10.1	10.1	10.2	9.8	10.0	9.9	10.1
pH	6.7	7.0	6.8	7.0	6.8	7.0	6.9	7.0	7.1	7.0	6.9	7.0	6.8	7.0
Cond. (µS/cm)	167	159		145		152		149		149		153		153
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 80	Days 14	15		16		17		18		19		20		21
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.2	10.0	10.0	10.0	10.1	10.2	10.1	10.1	10.1	9.8	[illegible]	9.9	10.1
pH	6.7	7.0	6.8	7.0	6.9	7.0	6.8	6.9	7.0	7.0	6.9	6.9	6.8	7.0
Cond. (µS/cm)	267	275		268		275		258		~~258~~ 263		270		271
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 160	Days 14	15		16		17		18		19		20		21
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.2	9.9	10.0	10.1	10.1	10.1	10.1	10.1	10.2	9.8	10.0	10.0	10.0
pH	6.7	7.0	6.8	7.0	6.9	7.0	6.7	6.8	7.0	6.8	6.8	6.9	6.8	6.8
Cond. (µS/cm)	~~5~~ 488	503		512		510		504		473		477		497
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration	Days 14	15		16		17		18		19		20		21
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	~~100-100~~ 142			
Alkalinity*	~~60-64~~ 71			

* mg/L as CaCO3

Analysts: KJL AWD, EMM
Reviewed by: JGL
Date reviewed: Jan-10/13

Sample Description: Clear; dechlor water spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	**Start Date & Time:**	25-Oct-12 @1700h
Sample ID:	Strontium (Dechlor)	**Stop Date & Time:**	26-Nov-12 @1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Concentration Control	Days													
	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.7	9.9	9.8	10.1	10.0	9.8	10.0	9.9	10.0	10.2	10.0	10.1	9.9	10.0
pH	6.9	7.1	7.2	7.1	7.2	7.1	7.2	7.1	7.1	6.7	7.0	6.5	7.2	7.5
Cond. (µS/cm)	34	31		32		32		32		33		32		35
Initials	KJL	KJL/JW		^		^		KJL		KJL		KJL		JJT

Concentration 5	Days													
	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.7	10.1	9.8	10.1	10.0	9.8	10.0	10.1	10.0	10.1	10.0	10.1	9.9	9.9
pH	6.9	7.1	7.1	7.1	7.2	7.1	7.2	7.2	7.1	6.7	7.2	6.6	7.1	7.2
Cond. (µS/cm)	51	46		43		46		47		50		47		48
Initials	KJL	KJL/JW		^		^		KJL		KJL		KJL		JJT

Concentration 10	Days													
	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.7	10.1	9.9	10.1	10.0	9.8	10.0	10.0	9.9	10.1	10.0	10.1	9.9	9.9
pH	6.9	7.0	7.1	7.1	7.2	7.1	7.3	7.2	7.1	6.7	7.1	6.7	7.1	7.1
Cond. (µS/cm)	69	62		54		55		52		62		49		70
Initials	KJL	KJL/JW		^		^		KJL		KJL		KJL		JJT

Concentration 20	Days													
	21	22		23		24		25		26		27		28
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.8	10.1	10.0	10.1	10.1	9.8	10.1	9.9	9.7	10.1	10.0	10.1	9.9	10.0
pH	6.9	7.1	7.0	7.1	7.2	7.1	7.2	7.1	7.1	6.8	7.1	6.6	7.1	7.1
Cond. (µS/cm)	94	98		84		86		93		89		92		95
Initials	KJL	KJL/JW		^		^		KJL		KJL		KJL		JJT

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	~~100~~ 11-12			
Alkalinity*	~~60-64~~ 7-11			

* mg/L as CaCO3

Analysts: KJL, AWD

Reviewed by: JGL

Date reviewed: Jan-10/13

Sample Description: Day 25 - Control A-26, B-28, C-23, D-23 hatch (approximate)

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: 26-Nov-12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration 40	21 old	22 new	22 old	23 new	23 old	24 new	24 old	25 new	25 old	26 new	26 old	27 new	27 old	28 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.8	10.1	10.0	10.1	10.0	9.8	9.9	10.0	9.8	10.1	10.1	10.0	10.0	10.0
pH	7.0	7.1	7.0	7.0	7.1	7.0	7.1	7.1	7.1	6.8	7.0	6.7	7.0	7.1
Cond. (µS/cm)	154	155		142		145		151		149		148		140
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

Concentration 80	21 old	22 new	22 old	23 new	23 old	24 new	24 old	25 new	25 old	26 new	26 old	27 new	27 old	28 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.7	10.1	10.0	10.1	10.0	9.8	9.9	10.0	9.9	10.1	10.1	10.1	9.9	10.0
pH	6.9	7.0	7.0	7.0	7.1	7.0	7.1	7.1	7.1	6.7	7.0	6.7	7.0	7.0
Cond. (µS/cm)	269	265		253		256		245		269		232		272
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

Concentration 160	21 old	22 new	22 old	23 new	23 old	24 new	24 old	25 new	25 old	26 new	26 old	27 new	27 old	28 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.7	10.1	10.0	10.1	10.0	9.8	10.0	10.0	10.1	10.1	10.0	10.0	9.9	10.0
pH	6.8	7.0	6.9	6.8	7.0	6.9	7.0	7.0	7.1	6.7	7.0	6.7	7.0	7.0
Cond. (µS/cm)	504	505		494		492		503		498		487		498
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

Concentration	21 Initial	22 new	22 old	23 new	23 old	24 new	24 old	25 new	25 old	26 new	26 old	27 new	27 old	28 new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials	[illegible]													

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	104/100 11-12			
Alkalinity*	6 7-11			

* mg/L as CaCO3

Analysts: KJL, AWD
Reviewed by: JGL
Date reviewed: Jan 10/13

Sample Description:

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date & Time: 26-Nov-12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration Control	28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	10.0	10.0	10.1	10.2	9.6	9.9	9.8	/	9.7					
pH	6.8	7.3	7.2	7.0	7.1	7.2	7.2	/	6.9					
Cond. (µS/cm)	37	33		34		35		43						
Initials	JJT	KJL		~		~		KJL						

Concentration 5	28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.9	10.0	10.1	10.2	9.7	9.9	9.8	/	9.7					
pH	6.8	7.2	7.2	7.0	7.2	7.2	7.1	/	6.9					
Cond. (µS/cm)	55	40		52		51		65						
Initials	JJT	KJL		~		~		KJL						

Concentration 10	28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	10.1	10.1	10.2	9.8	9.9	9.7	/	9.6					
pH	6.8	7.1	7.1	7.0	7.2	7.2	7.1	/	6.9					
Cond. (µS/cm)	70	67		74		72		83						
Initials	JJT	KJL		~		~		KJL						

Concentration 20	28	29		30		31		32		33		34		35
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	10.1	10.1	10.2	9.6	9.9	9.8	/	9.7					
pH	6.8	7.1	7.0	7.0	7.2	7.2	7.1	/	6.9					
Cond. (µS/cm)	101	94		102		105		105						
Initials	JJT	KJL		~		~		KJL						

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	11-12			
Alkalinity*	7-11			

* mg/L as $CaCO_3$

Analysts: JJT, KJL, AWD
Reviewed by: JGL
Date reviewed: Jan. 10/13

Sample Description:

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	**Start Date & Time:**	25-Oct-12 1700h
Sample ID:	Strontium (Dechlor)	**Stop Date & Time:**	26-Nov-12 1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Concentration 40	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	10.1	10.1	10.2	9.5	9.9	9.7	/	9.7					
pH	6.8	7.0	7.0	7.0	7.0	7.2	98	/	7.0					
Cond. (µS/cm)	162	~~204~~ 141		169		165		162						
Initials	JJT	KJL		″		″		KJL						

Concentration 80	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	9.8	10.1	10.2	9.6	9.9	9.7	/	9.8					
pH	6.8	7.1	6.9	7.0	7.0	7.2	7.1	/	7.0					
Cond. (µS/cm)	275	269		280		277		287						
Initials	JJT	KJL		″		″		KJL						

Concentration 160	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	13.5	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	9.9	10.1	10.2	9.5	9.9	9.8	/	9.8					
pH	6.8	6.9	6.9	7.0	7.0	7.1	7.1	/	7.0					
Cond. (µS/cm)	508	539		506		510		519						
Initials	JJT	KJL		″		″		KJL						

Concentration	Days 28	29		30		31		32		33		34		35
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: DO-1 **pH meter:** pH-1 **Conductivity meter:** C-1

	Control			
Hardness*	11-12			
Alkalinity*	7-11			

* mg/L as CaCO3

Analysts: JJT, KJL, AWD

Reviewed by: JGK

Date reviewed: Jan. 10/13

Sample Description:

Comments:

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client:	Golder	**Start Date & Time:**	25-Oct-12 @ 1700h
Sample ID:	Strontium (Dechlor)	**Stop Date:**	26-Nov-12 @ 1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 1	2	3	4	5	6	7	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	0	0	0	0	1	1			~~30~~ JGW
	B	0					0	1	1			
	C	0					1	2	3			
	D	0					0	1	1			
5	A	0					0	2	2			
	B	0					0	1	1			
	C	0					0	1	1			
	D	0					0	1	1			
10	A	0					0	1	1			
	B	0					0	1	1			
	C	0					1	2	3			
	D	0					0	0	0			
20	A	0					0	2	2			
	B	0					0	0	0			
	C	0					0	1	1			
	D	0					0	1	1			
40	A	0					0	1	1			
	B	0					0	1	1			
	C	0					0	2	2			
	D	0					0	0	0			
80	A	0					0	4	4			
	B	0					2	1	3			
	C	0					1	~~4~~ 1	2			
	D	0					1	4	5			
160	A	0					0	5	5			
	B	0					1	4	5			
	C	0					2	2	4			
	D	0					0	3	3			
	A											
	B											
	C											
	D											
Tech Initials		JW			KLB	KJL	JJL	KJL	KJL			KJL

Comments:

Reviewed by: JGW **Date reviewed:** Jan. 10/13

Version 1.0 Issued June 26, 2006

Nautilus Environmental

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 1700h
Stop Date: 26-Nov-12 @ 1100h
Test Species: *Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 8	9	10	11	12	13	14	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	1	0	0	0	0	0	✓	1			~~30~~ 40 [initials]
	B	0		0	0	0	0		0			
	C	1		1	0	0	0		2			
	D	0		0	0	0	1		1			
5	A	0		0	0	0	0		0			
	B	0		1	0	0	0		1			
	C	0		0	0	0	0		0			
	D	0		1	0	0	1		2			
10	A	0		0	0	1	0		1			
	B	0		0	0	0		[initials]	0			
	C	0		0	1	0			1			
	D	0		0	0	0			0			
20	A	0		1	0	1		[initials]	2			
	B	0		0	0	0			0			
	C	1				0			1			
	D	0				0			0			
40	A	0				0			0			
	B	0				0			0			
	C	1				0			1			
	D	0				0			0			
80	A	0				0			0			
	B	0			[initials] 1	0			1			
	C	0				0		[initials]	0			
	D	0				0			0			
160	A	0				0			0			
	B	0				0			0			
	C	0			[initials] 1	0			1			
	D	0				1			1			
	A											
	B											
	C											
	D											
Tech Initials		KJL	✓	✓	KJL	JW	KJL	KJL	KJL			KJL

Comments:

Reviewed by: JOh

Date reviewed: Jan. 10/13

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date: 26-Nov-12 @1400h
Test Species: *Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 15	16	17	18	19	20	21	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	0	0	0	0	1	1			30
	B							0	0			
	C							0	0			
	D							0	0			
5	A							0	0			
	B							0	0			
	C							0	0			
	D							0	0			
10	A			0			0	0	0			
	B	1		0			1	0	2			
	C	0		0			0	0	0			
	D	0		0				0	0			
20	A	1		1				0	2			
	B			0				0	0			
	C							0	0			
	D						1	0	1			
40	A						0	0	0			
	B						0	0	0			
	C						0	1	1			
	D						0	0	0			
80	A						1	0	1			
	B						1	0	1			
	C	1					0	0	1			
	D	0						0	0			
160	A							0	0			
	B							0	0			
	C							0	0			
	D							0	0			
	A											
	B											
	C											
	D											
Tech Initials		JW	"	"	"	KJL	KJL	KJL	KJL			KJL

Comments:

Reviewed by: JOh

Date reviewed: Jan. 10/13

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client:	Golder	**Start Date & Time:**	25-Oct-12 1700h
Sample ID:	Strontium (Dechlor)	**Stop Date:**	26-Nov-12 1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 22	23	24	25	26	27	28	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	1	0	1	0	0	2			30 KJL
	B			1	0	0	0	0	1			
	C			1	1	0	2	0	4			
	D			1	3	0	6	2	6			
5	A			5 (1)	0	2	0	1	8			
	B			0		0	3	0	3			
	C			1			0	3	4			
	D			0			0	0	0			
10	A		1	0			1	0	2			
	B		0			1	0		1			
	C		0			0	4		4			
	D		1			2	0		3			
20	A		0			1	0		1			
	B		2			0	0		2			
	C		0			2	1 ~~2~~		3			
	D		1			0	2	1	4 ~~3~~			
40	A		1				0	1	2			
	B		0					5	5			
	C		1			4		0	5			
	D		0			0		1	1			
80	A		0	0		2	0	0	2			
	B		1	2		0	2	0	5			
	C		2	0			1	2	5			
	D		0	0			0	1	1			
160	A		1	0			0	3	5			
	B	0	0	2			3	0	5			
	C	0	2	0			2	1	5			
	D	0	1	0			0	3	4			
	A											
	B											
	C											
	D											
Tech Initials		KJL	~	~	KJL	KJL	KJL	KJL	ECC			KJL

Comments: (1) egg breakdown debris present

Reviewed by: JGL **Date reviewed:** Jan-10/13

Version 1.0 Issued June 26, 2006

Nautilus Environmental

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (Dechlor)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date: 26-Nov-12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration (mg/L Sr)	Rep	Day of Test - No. of Mortalities 29	30	31	32	33	34	35	Total Dead Fish	Total Undeveloped	Total No. Fry	Total Exposed
Control	A	0	0	0	3				3			31
	B	0	↓	↓	2				2			31
	C	0	↓	↓	4				4			30
	D	0	↓	↓	1				1			31
5	A	0	↓	↓	3				3			28
	B	0	↓	1	1				2			31
	C	0	↓	0	1				1			29
	D	4	↓	↓	0				4			28
10	A	1	↓	↓	2				3			30
	B	1	↓	↓	6				7			30
	C	0	↓	↓	0				0			29
	D	0	↓	1	0				1			30
20	A	0	↓	1	1				2			30
	B	2	↓	0	2				4			29
	C	0	↓	↓	4				4			29
	D	0	↓	↓	0				0			28
40	A	1	↓	↓	5				6			30
	B	0	↓	↓	0				0			30
	C	↓	↓	↓	1				1			30
	D	↓	↓	↓	2				2			30
80	A	↓	↓	↓	2				2			30
	B	↓	↓	1	3				4			32
	C	↓	↓	0	4				4			31
	D	↓	↓	0	4				4			31
160	A	1	↓	0	7				8			29
	B	0	↓	0	5				5			26
	C	0	↓	1	9				10			32
	D	0	↓	1	8				9			29
	A											
	B											
	C											
	D											
Tech Initials		KJL	^	~	KJL				KJL			KJL

Comments:

Reviewed by: JGh **Date reviewed:** Jan. 11/13

Strontium (Dechlor Water)

Day: 32

		Normal hatched	Abnormal hatched	Unhatched	Dead
Control	A	23	0	0	3
Control	B	26	1	0	2
Control	C	16	1	0	4
Control	D	22	0	0	1
5	A	13	2	0	3
5	B	23	1	0	1
5	C	23	0	0	1
5	D	21	0	0	0
10	A	22	1	2	0
10	B	18	1	0	6
10	C	18	3	0	0
10	D	22	4	0	0
20	A	20	1	1	0
20	B	22	1	2	0
20	C	19	1	2	2
20	D	22	0	0	0
40	A	21	0	0	5
40	B	23	1	0	0
40	C	19	1	0	1
40	D	27	0	0	2
80	A	19	2	0	2
80	B	18	0	1	2
80	C	19	0	2	2
80	D	20	1	3	1
160	A	11	0	0	7
160	B	11	0	0	5
160	C	12	0	0	9
160	D	11	1	1	7

♀
A - 6h, 6un
B - 10h, 3d
C - 22h
D - 21h

JGh
Jan 11/13

Strontium (Dechlor Water)

Day - 32

		Normal hatched	Abnormal hatched	Dead
Control	A	23	0	3
Control	B	26	1	2
Control	C	16	1	4
Control	D	22	0	1
5	A	13	2	3
5	B	23	1	1
5	C	23	0	1
5	D	21	0	0
10	A	22	1	2
10	B	18	1	6
10	C	18	3	0
10	D	22	4	0
20	A	20	1	1
20	B	22	1	2
20	C	19	1	4
20	D	22	0	0
40	A	21	0	5
40	B	23	1	0
40	C	19	1	1
40	D	27	0	2
80	A	19	2	2
80	B	18	0	3
80	C	19	0	4
80	D	20	1	4
160	A	11	0	7
160	B	11	0	5
160	C	12	0	9
160	D	11	1	8

JGh
Jan. 10/13

Rainbow Trout Embryo Summary Sheet

Client: Golder

Start Date/Time: Oct 25, 2012 @ 1700h

Work Order No.: 12193

Test Species: *Oncorhynchus mykiss*

Sample Information:

Sample ID: Strontium in Moderately Hard Water
Sample Date: n/a
Date Received: n/a
Sample Volume: n/a

Dilution Water:

Type: Moderately Hard Water
Hardness (mg/L $CaCO_3$): 98 - 100
Alkalinity (mg/L $CaCO_3$): 58 - 64

Test Organism Information:

Batch No.: 102512
Source: Fraser Valley Trout Hatchery
Loading Density: n/a

SDS Reference Toxicant Results:

Reference Toxicant ID: RTE39
Stock Solution ID: 12SO2
Date Initiated: 25-Oct-12
7-d EC50 (95% CL): 2.3 (2.1 - 2.5) mg/L SDS

Reference Toxicant Mean and Range: 4.2 (1.9 - 9.4) mg/L SDS
Reference Toxicant CV (%): 49

Test Results:

	Survival	Proportion normal
EC25 (mg/L) (95% CL)	>151	>151
EC50 (mg/L) (95% CL)	>151	>151

Reviewed by: JGL

Date reviewed: Jan. 4/13

CETIS Analytical Report

Report Date: 21 Dec-12 11:38 (p 1 of 2)
Test Code: 12193b | 11-8840-3279

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	12-4770-7529	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.8.4
Analyzed:	21 Dec-12 11:38	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	09-1470-1516	**Test Type:**	Survival-Development	**Analyst:**	Karen Lee
Start Date:	25 Oct-12 17:00	**Protocol:**	EC/EPS 1/RM/28	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	26 Nov-12 14:00	**Species:**	Oncorhynchus mykiss	**Brine:**	
Duration:	31d 21h	**Source:**	Fraser Valley Trout Hatchery	**Age:**	

Sample ID:	06-0694-0544	**Code:**	242D2D80	**Client:**	Golder
Sample Date:	25 Oct-12 17:00	**Material:**	Strontium	**Project:**	
Receive Date:	~~26 Nov-12 14:00~~ JCL	**Source:**	Golder		
Sample Age:	NA	**Station:**	Strontium in Moderately Hard Water		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	1970874	200	Yes	Two-Point Interpolation

Point Estimates

Level	mg/L	95% LCL	95% UCL
EC5	1.422	N/A	N/A
EC10	>151	N/A	N/A
EC15	>151	N/A	N/A
EC20	>151	N/A	N/A
EC25	>151	N/A	N/A
EC40	>151	N/A	N/A
EC50	>151	N/A	N/A

Survival Rate Summary

			Calculated Variate(A/B)								
C-mg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect	A	B
0	Negative Control	4	0.8391	0.7241	0.9655	0.05639	0.1128	13.44%	0.0%	99	118
4		4	0.6737	0.5862	0.7419	0.03298	0.06596	9.79%	19.71%	81	120
10.7		4	0.7937	0.7419	0.8387	0.02342	0.04685	5.9%	5.41%	96	121
20.1		4	0.7859	0.7143	0.8571	0.03624	0.07247	9.22%	6.34%	92	117
39.5		4	0.7658	0.7333	0.8	0.01781	0.03563	4.65%	8.73%	83	108
78.4		4	0.7649	0.6786	0.8462	0.0358	0.0716	9.36%	8.84%	87	114
151		4	0.7899	0.7241	0.8276	0.02305	0.0461	5.84%	5.86%	90	114

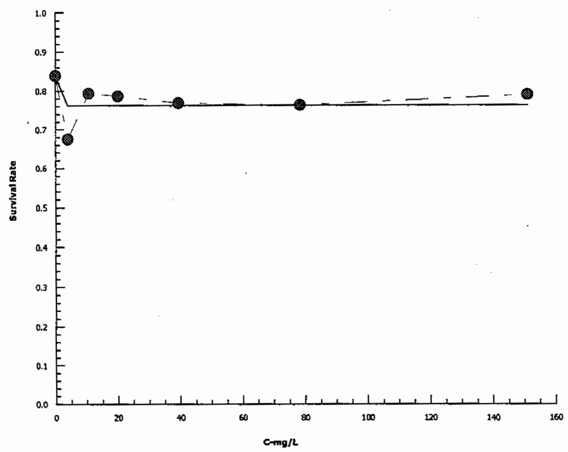
Survival Rate Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	0.7241	0.9655	0.7667	0.9
4 ✓		0.6667	0.7419	0.5862	0.7
10.7 ✓		0.8387	0.7667	0.8276	0.7419
20.1 ✓		0.7143	0.8571	0.7333	0.8387
39.5 ✓		0.8	0.7931	0.7368	0.7333
78.4 ✓		0.7931	0.6786	0.8462	0.7419
151 ✓		0.7241	0.8276	0.8148	0.7931

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	12-4770-7529	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.8.4
Analyzed:	21 Dec-12 11:38	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



CETIS Analytical Report

Report Date:	21 Dec-12 11:38 (p 1 of 2)	**Test Code:**	12193b | 11-8840-3279

Salmonid Embryo-Alevin Survival and Development Test — **Nautilus Environmental**

Analysis ID:	01-8558-3418	**Endpoint:**	Proportion Normal	**CETIS Version:**	CETISv1.8.4
Analyzed:	21 Dec-12 11:38	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	09-1470-1516	**Test Type:**	Survival-Development	**Analyst:**	Karen Lee
Start Date:	25 Oct-12 17:00	**Protocol:**	EC/EPS 1/RM/28	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	26 Nov-12 14:00	**Species:**	Oncorhynchus mykiss	**Brine:**	
Duration:	31d 21h	**Source:**	Fraser Valley Trout Hatchery	**Age:**	

Sample ID:	06-0694-0544	**Code:**	242D2D80	**Client:**	Golder
Sample Date:	25 Oct-12 17:00	**Material:**	Strontium	**Project:**	
Receive Date:	~~26 Nov-12 14:00~~ 10A	**Source:**	Golder		
Sample Age:	NA	**Station:**	Strontium in Moderately Hard Water		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	43786	200	Yes	Two-Point Interpolation

Point Estimates

Level	mg/L	95% LCL	95% UCL
EC5	1.012	0.116	N/A
EC10	3.048	N/A	N/A
EC15	>151	N/A	N/A
EC20	>151	N/A	N/A
EC25	>151	N/A	N/A
EC40	>151	N/A	N/A
EC50	>151	N/A	N/A

Proportion Normal Summary

			Calculated Variate(A/B)								
C-mg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect	A	B
0	Negative Control	4	0.8135	0.6552	0.9655	0.06658	0.1332	16.37%	0.0%	96	118
4		4	0.632	0.5517	0.7097	0.035	0.07001	11.08%	22.31%	76	120
10.7		4	0.7451	0.6774	0.8276	0.031	0.062	8.32%	8.41%	90	121
20.1		4	0.7254	0.6429	0.8065	0.0413	0.0826	11.39%	10.83%	85	117
39.5		4	0.7658	0.7333	0.8	0.01781	0.03563	4.65%	5.86%	83	108
78.4		4	0.7198	0.6071	0.7931	0.04144	0.08289	11.52%	11.52%	82	114
151		4	0.7283	0.6897	0.7931	0.02473	0.04947	6.79%	10.48%	83	114

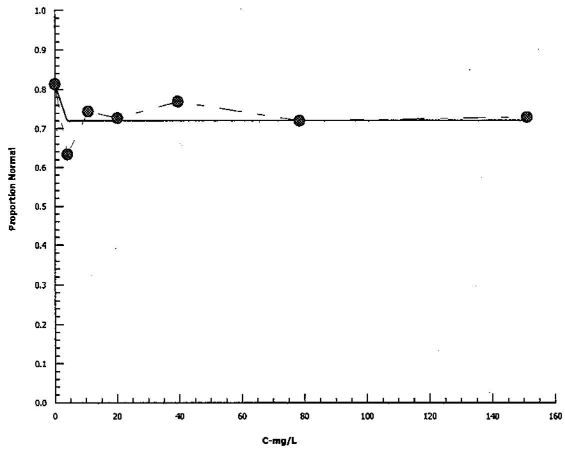
Proportion Normal Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	0.6552	0.9655	0.7667	0.8667
4		0.6667	0.7097	0.5517	0.6
10.7		0.7419	0.7333	0.8276	0.6774
20.1		0.6429	0.7857	0.6667	0.8065
39.5		0.8	0.7931	0.7368	0.7333
78.4		0.7931	0.6071	0.7692	0.7097
151		0.6897	0.7931	0.7407	0.6897

Salmonid Embryo-Alevin Survival and Development Test | **Nautilus Environmental**

Analysis ID:	01-8558-3418	**Endpoint:**	Proportion Normal	**CETIS Version:**	CETISv1.8.4
Analyzed:	21 Dec-12 11:38	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



Rainbow Trout Embryo-Alevin Toxicity Test

Client: Golder

Test Date:October 25, 2012

WO: 12193

Test Conc.	Rep	Weekly Mortality Counts 1	2	3	4	5	Total Dead	Total Abnormal Alevins	Total Normal Alevins	Total Number Exposed
Control-MHW	1	1	0	0	3	4	8 ✓	2	19	29 ✓
	2	0	0	0	1	0	1 ✓	0	28	29 ✓
	3	0	2	0	1	4	7 ✓	0	23	30 ✓
	4	0	0	0	1	2	3 ✓	1	26	30 ✓
5	1	2	0	0	3	5	10 ✓	0	20	30 ✓
	2	2	0	0	3	3	8 ✓	1	22	31 ✓
	3	1	4	0	6	1	12 ✓	1	16	29 ✓
	4	2	0	0	7	0	9 ✓	3	18	30 ✓
10	1	0	0	0	3	2	5 ✓	3	23	31 ✓
	2	3	0	0	1	3	7 ✓	1	22	30 ✓
	3	2	0	0	2	1	5 ✓	0	24	29 ✓
	4	0	0	0	6	2	8 ✓	2	21	31 ✓
20	1	3	1	0	3	1	8 ✓	2	18	28 ✓
	2	1	0	0	3	0	4 ✓	2	22	28 ✓
	3	1	0	0	5	2	8 ✓	2	20	30 ✓
	4	1	0	0	4	0	5 ✓	1	25	31 ✓
40	1	0	0	0	2	4	6 ✓	0	24	30 ✓
	2	2	1	0	1	2	6 ✓	0	23	29 ✓
	3	0	2	0	1	2	5 ✓	0	14	19 ✓
	4	2	0	1	4	1	8 ✓	0	22	30 ✓
80	1	1	0	1	2	2	6 ✓	0	23	29 ✓
	2	2	2	0	2	3	9 ✓	2	17	28 ✓
	3	1	1	0	1	1	4 ✓	2	20	26 ✓
	4	3	1	0	1	3	8 ✓	1	22	31 ✓
160	1	2	1	0	2	3	8 ✓	1	20	29 ✓
	2	1	0	2	2	0	5 ✓	1	23	29 ✓
	3	0	0	2	2	1	5 ✓	2	20	27 ✓
	4	2	0	1	1	2	6 ✓	3	20	29 ✓

JOL
Jan-11/13

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	**Start Date & Time:**	25-Oct-12 @ 1700h
Sample ID:	Strontium (MHW)	**Stop Date & Time:**	Nov 26/12 @ 1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Concentration Control	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.1	9.9	10.1	10.1	10.1	10.1	10.0	9.9	10.1	10.1	10.3	9.6	9.6
pH	7.8	7.6	7.6	7.7	7.7	7.8	7.7	7.9	7.8	~~10.1~~	7.7	7.8	7.6	7.8
Cond. (µS/cm)	302	300		299		302		308		7.8 315		322		321
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

Concentration 5	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	15.0	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.1	10.0	10.1	10.1	10.1	10.1	10.0	10.0	10.2	10.2	9.7	9.7	9.8
pH	7.8	7.7	7.7	7.7	7.7	7.8	7.7	~~7.8~~ 7.9	7.8	~~10.1~~ 7.8	7.8	7.7	7.7	7.7
Cond. (µS/cm)	314	316		310		309		323		328		319		335
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

Concentration 10	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.0	10.0	10.1	10.1	10.1	10.1	10.0	10.0	10.1	10.1	9.8	9.7	9.8
pH	7.9	7.8	7.7	7.7	7.7	7.8	7.7	7.9	7.8	~~10.1~~ KJL	7.8	7.7	7.7	7.8
Cond. (µS/cm)	328	328		321		324		338		7.8 331		323		344
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

Concentration 20	Day 0 Initial	Day 1 new	Day 1 old	Day 2 new	Day 2 old	Day 3 new	Day 3 old	Day 4 new	Day 4 old	Day 5 new	Day 5 old	Day 6 new	Day 6 old	Day 7 new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.0	10.0	10.1	10.2	10.1	10.1	10.0	10.0	10.0 7.7	10.1	9.8	9.7	10.0
pH	7.8	7.8	7.7	7.7	7.7	7.8	7.7	7.9	7.8	~~10.0~~	7.8	7.8	7.7	7.8
Cond. (µS/cm)	354	353		348		342		363		414		350		361
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

DO meter: ______ **pH meter:** ______ **Conductivity meter:** ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KLB, AND, KJL, JW

Reviewed by: JOle

Date reviewed: Jan. 11/13

Sample Description: Clear; Moderately hard water spiked with Strontium

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	**Start Date & Time:**	25-Oct-12 @1700h
Sample ID:	Strontium (MHW)	**Stop Date & Time:**	Nov 26/12 @1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Concentration 40	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.1	10.0	10.1	10.0	10.1	10.0	10.0	10.0	10.1	10.1	9.9	9.7	10.0
pH	7.8	7.8	7.7	7.7	7.8	7.8	7.7	7.9	7.8	~~10.1~~	7.8	7.8	7.7	7.7
Cond. (µS/cm)	406	405		402		403		420		~~7.74~~ 460		417		440
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

Concentration 80	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.1	10.0	10.1	10.0	10.1	10.0	10.0	10.0	10.2	10.1	9.9	9.7	10.1
pH	7.8	7.7	7.7	7.7	7.8	7.7	7.7	7.9	7.8	~~10.2~~ 7.6	7.7	7.8	7.7	7.8
Cond. (µS/cm)	509	502		497		495		528		526		537		511
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

Concentration 160	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.5	14.0	14.5	14.5	14.5	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.1	10.0	10.1	10.0	10.1	10.0	10.0	10.0	10.2 ~~7.7~~	6.1	10.0	9.7	10.0
pH	7.8	7.7	7.7	7.7	7.8	7.7	7.7	7.8	7.7	~~10.2~~	7.7	7.8	7.7	7.8
Cond. (µS/cm)	640	690		705		695		743		748		721		~~792~~ 770
Initials	KLB	KLB		~		~		KLB		KJL		JW		KJL

Concentration	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: ____________ **pH meter:** ____________ **Conductivity meter:** ____________

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KLB, AVD, KJL, JW

Reviewed by: JGM

Date reviewed: Jan. 11/13

Sample Description: clear; MHW spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration Control	Day 7 old	Day 8 new	Day 8 old	Day 9 new	Day 9 old	Day 10 new	Day 10 old	Day 11 new	Day 11 old	Day 12 new	Day 12 old	Day 13 new	Day 13 old	Day 14 new
Temperature (°C)	14.0	14.0	14.0	~~[illegible]~~ 14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.2	10.0	10.0	10.3	9.8	10.0	10.1	10.3	9.8	9.8	9.5	10.1
pH	7.7	7.7	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.7	7.76	7.7	7.8
Cond. (µS/cm)	325	320		323		314		315		322		JW 320		~~[illegible]~~ 323
Initials	KJL	KJL			^	^		KJL		JW		JW		KJL

Concentration 5	Day 7 old	Day 8 new	Day 8 old	Day 9 new	Day 9 old	Day 10 new	Day 10 old	Day 11 new	Day 11 old	Day 12 new	Day 12 old	Day 13 new	Day 13 old	Day 14 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.5	14.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.2	10.0	10.1	10.0	9.8	10.0	10.1	9.8	9.8	10.0	9.8	10.0
pH	7.7	7.8	7.8	7.9	7.8	7.8	7.8	~~7.7~~ 7.8	7.8	7.7	7.7	7.67	7.7	7.7
Cond. (µS/cm)	338	354		334		339		320		328		JW 336		325
Initials	KJL	KJL			^	^		KJL		JW		JW		KJL

Concentration 10	Day 7 old	Day 8 new	Day 8 old	Day 9 new	Day 9 old	Day 10 new	Day 10 old	Day 11 new	Day 11 old	Day 12 new	Day 12 old	Day 13 new	Day 13 old	Day 14 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.0	14.0	14.0
DO (mg/L)	10.1	10.3	10.1	10.0	10.1	10.0	9.8	10.0	10.1	9.9	9.8	9.9	9.8	10.0
pH	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.7	7.7	7.6	7.7	7.7
Cond. (µS/cm)	354	383		350		347		350		342		330		343
Initials	KJL	KJL			^	^		KJL		JW		JW		KJL

Concentration 20	Day 7 Initial	Day 8 new	Day 8 old	Day 9 new	Day 9 old	Day 10 new	Day 10 old	Day 11 new	Day 11 old	Day 12 new	Day 12 old	Day 13 new	Day 13 old	Day 14 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.0	14.0	14.0
DO (mg/L)	KJL ~~7.8~~ 10.1	10.1	10.2	10.0	10.1	10.0	9.9	10.0	10.2	9.9	9.8	10.1	9.8	10.0
pH	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.7	7.7	7.6	7.7	7.7
Cond. (µS/cm)	390	381		375		378		380		373		380		365
Initials	KJL	KJL			^	^		KJL		JW		JW		KJL

DO meter: ______ **pH meter:** ______ **Conductivity meter:** ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL, AWD, JW
Reviewed by: JW
Date reviewed: Jan. 11/13

Sample Description: Clear; MHW spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration 40	Days 7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.0	14.0	14.0
DO (mg/L)	10.1	10.2	10.2	10.0	10.1	10.0	9.9	10.0	10.1	9.9	9.9	10.0	9.9	10.2
pH	7.8	7.8	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.7	7.7	7.6	7.7	7.7
Cond. (µS/cm)	434	421		415		418		418		418		436		495
Initials	KJL	KJL		^		^		KJL		JW		JW		KJL

Concentration 80	Days 7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.0	14.0	14.0
DO (mg/L)	10.0	10.3	10.2	10.0	10.1	10.0	9.8	10.1	10.1	9.9	9.9	10.1	9.9	10.2
pH	7.7	7.8	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.7	7.6	7.7	7.7
Cond. (µS/cm)	497	529		508		515		520		521		~~577~~ 533		586
Initials	KJL	KJL		^		^		KJL		JW		JW		KJL

Concentration 160	Days 7	8		9		10		11		12		13		14
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.5	14.0	14.0	14.0
DO (mg/L)	10.2	10.1	10.3	10.0	10.0	10.0	9.8	10.1	10.1	9.9	9.9	10.1	9.9	10.1
pH	7.7	7.9	7.8	7.9	7.8	7.8	7.7	7.8	7.8	7.8	7.7	7.6	7.7	7.7
Cond. (µS/cm)	733	778		737		732		770		733		755		732
Initials	KJL	KJL		^		^		KJL		JW		JW		KJL

Concentration	Days 7	8		9		10		11		12		13		14
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: ______ **pH meter:** ______ **Conductivity meter:** ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL, AWD, JW
Reviewed by: JGL
Date reviewed: Jan. 11/13

Sample Description: Clear; MHW spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: Nov 26/12 @1400h
Test Species: *Oncorhynchus mykiss*

Concentration Control	14 old	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.1	10.0	10.1	10.1	10.1	10.1	10.1	10.1	10.2	9.8	10.1	10.0	10.1
pH	7.7	7.6	7.6	7.7	7.5	7.8	7.8	7.7	7.8	7.8	7.7	7.7	7.7	7.8
Cond. (µS/cm)	326	335		333 ~~333~~		332		333		330		328		355
Initials	KJL	EMM		^		~		^		KJL		KJL		KJL

Concentration 5	14 old	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.1	10.0	10.1	10.0	10.1	10.1	10.1	10.0	10.2	9.8	10.0	9.9	10.1
pH	7.7	7.7	7.7	7.7	7.5	7.8	7.8	7.7	7.8	7.7	7.8	7.8	7.7	7.7
Cond. (µS/cm)	KJL 338	350		345		348		340		342		343		343
Initials	KJL	EMM		^		~		^		KJL		KJL		KJL

Concentration 10	14 old	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.2	10.0	10.1	10.0	10.1	10.1	10.1	10.0	10.2	9.8	10.0	9.9	10.1
pH	7.7	7.7	7.7	7.7	7.5	7.8	7.8	7.7	7.8	7.7	7.8	7.8	7.7	7.8
Cond. (µS/cm)	349	362		351		355		348		353		346		358
Initials	KJL	EMM		^		~		^		KJL		KJL		KJL

Concentration 20	14 Initial	15 new	15 old	16 new	16 old	17 new	17 old	18 new	18 old	19 new	19 old	20 new	20 old	21 new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.2	10.2	9.9	10.1	10.0	10.1	10.1	10.1	10.0	10.2	9.9	10.0	9.7	10.1
pH	7.7	7.7	7.7	7.7	7.6	7.8	7.8	7.7	7.8	7.8	7.8	7.8	7.7	7.8
Cond. (µS/cm)	374	388		385		388		382		371 ~~358~~ KJL		390		371
Initials	KJL	EMM		^		~		^		KJL		KJL		KJL

DO meter: ______ pH meter: ______ Conductivity meter: ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL, AWD, EMM
Reviewed by: JGb
Date reviewed: Jan. 4/13

Sample Description: Clear; MHW spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	Start Date & Time:	25-Oct-12 @1700h
Sample ID:	Strontium (MHW)	Stop Date & Time:	Nov 26/12 @1400h
Work Order #:	12193	Test Species:	*Oncorhynchus mykiss*

Concentration 40	14	15		16		17		18		19		20		21
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.1	10.1	10.0	10.1	10.0	10.1	10.1	10.1	10.1	10.2	9.8	10.0	10.0	10.1
pH	7.7	7.7	7.7	7.7	7.5	7.8	7.8	7.7	7.7	7.8	7.8	7.8	7.7	7.8
Cond. (µS/cm)	426	452		435		438		431		472		420		444
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 80	14	15		16		17		18		19		20		21
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.1	10.2	9.9	10.1	10.0	10.2	10.1	10.1	10.1	10.2	9.8	10.0	10.0	10.1
pH	7.6	7.7	7.6	7.6	7.5	7.7	7.7	7.7	7.7	7.7	7.8	7.8	7.7	7.8
Cond. (µS/cm)	554	556		542		536		529		539		556		547
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration 160	14	15		16		17		18		19		20		21
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.5
DO (mg/L)	10.1	10.2	9.9	10.1	10.1	10.1	10.1	10.1	10.1	10.1	9.9	10.0	10.0	10.1
pH	7.7	7.7	7.6	7.6	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.6	7.7	7.7
Cond. (µS/cm)	727	762		764		767		759		769		695		660
Initials	KJL	EMM		^		^		^		KJL		KJL		KJL

Concentration	14	15		16		17		18		19		20		21
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: ____________ pH meter: ____________ Conductivity meter: ____________

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL, AWD, EMM

Reviewed by: JGL

Date reviewed: Jan 11/13

Sample Description: clear; MHW spiked with Sr

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	**Start Date & Time:**	25-Oct-12 @1700h
Sample ID:	Strontium (MHW)	**Stop Date & Time:**	Nov26/12 @ 1400h
Work Order #:	12193	**Test Species:**	*Oncorhynchus mykiss*

Concentration Control	Days													
	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.5	10.1	10.0	10.1	10.0	10.0	9.8	10.1	9.7	10.2	9.6	10.1	10.0	10.0
pH	7.7	7.6	7.5	7.8	7.8	7.7	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.6
Cond. (µS/cm)	332	334		332		335		333		343		337		351
Initials	KJL	JW		~		~		KJL		KJL		KJL		JJT

Concentration 5	Days													
	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.4	10.1	10.0	10.1	10.0	10.0	9.9	10.0	9.7	10.0	9.7	10.1	9.9	10.0
pH	7.7	7.6	7.6	7.8	7.8	7.7	7.8	7.6	7.7	7.6	7.6	7.2	7.6	7.6
Cond. (µS/cm)	352	350		354		352		348		358		348		357
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

Concentration 10	Days													
	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.4	10.1	10.0	10.1	10.1	10.0	9.9	10.1	9.8	10.1	9.7	10.2	9.9	10.0
pH	7.7	7.6	7.6	7.8	7.8	7.7	7.8	7.7	7.7	7.6	7.6	7.4	7.6	7.7
Cond. (µS/cm)	366	363		357		359		368		356		371		369
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

Concentration 20	Days													
	21	22		23		24		25		26		27		28
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.6	10.1	10.0	10.1	10.1	10.0	9.8	10.1	9.7	10.1	9.9	10.2	10.0	10.0
pH	7.7	7.6	7.6	7.8	7.8	7.7	7.8	7.7	7.7	7.6	7.6	7.5	7.6	7.7
Cond. (µS/cm)	389	389		379		372		369		363		380		399
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

DO meter: ______ **pH meter:** ______ **Conductivity meter:** ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL, AWD, JW, JJT

Reviewed by: JGL

Date reviewed: Jan. 11/13

Sample Description: 5A not aerating D21, aeration restarted. D25 CONTROL: A-25, B-30, C-25, D-27 hatch (approximate)

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: Nov 26/12 @1400h
Test Species: *Oncorhynchus mykiss*

Concentration 40	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.6	10.1	10.0	10.1	10.0	10.0	10.0	10.0	9.7	10.1	9.7	10.1	10.0	10.0
pH	7.7	7.6	7.6	7.8	7.8	7.7	7.8	7.7	7.7	7.6	7.6	7.6	7.7	7.7
Cond. (µS/cm)	442	436		425		429		444		395		432		448
Initials	KJL	KJL/JW		~		~		KJL		KJL		KJL		JJT

Concentration 80	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.6	10.1	10.0	10.1	10.0	~~9.8~~ 10.0	9.9	10.0	9.9	10.1	9.9	10.2	9.9	10.0
pH	7.7	7.6	7.6	7.8	7.8	7.7	7.8	7.7	7.7	7.6	7.6	7.5	7.6	7.7
Cond. (µS/cm)	548	553		549		552		552		557		515		566
Initials	KJL	KJL/JW		~		^		KJL		KJL		KJL		JJT

Concentration 160	21	22		23		24		25		26		27		28
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	14.0	14.0	14.0	14.0
DO (mg/L)	9.7	10.1	10.0	10.1	10.1	10.0	9.8	9.9	9.9	10.1	9.9	10.0	10.0	10.0
pH	7.7	7.6	7.6	7.8	7.7	7.7	7.7	7.7	7.7	7.6	7.6	7.6	7.6	7.7
Cond. (µS/cm)	748	737		731		729		763		~~775~~ 762		739		772
Initials	KJL	KJL/JW		~		^		KJL		KJL KJL		KJL		JJT

Concentration	21	22		23		24		25		26		27		28
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials	~~KJL~~ KJL													

DO meter: ______ **pH meter:** ______ **Conductivity meter:** ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL, AWD, JW, JJT
Reviewed by: JGu
Date reviewed: Jan-11/13

Sample Description:

Comments:

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client:	Golder	Start Date & Time:	25-Oct-12 @1700h
Sample ID:	Strontium (MHW)	Stop Date & Time:	Nov 26/12 @1400h
Work Order #:	12193	Test Species:	*Oncorhynchus mykiss*

Concentration Control	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.7	10.0	10.0	10.2	9.8	9.9	9.8	/	9.6					
pH	7.5	7.8	7.5	7.8	7.8	7.8	7.8	/	7.7					
Cond. (µS/cm)	348	324		325		325		326						
Initials	JJT	KJL		~		~		KJL						

Concentration 5	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.7	10.0	10.0	10.2	9.7	9.9	9.8	/	9.6					
pH	7.6	7.8	7.5	7.8	7.7	7.8	7.9	/	7.7					
Cond. (µS/cm)	367	325		358		360		349						
Initials	JJT	KJL		^		^		KJL						

Concentration 10	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	① 9.7	10.1	10.0	10.2	9.6	9.5	9.8	/	9.7					
pH	7.6	~~347~~ 7.9	7.6	7.8	7.7	7.8	7.9	/	7.6					
Cond. (µS/cm)	380	~~333~~ 336		370		367		367						
Initials	JJT	KJL		^		^		KJL						

Concentration 20	Days 28	29		30		31		32		33		34		35
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.7	10.1	10.0	10.2	9.6	9.5	9.8	/	9.7					
pH	7.7	7.9	7.6	7.8	7.7	7.8	7.9	/	7.6					
Cond. (µS/cm)	405	373		402		405		394						
Initials	JJT	KJL		~		~		KJL						

DO meter: ____________ pH meter: ____________ Conductivity meter: ____________

	Control			
Hardness*	98-100			
Alkalinity*	56-64			

* mg/L as CaCO3

Analysts: KJL/AWD/JJT

Reviewed by: JGu

Date reviewed: Jan 4/13

Sample Description: ____________

Comments: ① Day 28: Rep 10B was not aerated (DO = 5.6) - Aeration restored.

Embryo-Alevin Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date & Time: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Concentration 40	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	10.2	10.0	10.2	9.7	9.9	9.8	/	9.7					
pH	7.7	8.0	7.6	7.8	7.6	7.8	7.8	/	7.6					
Cond. (µS/cm)	452	444		450		442		451						
Initials	JJT	KJL		~		~		KJL						

Concentration 80	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.0	14.0	~~14.6~~ 14.0	/	14.0					
DO (mg/L)	9.8	10.1	10.0	10.2	9.6	9.9	9.8	/	9.7					
pH	7.7	8.0	7.5	7.7	7.7	7.7	7.8	/	7.6					
Cond. (µS/cm)	570	530		567		559		556						
Initials	JJT	KJL		~		~		KJL						

Concentration 160	Days 28	29		30		31		32		33		34		35
	old	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)	14.5	14.0	14.0	14.0	14.0	14.0	14.0	/	14.0					
DO (mg/L)	9.8	10.1	10.0	10.2	9.6	9.9	9.8	/	9.7					
pH	7.7	8.0	7.5	7.7	7.6	7.6	7.8	/	7.6					
Cond. (µS/cm)	764	750		768		762		761						
Initials	JJT	KJL		~		~		KJL						

Concentration	Days 28	29		30		31		32		33		34		35
	Initial	new	old	new	old	new	old	new	old	new	old	new	old	new
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

DO meter: ______ pH meter: ______ Conductivity meter: ______

	Control			
Hardness*	98-100			
Alkalinity*	58-64			

* mg/L as CaCO3

Analysts: KJL/AWD/JJT

Reviewed by: JGL

Date reviewed: Jan. 11/13

Sample Description:

Comments:

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 1	2	3	4	5	6	7	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	0	0	0	0	1	1			~~30~~ JOU
	B	0	↓	↓	↓	↓	0	0	0			↓
	C	0					0	0	0			
	D	0					0	0	0			
5	A	0					1	1	2			
	B	0					0	2	2			
	C	0					0	1	1			
	D	0					0	2	2			
10	A	0					0	0	0			
	B	0					0	3	3			
	C	0					0	2	2			
	D	0					0	0	0			
20	A	0					2	1	3			
	B	0					0	1	1			
	C	0					0	1	1			
	D	0					0	1	1			
40	A	0					0	0	0			
	B	0					1	~~2~~ 1 KJL	2			
	C	0					0	0	0			
	D	0					0	2	2			
80	A	0					0	1	1			
	B	0					1	1	2			
	C	0					0	1	1			
	D	0					0	3	3			
160	A	0					0	2	2			
	B	0					0	1	1			
	C	0					0	0	0			
	D	0	↓	↓	↓	↓	1	1	2			
	A											
	B											
	C											
	D											↓
Tech Initials		JW	~	~	KW	KJL	JJT	KJL	KJL			KJL

Comments:

Reviewed by: JGh

Date reviewed: Jan-11/13

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 1700h
Stop Date: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities: 8	9	10	11	12	13	14	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	0	0	0	0	0	0			~~80~~ 100
	B	0	↓	↓	0	0	0	0	0			↓
	C	0			0	1	1	0	2			
	D	0			0	0	0	0	0			
5	A	0			0	0	0	0	0			
	B	0		↓	0	0	0	0	0			
	C	0		2	1	0	1	0	4			
	D	0		0	0	0	0	0	0			
10	A	0		↓	0	0	0	0	0			
	B	0			0	0	↓	0	0			
	C	0			0	0		0	0			
	D	0			0	0		0	0			
20	A	0			1	0		0	1			
	B	0			0	0		0	0			
	C	0			0	0		0	0			
	D	0			0	0		0	0			
40	A	0			0	0		0	0			
	B	1			0	0		0	1			
	C	0			2	0		0	2			
	D	0			0	0		0	0			
80	A	0			0	0		0	0			
	B	1			1	0		0	2			
	C	1			0	0		0	1			
	D	0			1	0		0	1			
160	A	1				0		0	1			
	B	0			0	0		0	0			
	C	0			0	0		0	0			
	D	0	↓	↓	0	0	↓	0	0			
	A											
	B											
	C											
	D											↓
Tech Initials		KJL	"	"	KJL	JW	KJL	KJL	KJL			KJL

Comments:

Reviewed by: JCole

Date reviewed: Jan. 11/13

Version 1.0 Issued June 26, 2006

Nautilus Environmental

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 1700h
Stop Date: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 15	16	17	18	19	20	21	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	0	0	0	0	0	0			30
	B							0	0			
	C							0	0			
	D							0	0			
5	A							0	0			
	B							0	0			
	C							0	0			
	D							0	0			
10	A							0	0			
	B							0	0			
	C							0	0			
	D							0	0			
20	A							0	0			
	B							0	0			
	C							0	0			
	D							0	0			
40	A							0	0			
	B							0	0			
	C							0	0			
	D			1				0	1			
80	A			0			1	0	1			
	B						0	0	0			
	C							0	0			
	D							0	0			
160	A							0	0			
	B			1	1			0	KJL 2			
	C			2	0			0	KJL 2			
	D	1		0	0			0	1			
	A											
	B											
	C											
	D											
Tech Initials		JW	"	"	"	KJL	KJL	KJL	KJL			KJL

Comments:

Reviewed by: JGL

Date reviewed: Jan. 11/13

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @ 1700h
Stop Date: Nov 26/12 @ 1400h
Test Species: *Oncorhynchus mykiss*

Treatments (mg/L Sr)	Rep	Day of Test - No. of Mortalities 22	23	24	25	26	27	28	Total Dead Eggs/ Embryos Alevins	Total Undeveloped/ Unhatched Embryos	Total No. Alevins	Total Exposed
Control	A	0	0	2	0	0	1	0	3			~~30~~ JCK
	B	0		1	0		0	0	1			
	C	0		1	0			0	1			
	D	0		1	0			0	1			
5	A	0		2	0			1	3			
	B	1		0	0		1	1	3			
	C	0		1	0		0	5	6			
	D			4	1			2	7			
10	A			1	1			1	3			
	B			0	0			1	1			
	C			2	0			0	2			
	D			0	0	4		2	6			
20	A		0	0	1	0		2	3			
	B	1	0		0			2	3			
	C	0	4		0			1	5			
	D	0	0		2			2	4			
40	A	0	0		1	1		0	2			
	B	1	0		0	0		0	1			
	C	0	0					1	1			
	D		0					4	4			
80	A		0	1				1	2			
	B		1	0				1	2			
	C		0	0				1	1			
	D			0			1	0	1			
160	A			0		2	0	0	2			
	B			0	1	0	0	1	2			
	C			1	0	0	0	1	2			
	D			0	0	0	0	1	1			
	A											
	B											
	C											
	D											
Tech Initials		KJL	^	~	KJL	KJL	KJL	KJL	ECC			KJL

Comments:

Reviewed by: JCK

Date reviewed: Jan. 11/13

Version 1.0 Issued June 26, 2006

Nautilus Environmental

Embryo-Alevin-Fry Toxicity Test
Daily Mortality

Client: Golder
Sample ID: Strontium (MHW)
Work Order #: 12193

Start Date & Time: 25-Oct-12 @1700h
Stop Date: 26-NOV-12 @1400h
Test Species: *Oncorhynchus mykiss*

Concentration (mg/L Sr)	Rep	Day of Test - No. of Mortalities 29	30	31	32	33	34	35	Total Dead Fish	Total Undeveloped	Total No. Fry	Total Exposed
Control	A	0	0	0	4				4			29
	B	0			0				0			29
	C	0			4				4			30
	D	1			1				2			30
5	A	3			2				5			30
	B	0			3				3			31
	C	1			1				1			29
	D				0				0			30
10	A	↓			2				2			31
	B	1			2				3			30
	C	0			1				1			29
	D				2				2			31
20	A				1				1			28
	B			↓	0				0			28
	C			1	1				2			30
	D			0	0				0			31
40	A	↓		1	3				4			30
	B	1		0	1				2			29
	C	0		1	2				2			19
	D				1				1			30
80	A			↓	2				2			29
	B			1	2				3			28
	C			0	1				1			26
	D			1	2				3			31
160	A			1	2				3			29
	B			0	0				0			29
	C			0	1				1			27
	D	↓	↓	0	2				2			29
	A											
	B											
	C											
	D											
Tech Initials		KJL	^	^	KJL				KJL			KJL

Comments:

Reviewed by: JCh

Date reviewed: Jan. 11/13

Strontium (Moderately Hard Water)

Day: 32

		Normal hatched	Abnormal hatched	Unhatched	Dead
Control	A	19	2	3	1
Control	B	28	0	0	0
Control	C	23	0	3	1
Control	D	26	1	0	1
5	A	20	0	2	0
5	B	22	1	2	1
5	C	16	1	1	0
5	D	18	3	0	0
10	A	23	3	1	1
10	B	22	1	0	2
10	C	24	0	1	0
10	D	21	2	2	0
20	A	18	2	0	1
20	B	22	2	0	0
20	C	20	2	0	1
20	D	25	1	0	0
40	A	24	0	2	1
40	B	23	0	0	1
40	C	14	0	1	1
40	D	22	0	1	0
80	A	23	0	2	0
80	B	17	2	0	2
80	C	20	2	1	0
80	D	22	1	1	1
160	A	20	1	0	2
160	B	23	1	0	0
160	C	20	2	1	0
160	D	20	3	1	1

J Oh
Jan. 11/13

Strontium (Moderately Hard Water)

Day - 32

		Normal hatched	Abnormal hatched	Dead
Control	A	19	2	~~3~~ 4
Control	B	28	0	0
Control	C	23	0	4
Control	D	26	1	1
5	A	20	0	2
5	B	22	1	3
5	C	16	1	1
5	D	18	3	0
10	A	23	3	2
10	B	22	1	2
10	C	24	0	1
10	D	21	2	2
20	A	18	2	1
20	B	22	2	0
20	C	20	2	1
20	D	25	1	0
40	A	24	0	3
40	B	23	0	1
40	C	14	0	2
40	D	22	0	1
80	A	23	0	2
80	B	17	2	2
80	C	20	2	1
80	D	22	1	2
160	A	20	1	2
160	B	23	1	0
160	C	20	2	1
160	D	20	3	2

JOK
Jan. 11/13

Client: Golder

W.O.#: 12193

Hardness and Alkalinity Datasheet

	Alkalinity						Hardness			
Sample ID	Sample Date	Sample Volume (mL)	(mL) 0.02N HCL/H_2SO_4 used to pH 4.5	(mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Total Alkalinity (mg/L$CaCO_3$)		Sample Volume (mL)	Volume of 0.01M EDTA Used (mL)	Total Hardness (mg/L $CaCO_3$)	Technician
MHW Control	Oct 26/12	50	3.0	3.1	58		50	4.9	98	KLB
MHW Control	Nov 5/12	50	3.1	3.2	60		50	5.0	100	KLB
MHW Control	Nov 14/12	50	3.3	3.4	64		50	5.0	100	KLB

Notes:

Reviewed by: JGh

Date Reviewed: Jan. 10/13

APPENDIX B – Analytical chemistry data

Analytical measurements on solutions at test initiation

NAUTILUS ENVIRONMENTAL
ATTN: Karen Lee
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 27-NOV-12
Report Date: 04-DEC-12 13:19 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: **L1242991**
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers: 1, 2
Legal Site Desc:

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1242991-1	L1242991-2	L1242991-3	L1242991-4	L1242991-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	25-OCT-12	25-OCT-12	25-OCT-12	25-OCT-12	25-OCT-12
	Sampled Time					
	Client ID	DC - CONTROL SR	DC - 5MG/L SR	DC - 10MG/L SR	DC - 20MG/L SR	DC - 40MG/L SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	0.0140	4.70	10.1	22.0	46.2

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1242991-6	L1242991-7	L1242991-8	L1242991-9	L1242991-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	25-OCT-12	25-OCT-12	25-OCT-12	25-OCT-12	25-OCT-12
	Sampled Time					
	Client ID	DC - 80MG/L SR	DC - 160MG/L SR	MHW - CONTROL SR	MHW - 5MG/L SR	MHW - 10MG/L SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	84.0	165	0.0176	5.62	10.9

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1242991-11 WATER 25-OCT-12 MHW - 20MG/L SR	L1242991-12 WATER 25-OCT-12 MHW - 40MG/L SR	L1242991-13 WATER 25-OCT-12 MHW - 80MG/L SR	L1242991-14 WATER 25-OCT-12 MHW - 160MG/L SR	
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	21.7	41.2	82.0	165	

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
MET-TOT-MS-VA	Water	Total Metals in Water by ICPMS	EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

1	2

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

L1242991

L1242991-COFC

British Columbia
8664 Commerce Court
Canada V5A 4N3

Chain of Custody

Date ~~Oct 25/12~~ Nov 27/12 KL Page 1 of 2

Sample Collection By:

Report to:		Invoice To:	
Company	Nautilus Environmental	Company	Nautilus Environmental
Address	8664 Commerce Court	Address	8664 Commerce Court
City/State/Zip	Burnaby, BC, V5A 4N3	City/State/Zip	Burnaby, BC, V5A 4N3
Contact	Karen Lee	Contact	Karen Lee
Phone		Phone	
Email	karen@nautilusenvironmental.com	Email	karen@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	DC - Control Sr	25-Oct-12			125ml Bottle	1		x										
2	DC - 5mg/L Sr	25-Oct-12			125ml Bottle	1		x										
3	DC - 10mg/L Sr	25-Oct-12			125ml Bottle	1		x										
4	DC - 20mg/L Sr	25-Oct-12			125ml Bottle	1		x										
5	DC - 40mg/L Sr	25-Oct-12			125ml Bottle	1		x										
6	DC - 80mg/L Sr	25-Oct-12			125ml Bottle	1		x										
7	DC - 160mg/L Sr	25-Oct-12			125ml Bottle	1		x										
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

RELINQUISHED BY (CLIENT)
(Signature) [signature] (Time) 1800 h
(Printed Name) Karen Lee (Date) ~~October 25,~~ Nov 27 2012 KL
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

SPECIAL INSTRUCTIONS/COMMENTS: RBT embryo strontium test in dechlorinated water. Day 0. Samples are not preserved.

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) [signature] (Time) 18:45
(Printed Name) (Date) Nov 27
(Company) temp 11.2

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

Nautilus Environmental

Chain of Custody

British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

L1242991

Date ~~Oct 25/12~~ Nov 27/12 Page 2 of 2

L1242991-COFC

Sample Collection By:

Report to:

Company	Nautilus Environmental
Address	8664 Commerce Court
City/State/Zip	Burnaby, BC, V5A 4N3
Contact	Karen Lee
Phone	
Email	karen@nautilusenvironmental.com

Invoice To:

Company	Nautilus Environmental
Address	8664 Commerce Court
City/State/Zip	Burnaby, BC, V5A 4N3
Contact	Karen Lee
Phone	
Email	karen@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	MHW - Control Sr	25-Oct-12			125ml Bottle	1		x										
2	MHW - 5mg/L Sr	25-Oct-12			125ml Bottle	1		x										
3	MHW - 10mg/L Sr	25-Oct-12			125ml Bottle	1		x										
4	MHW - 20mg/L Sr	25-Oct-12			125ml Bottle	1		x										
5	MHW - 40mg/L Sr	25-Oct-12			125ml Bottle	1		x										
6	MHW - 80mg/L Sr	25-Oct-12			125ml Bottle	1		x										
7	MHW - 160mg/L Sr	25-Oct-12			125ml Bottle	1		x										
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: RBT embryo strontium test in ~~dechlorinated~~ KSL moderately hard water. Day 0. Samples are not preserved.

RELINQUISHED BY (CLIENT)
(Signature) Karen (Time) KSL 800h
(Printed Name) Karen Lee (Date) ~~October 25,~~ 2012 Nov 27
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) [signature] (Time) 18:45
(Printed Name) (Date) Nov 27
(Company)
11.2

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

Analytical measurements on test solutions at test termination

NAUTILUS ENVIRONMENTAL
ATTN: Karen Lee
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 27-NOV-12
Report Date: 04-DEC-12 14:56 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: L1242999

Project P.O. #:	NOT SUBMITTED
Job Reference:	
C of C Numbers:	1, 2
Legal Site Desc:	

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1242999-1	L1242999-2	L1242999-3	L1242999-4	L1242999-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	27-NOV-12	27-NOV-12	27-NOV-12	27-NOV-12	27-NOV-12
	Sampled Time					
	Client ID	DC - CONTROL	DC - 5MG /L SR	DC - 10MG /L SR	DC - 20MG /L SR	DC - 40MG /L SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	0.0553	4.79	10.5	19.5	38.6

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1242999-6	L1242999-7	L1242999-8	L1242999-9	L1242999-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	27-NOV-12	27-NOV-12	27-NOV-12	27-NOV-12	27-NOV-12
	Sampled Time					
	Client ID	DC - 80MG /L SR	DC - 160MG /L SR	MHW - CONTROL	MHW - 5MG /L SR	MHW - 10MG /L SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	75.8	150	0.271	2.39	10.5

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L1242999-11 WATER 27-NOV-12 MHW - 20MG /L SR	L1242999-12 WATER 27-NOV-12 MHW - 40MG /L SR	L1242999-13 WATER 27-NOV-12 MHW - 80MG /L SR	L1242999-14 WATER 27-NOV-12 MHW - 160MG /L SR	
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	18.5	37.8	74.7	137	

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
MET-TOT-MS-VA	Water	Total Metals in Water by ICPMS	EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

1	2

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

Chain of Custody

L1242999

L1242999-COFC

Date Nov 27/12 Page 1 of 2

Sample Collection By:

Report to:

Company	Nautilus Environmental
Address	8664 Commerce Court
City/State/Zip	Burnaby, BC, V5A 4N3
Contact	Karen Lee
Phone	
Email	karen@nautilusenvironmental.com

Invoice To:

Company	Nautilus Environmental
Address	8664 Commerce Court
City/State/Zip	Burnaby, BC, V5A 4N3
Contact	Karen Lee
Phone	
Email	karen@nautilusenvironmental.com

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	DC - Control	27-Nov-12			125ml Bottle	1		x										
2	DC - 5mg/L Sr	27-Nov-12			125ml Bottle	1		x										
3	DC - 10mg/L Sr	27-Nov-12			125ml Bottle	1		x										
4	DC - 20mg/L Sr	27-Nov-12			125ml Bottle	1		x										
5	DC - 40mg/L Sr	27-Nov-12			125ml Bottle	1		x										
6	DC - 80mg/L Sr	27-Nov-12			125ml Bottle	1		x										
7	DC - 160mg/L Sr	27-Nov-12			125ml Bottle	1		x										
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

RELINQUISHED BY (CLIENT)

(Signature) [signature] (Time) 1800h

(Printed Name) Karen Lee (Date) November 27, 2012

(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)

(Signature) (Time)

(Printed Name) (Date)

(Company)

SPECIAL INSTRUCTIONS/COMMENTS: RBT embryo strontium test in dechlorinated water. Day 32. Samples are not preserved.

RECEIVED BY (COURIER)

(Signature) (Time)

(Printed Name) (Date)

(Company)

RECEIVED BY (LABORATORY)

(Signature) [signature] (Time) 18:45

(Printed Name) (Date) Nov 27

(Company) temp 17.2

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

Nautilus Environmental

Chain of Custody

L1242999.

L1242999-COFC

Date Nov27/12 Page 2 of 2

Sample Collection By:

Report to:		Invoice To:	
Company	Nautilus Environmental	Company	Nautilus Environmental
Address	8664 Commerce Court	Address	8664 Commerce Court
City/State/Zip	Burnaby, BC, V5A 4N3	City/State/Zip	Burnaby, BC, V5A 4N3
Contact	Karen Lee	Contact	Karen Lee
Phone		Phone	
Email	karen@nautilusenvironmental.com	Email	karen@nautilusenvironmental.com

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	MHW - Control	27-Nov-12			125ml Bottle	1		x										
2	MHW - 5mg/L Sr	27-Nov-12			125ml Bottle	1		x										
3	MHW - 10mg/L Sr	27-Nov-12			125ml Bottle	1		x										
4	MHW - 20mg/L Sr	27-Nov-12			125ml Bottle	1		x										
5	MHW - 40mg/L Sr	27-Nov-12			125ml Bottle	1		x										
6	MHW - 80mg/L Sr	27-Nov-12			125ml Bottle	1		x										
7	MHW - 160mg/L Sr	27-Nov-12			125ml Bottle	1		x										
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: RBT embryo strontium test in moderately hard water. Day 32. Samples are not preserved.

RELINQUISHED BY (CLIENT)

(Signature) [signature] (Time) 1800h
(Printed Name) Karen Lee (Date) November 27, 2012
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)

(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)

(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)

(Signature) [signature] (Time) Nov 27
(Printed Name) (Date) 18:45
(Company) 17.2°C

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

Appendix C

Nautilus Laboratory Report - Amphipod (*Hyalella azteca*) Toxicity Tests

Nautilus Environmental

Evaluation of the chronic toxicity of strontium to *Hyalella azteca*

Final Report

Report date:
November 26, 2012

Submitted to:

Golder Associates
Burnaby, BC

8664 Commerce Court
Burnaby, BC
V5A 4N7

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1.0 INTRODUCTION

The toxicity of strontium to *Hyalella azteca* is not well characterized. Borgmann et al. (2005) reported results for survival of this species following a 7-day exposure to strontium; however, it is not clear whether actual toxicological effects were observed in the test solutions, or whether the apparent effects observed were related to natural background mortality, because the results were not corrected for control mortality, and a relatively small reduction in survival was observed.

The testing described here was performed to definitively evaluate the sensitivity of this amphipod to strontium using both survival and growth endpoints over a 14-day exposure.

2.0 METHODS

The toxicity tests were conducted according to procedures summarized in Table 1, which were adapted from Environment Canada (1997) test methods for evaluating sediments for toxicity; tests were adapted by using control sediment for all exposures, and exposing the organisms to various concentrations of strontium in the overlying water, which was renewed with freshly prepared solution three times per week. Control sediment was pre-rinsed sand.

Control water was moderately hard water (80 to 100 mg/L hardness), prepared according to Environment Canada (1997), and strontium was introduced to the test solutions as strontium chloride. The test involved a 14 day exposure, following which survival and biomass were evaluated.

Subsamples of the test solutions were collected at the beginning and end of the test and measured for strontium by ALS Environmental. Statistical analyses were conducted using measured concentrations of strontium and using CETIS version 1.8 (Tidepool Software).

Table 1. Summary of test conditions: 14-d *Hyalella azteca* toxicity test.

Test organism	*Hyalella azteca*
Test organism source	Aquatic BioSystems, Fort Collins, CO
Test organism age	7 - 8 d old
Test type	Static-renewal (three times per week)
Test duration	14 days
Test vessel	375-mL glass jars
Test Treatment	100 mL control sediment; 175 mL overlying water
Test replicates	3 replicates per treatment
No. of organisms	10 per replicate
Test temperature	23 ± 1°C
Feeding	1.5 mL of yeast, cerophyl trout chow (YCT) per replicate daily
Photoperiod	16 hours light/8 hours dark
Aeration	Gentle aeration throughout test
Test protocol	Environment Canada (1997), EPS 1/RM/33
Test endpoints	Survival and biomass
Test acceptability criterion for controls	Mean control survival of ≥80% and ≥0.1 mg/amphipod dry weight
Reference Toxicant	NaCl

3.0 RESULTS

Measured concentrations were in good agreement with target concentrations of strontium and the test met acceptance criteria specified in the test method.

Results of initial chronic toxicity test using *H. azteca* are provided in Table 2. Results from this test did not produce substantial adverse effects (i.e., toxicity) on *H. azteca*; the highest test concentration of 63.6 mg/L produced biomass that was only reduced by 23% relative to the control. Point estimates derived from such a small adverse effect are not robust, and IC10 and IC20 values have not been reported from this test. Consequently, the test was repeated using higher concentrations of strontium, so that point estimates could be calculated (Table 3). Bench-sheets from these tests, as well as printouts of statistical analyses are provided in Appendix A. The IC10 and IC20 from the repeated test based on biomass were 31.2 and 43.0 mg/L strontium, respectively.

Results of reference toxicant (positive control) tests are provided in Table 4. The reference toxicant tests result fell within the range of historical data from the laboratory (mean ± 2 SD), indicating that the sensitivity of the test organisms was appropriate.

Table 2. Results of the initial chronic toxicity test using *Hyalella azteca*.

Concentration (mg/L)		Survival (%)	Biomass (mg)
Sr (nominal)	Sr (measured)		
Control	0.04	100 ± 0	0.31 ± 0.04
0.25	0.26	98 ± 5	0.29 ± 0.03
0.5	0.52	100 ± 0	0.31 ± 0.02
1.0	0.95	100 ± 0	0.30 ± 0.06
2.0	1.9	100 ± 0	0.31 ± 0.03
4.0	3.7	100 ± 0	0.28 ± 0.04
8.0	7.5	100 ± 0	0.27 ± 0.02
16.0	15.4	100 ± 0	0.31 ± 0.02
32.0	30.2	95 ± 10	0.25 ± 0.03
64.0	63.6	100 ± 0	0.24 ± 0.02
Point estimates	LC50	>63.6	--
(mg/L measured Sr)	IC50	--	>63.6

Table 3. Results of the second chronic toxicity test using *Hyalella azteca*.

Concentration (mg/L)		Survival (%)	Biomass (mg)
Sr (nominal)	Sr (measured)		
Control	0.0	100 ± 0	0.41 ± 0.03
30	30.1	100 ± 0	0.38 ± 0.05
60	61.2	100 ± 0	0.25 ± 0.05
120	125.0	100 ± 0	0.13 ± 0.01
240	242.0	0 ± 0	--
480	469.0	0 ± 0	--
Point estimates	LC50	176.8 (159.2–196.2)	--
(mg/L measured Sr)	IC50	--	79.6 (70.6 – 89.8)
	IC20	--	43.0 (34.9 – 50.9)
	IC10	--	31.2 (21.7 – 38.7)

Table 4. Reference toxicant test results.

Endpoint	Date	Toxicant	Point estimate	Acceptable Range	CV
H. azteca 96 hr LC50	3 May 2012	NaCl	4.0 g/L	3.1 – 6.5 g/L	20
	5 July 2012	NaCl	5.3 g/L	3.0 – 6.3 g/L	21

4.0 REFERENCES

Borgmann U, Couillard Y, Doyle P, Dixon DG. 2005. Toxicity of sixty-three metals and metalloids to *Hyalella azteca* at two levels of water hardness. Environ Toxicol Chem 24:641-652.

Environment Canada. 1997. Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*. Environmental Protection Series EPS 1/RM/33. December 1997. Environment Canada, Method Development and Application Section, Environmental Technology Centre, Ottawa, ON. 123 pp.

Tidepool Scientific Software. 2007. CETIS comprehensive environmental toxicity information system. Tidepool Scientific Software, McKinleyville, CA. 222 pp.

APPENDIX A – Toxicity test data

Hyalella azteca Sediment Test Summary Sheet

Client: Golder
Work Order No.: 12192
Start Date: 03-May-12
Set up by: KJL

Sample Information:

Sample ID: Strontium Study
Sample Date: n/a
Date Received: n/a
Sample Volume: n/a

Test Organism Information:

Species: *H. azteca*
Supplier: Aquatic Biosystems, CO
Date received: 02-May-12
Age or size (Day 0): 7-8 Days

NaCl Reference Toxicant Results:

Reference Toxicant ID HA48
Stock Solution ID: NaCl
Date Initiated: 03-May-12

96-h LC50 (95% CL): 4.0 (3.1 - 5.2) g/L NaCl

96-h LC50 Reference Toxicant
Mean and 2SD Range: 4.5, 3.1 - 6.5 g/L NaCl CV (%) 20

Test Results:

Sample ID	Survival ± SD (%)			Average Biomass ± SD (mg)		
Control Sediment	100.0	±	0.0	0.31	±	0.04
0.2595 mg/L Sr	97.5	±	5.0	0.29	±	0.02
0.516 mg/L Sr	100.0	±	0.0	0.31	±	0.02
0.951 mg/L Sr	100.0	±	0.0	0.30	±	0.06
1.925 mg/L Sr	100.0	±	0.0	0.30	±	0.04
3.7 mg/L Sr	100.0	±	0.0	0.28	±	0.04
7.495 mg/L Sr	100.0	±	0.0	0.27	±	0.02
15.35 mg/L Sr	100.0	±	0.0	0.31	±	0.02
30.2 mg/L Sr	95.0	±	10.0	0.23	±	0.04
63.6 mg/L Sr	100.0	±	0.0	0.24	±	0.02

Reviewed by: [signature]

Date reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet
Freshwater Sediment Water Quality

Client:	Golder	Start Date:	03-May-12
Work Order No.:	12192	Termination Date:	17-Mar-12
Sample ID:	Strontium	Test Organism:	*Hyalella azteca*

Temperature (°C)

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.0
0.25	24.0	23.0	24.0	24.0	24.0	24.0	24.0	22.5	24.0	23.0	24.0	23.0	24.0	23.0
0.5	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.0
1	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.0
2	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.0
4	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.0
8	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.0
16	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.5
32	24.0	23.0	24.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.5
64	24.0	23.0	23.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.0	24.0	23.5
Technician Initials	KJL	KJL	KJL	^	^	^	^	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Conductivity (µS)

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	347	375	349	368	351	373	348	379	361	386	343	395	344	384
0.25	347	386	355	374	350	383	353	389	344	387	346	385	346	382
0.5	350	399	355	392	350	382	356	400	348	389	346	389	351	384
1	348	378	356	372	351	375	361	382	347	382	348	387	354	386
2	350	386	359	375	356	376	362	385	350	387	351	386	348	384
4	357	392	365	379	366	385	371	390	356	392	356	391	351	390
8	367	390	376	393	381	392	391	399	367	403	368	398	356	335
16	389	416	398	429	430	411	425	422	389	444	390	427	387	424
32	433	452	443	469	449	462	443	479	432	387	431	469	438	405
64	521	532	527	531	518	537	525	548	521	527	519	547	520	550
Technician Initials	KJL	KJL	KJL	^	^	^	^	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments:

Reviewed by: [signature] Date Reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet

Freshwater Sediment Water Quality

Client:	Golder	Start Date:	03-May-12
Work Order No.:	12192	Termination Date:	17-May-12
Test Condition:	Strontium	Test Organism:	*Hyalella azteca*

Dissolved Oxygen (mg/L)

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	8.1	8.1	7.9	7.9	7.8	7.4	7.6	7.5	8.0	8.2	8.2	7.3	7.7	8.1
0.25	7.9	8.1	7.9	7.9	7.8	7.5	7.7	7.5	7.9	8.2	8.1	7.2	7.9	8.1
0.5	8.0	8.0	7.9	7.9	7.8	7.5	7.6	7.5	7.9	8.2	8.1	7.2	7.9	8.1
1	8.0	8.0	7.9	7.8	7.8	7.4	7.7	7.4	7.8	8.2	8.2	7.2	7.8	8.1
2	8.1	8.0	7.9	7.9	7.8	7.5	7.7	7.5	7.8	8.2	8.1	7.2	7.8	8.0
4	8.1	8.0	7.9	7.9	7.8	7.5	7.8	7.4	7.9	8.2	8.1	7.3	7.8	8.0
8	8.1	8.0	7.9	7.9	7.8	7.6	7.8	7.5	7.8	8.2	8.1	7.2	7.9	8.1
16	8.1	8.0	8.0	7.9	7.8	7.5	7.9	7.5	7.9	8.2	8.2	7.2	7.9	8.1
32	8.1	8.1	7.9	7.9	7.8	7.6	7.9	7.5	7.9	8.2	8.2	7.2	7.9	8.1
64	8.1	8.1	7.9	7.9	7.8	7.5	7.9	7.4	7.9	8.2	8.0	7.2	8.0	8.0
Technician Initials	KJL	KJL	KJL	"	"	"	"	KJL	KJL	KJL	KJL	KJL	KJL	KJL

pH

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	8.0	8.0	8.0	8.0	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
0.25	8.0	8.0	8.0	8.0	8.1	8.0	8.0	8.0	7.9	8.0	8.0	8.0	8.0	8.0
0.5	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.0	7.9	8.0	8.0	8.0	8.0	8.0
1	8.0	8.0	8.0	8.0	8.0	8.1	8.0	8.0	7.9	8.0	8.0	8.0	8.0	8.0
2	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.0	7.9	8.0	8.0	8.0	8.0	7.9
4	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.0	7.9	8.0	8.0	8.0	8.0	8.0
8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	8.0	8.0	8.1	8.0	8.0
16	8.0	8.0	8.0	8.0	8.0	8.1	8.0	8.0	7.9	8.0	8.0	8.1	7.9	8.0
32	8.0	7.9	7.9	8.0	7.9	8.0	8.0	8.0	7.9	8.0	7.9	8.0	7.9	8.0
64	7.9	7.9	7.8	7.9	7.9	8.0	8.0	~~8.0~~ 7.6	7.8	7.9	7.9	8.0①	7.8	8.0②
Technician Initials	KJL	KJL	KJL	"	"	"	"	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments: ① Rep B pH = 7.6 ② Rep B ph = 7.3

Reviewed by: [signature] Date Reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet

Freshwater Sediment Water Quality

Client: Golder
Work Order No.: 12192
Sample ID: Strontium

Start Date: 03-May-12
Termination Date: 17-Mar-12
Test Organism: *Hyalella azteca*

Temperature (°C)

Sample ID (mg/L Sr)	Day 7	Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Day 14
	new	old	new	old	new	old	new	old	new	old	new	old	new	old
Control	24.0	23.0	24.0	23.5	~~23.5~~	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
0.25	23.5	23.0	24.0	23.6	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
0.5	23.5	23.0	24.0	23.5	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
1	23.5	23.0	24.0	23.5	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
2	23.5	23.0	24.0	23.6	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
4	24.0	23.0	24.0	23.6	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
8	24.0	23.0	24.0	23.6	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
16	24.0	23.0	24.0	23.5	24.0	23.0	24.0	23.5	23.5	24.0	24.0	24.0	23.5	24.0
32	24.0	23.5	24.0	23.5	24.0	23.0	24.0	23.5	24.0	24.0	24.0	24.0	24.0	24.0
64	23.0	23.5	24.0	23.6	24.0	23.5	24.0	23.5	24.0	24.0	23.5	24.0	24.0	24.0
Technician Initials	KJL	KJL	KJL	[illegible]	[illegible]	[illegible]	[illegible]	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Conductivity (µS)

Sample ID (mg/L Sr)	Day 7	Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Day 14
	new	old	new	old	new	old	new	old	new	old	new	old	new	old
Control	343	390	344	402	348	354	~~354~~ 412	403	344	397	347	381	345	387
0.25	351	395	343	399	360	372	408	417	347	410	356	405	340	389
0.5	348	407	347	406	362	374	417	411	348	409	357	406	343	396
1	350	375	349	403	364	380	416	420	350	408	359	399	350	394
2	352	389	339	414	366	386	418	415	352	410	362	397	353	404
4	358	400	357	422	370	391	421	430	360	415	368	417	359	408
8	369	409	370	410	375	416	433	430	376	431	380	424	370	419
16	376	429	391	440	435	445	454	455	392	458	402	442	393	441
32	432	480	436	492	~~485~~ 488	469	500	501	436	497	448	484	438	477
64	525	552	522	561	545	539	576	568	527	585	538	540	531	565
Technician Initials	KJL	KJL	KJL	[illegible]	[illegible]	[illegible]	[illegible]	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments:

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet

Freshwater Sediment Water Quality

Client:	Golder	Start Date:	03-May-12
Work Order No.:	12192	Termination Date:	17-May-12
Test Condition:	Strontium	Test Organism:	*Hyalella azteca*

Dissolved Oxygen (mg/L)

Sample ID (mg/L Sr)	Day 7	Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Day 14
	new	old	new	old	new	old	new	old	new	old	new	old	new	old
Control	7.9	7.4	8.0	7.9	7.9	7.9	8.0	8.0	8.2	7.4	7.7	7.5	8.0	7.7
0.25	7.9	7.4	8.0	7.8	7.9	7.9	8.0	8.0	8.2	7.4	7.7	7.5	7.9	7.7
0.5	7.8	7.4	8.0	7.9	7.9	8.0	8.1	7.9	8.2	7.3	7.8	7.5	8.0	7.7
1	7.8	7.4	8.0	7.8	7.9	8.0	8.0	7.8	8.2	7.3	7.9	7.5	8.0	7.7
2	7.8	7.4	8.0	7.8	7.9	8.0	8.0	7.8	8.2	7.4	7.9	7.5	8.0	7.7
4	7.9	7.4	8.0	7.9	7.9	8.0	8.0	7.8	8.2	7.4	7.9	7.5	8.0	7.7
8	7.9	7.6	8.0	7.8	7.9	7.9	8.0	7.8	8.2	7.4	7.9	4.3 ②	8.0	7.7
16	8.0	7.7	8.0	7.9	7.8	7.9	8.0	7.8	8.2	7.4	7.9	4.3 ②	7.9	7.7
32	7.9	7.5	8.0	7.9	7.8	8.0	8.0	7.8	8.2	7.3	7.9	4.3 ②	7.9	7.7
64	7.9	7.5	8.0	7.9	7.8	8.0	8.0	7.8	8.2	7.2	7.9	4.3 ②	8.0	7.7
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

pH

Sample ID (mg/L Sr)	Day 7	Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Day 14	
	new	old	new	old	new	old	new	old	new	old	new	old	new	old	
Control	8.0	7.9	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	~~7.7~~	8.1
0.25	8.0	8.0	8.0	8.0	8.0	8.1	8.0	8.0	7.9	7.9	7.9	8.0	7.9	~~7.7~~	8.1
0.5	8.0	7.9	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.8	7.9	7.9	7.9	7.9	
1	8.0	7.9	8.0	8.1	8.0	8.0	8.1	8.0	8.0	7.9	7.9	8.0	7.9	~~7.7~~	8.1
2	8.0	7.9	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	~~7.7~~	8.0
4	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	~~7.7~~	8.1
8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.3 ③	7.9	~~7.7~~	8.1
16	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.3 ③	7.9	~~7.7~~	8.1
32	8.0	8.0	7.9	8.0	8.0	8.0	7.9	8.0	7.9	7.9	7.8	7.3 ③	7.9	~~7.7~~	8.1
64	7.8	7.9 ①	7.8	8.0	8.0	8.0	7.9	7.9	7.8	7.9	7.8	7.3 ③	7.7	~~7.7~~	8.0
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL	

Comments: ① Rep B pH=7.3 ② aeration line clipped off pump, organisms look ok ③ all reps

Reviewed by: [signature] Date Reviewed: 6 Nov 2012

H. azteca Sediment Toxicity Test Data Sheet
Freshwater Sediment Survival and Weight

Client: Golder
Work Order No.: 12192
Sample ID: Strontium

Start Date: May 3, 2012
Termination Date: May 17, 2012
Test Organism: *H. azteca*

Sample ID	Pan No. green	Rep	No. alive	No. dead	No. missing	Initials	Pan weight (mg)	Pan + organism (mg)	No. weighed	Initials
Control	1	A	10	0	0	KJL	1332.89	1336.17	10	KJL
	2	B	10	0	0	↓	1331.16	1334.79	10	↓
	3	C	10	0	0	↓	1341.78	1344.41	10	↓
	4	D	10	0	0	↓	1336.23	1339.26	10	↓
0.25	5	A	10	0	0	KJL	1314.63	1317.75	10	↓
	6	B	10	0	0	↓	1335.14	1338.05	10	↓
	7	C	9	0	1	↓	1335.04	1337.80	9	↓
	8	D	10	0	0	↓	1331.91	1334.46	10	↓
0.5	9	A	10	0	0	KJL	1340.41	1343.75	10	↓
	10	B	10	0	0	↓	1325.03	1328.19	10	↓
	11	C	10	0	0	↓	1339.88	1342.92	10	↓
	12	D	10	0	0	↓	1337.11	1339.96	10	↓
1	13	A	10	0	0	KJL	1342.62	1345.75	10	↓
	14	B	10	0	0	↓	1335.78	1338.59	10	↓
	15	C	10	0	0	↓	1343.73	1347.44	10	↓
	16	D	10	0	0	↓	1336.69	1339.09	10	↓
2	17	A	10	0	0	KJL	1336.21	1339.47	10	↓
	18	B	10	0	0	↓	1338.59	1341.81	10	↓
	19	C	10	0	0	↓	1338.22	1340.61	9 ①	↓
	20	D	10	0	0	↓	1340.98	1344.09	10	↓

Comments: ① lost in transfer
Reweighed pans: 6 - 1337.92 11 - 1342.81

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

Nautilus Environmental

H. azteca Sediment Toxicity Test Data Sheet
Freshwater Sediment Survival and Weight

Client: Golder
Work Order No.: 12192
Sample ID: Strontium

Start Date: May 3, 2012
Termination Date: May 17, 2012
Test Organism: H. azteca

Sample ID	Pan No.	Rep	No. alive	No. dead	No. missing	Initials	Pan weight (mg)	Pan + organism (mg)	No. weighed	Initials
4	21	A	10	0	0	KJL	1331.60	1334.08	10	KJL
	22	B	10	0	0	↓	1335.32	1338.05	10	↓
	23	C	10	0	0	↓	1336.73	1339.42	10	↓
	24	D	10	0	0	↓	1336.41	1339.75	10	↓
8	25	A	10	0	0	KJL	1334.69	1337.36	10	↓
	26	B	10	0	0	↓	1333.52	1335.95	10	↓
	27	C	10	0	0	↓	1336.50	1339.40	10	↓
	28	D	10	0	0	↓	1342.23	1345.00	10	↓
16	29	A	11	0	0	KJL	1339.03	1342.56	11	↓
	30	B	10	0	0	↓	1333.27	1336.53	10	↓
	31	C	10	0	0	↓	1336.14	1339.25	10	↓
	32	D	10	0	0	↓	1342.34	1345.15	10	↓
32	33	A	10	0	0	KJL	1336.04	1338.81	10	↓
	34	B	8	0	2	↓	1337.78	1339.74	8	↓
	35	C	10	0	0	↓	1339.22	1341.27	10	↓
	36	D	10	0	0	↓	1309.22	1311.83	10	↓
64	37	A	10	0	0	KJL	1317.15	1319.43	10	↓
	38	B	10	0	0	↓	1325.44	1327.75	10	↓
	39	C	10	0	0	↓	1330.21	1332.63	10	↓
	40	D	10	0	0	↓	1309.90	1312.59	10	↓

Comments: Reweighed pans: 26-1335.71 33-1338.70

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

Nautilus Environmental

CETIS Summary Report

Report Date: 29 May-12 09:04 (p 1 of 1)
Test Code: 12192 | 08-9611-4161

Hyalella 14-d Survival and Growth Sediment Test — **Nautilus Environmental**

Batch ID:	07-1508-5401	**Test Type:**	Survival-Growth	**Analyst:**	Karen Lee
Start Date:	03 May-12	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	17 May-12	**Species:**	Hyalella azteca	**Brine:**	
Duration:	14d 0h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Sample ID:	12-9817-1117	**Code:**	4D6084ED	**Client:**	Golder
Sample Date:	03 May-12	**Material:**	Strontium	**Project:**	
Receive Date:	03 May-12	**Source:**	Golder		
Sample Age:	NA	**Station:**	Strontium		

Point Estimate Summary

Analysis ID	Endpoint	Level	mg/L	95% LCL	95% UCL	TU	Method
07-1606-1540	Survival Rate	EC5	>63.6	N/A	N/A		Linear Interpolation (ICPIN)
		EC10	>63.6	N/A	N/A		
		EC15	>63.6	N/A	N/A		
		EC20	>63.6	N/A	N/A		
		EC25	>63.6	N/A	N/A		
		EC40	>63.6	N/A	N/A		
		EC50	>63.6	N/A	N/A		

Survival Rate Summary

C-mg/L	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	4	1	1	1	1	1	0	0	0.0%	0.0%
0.2595		4	0.975	0.9563	0.9937	0.9	1	0.025	0.05	5.13%	2.5%
0.516		4	1	1	1	1	1	0	0	0.0%	0.0%
0.951		4	1	1	1	1	1	0	0	0.0%	0.0%
1.925		4	1	1	1	1	1	0	0	0.0%	0.0%
3.7		4	1	1	1	1	1	0	0	0.0%	0.0%
7.495		4	1	1	1	1	1	0	0	0.0%	0.0%
15.35		4	1	1	1	1	1	0	0	0.0%	0.0%
30.2		4	0.95	0.9127	0.9873	0.8	1	0.05	0.1	10.53%	5.0%
63.6		4	1	1	1	1	1	0	0	0.0%	0.0%

Survival Rate Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	1	1	1	1
0.2595		1	1	0.9	1
0.516		1	1	1	1
0.951		1	1	1	1
1.925		1	1	1	1
3.7		1	1	1	1
7.495		1	1	1	1
15.35		1	1	1	1
30.2		1	0.8	1	1
63.6		1	1	1	1

Survival Rate Binomials

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	10/10	10/10	10/10	10/10
0.2595		10/10	10/10	9/10	10/10
0.516		10/10	10/10	10/10	10/10
0.951		10/10	10/10	10/10	10/10
1.925		10/10	10/10	10/10	10/10
3.7		10/10	10/10	10/10	10/10
7.495		10/10	10/10	10/10	10/10
15.35		11/11	10/10	10/10	10/10
30.2		10/10	8/10	10/10	10/10
63.6		10/10	10/10	10/10	10/10

Hyalella 14-d Survival and Growth Sediment Test — **Nautilus Environmental**

Analysis ID:	12-2159-0124	**Endpoint:**	Mean Dry Biomass-mg	**CETIS Version:**	CETISv1.8.4
Analyzed:	07 Nov-12 15:16	**Analysis:**	Nonlinear Regression	**Official Results:**	Yes

Batch ID:	07-1508-5401	**Test Type:**	Survival-Growth	**Analyst:**	Karen Lee
Start Date:	03 May-12	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	17 May-12	**Species:**	Hyalella azteca	**Brine:**	
Duration:	14d 0h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Sample ID:	12-9817-1117	**Code:**	4D6084ED	**Client:**	Golder
Sample Date:	03 May-12	**Material:**	Strontium	**Project:**	
Receive Date:	03 May-12	**Source:**	Golder		
Sample Age:	NA	**Station:**	Strontium		

Non-Linear Regression Options

Model Function	X Transform	Y Transform	Weighting Function	PTBS Function
3P Log-Logistic EV [Y=A/(1+(X/D)^C)]	None	None	Normal [W=1]	Off [Y*=Y]

Regression Summary

Iters	Log LL	AICc	BIC	Adj R2	Optimize	F Stat	Critical	P-Value	Decision(α:5%)
62	115.3	-224	-219.6	0.2352	Yes	1.371	2.334	0.2534	Non-Significant Lack of Fit

Point Estimates

Level	mg/L	95% LCL	95% UCL
IC5	3.215	0.002521	11.88
IC10	12.1	2.509	29.95
IC15	27.49	10.37	55.4
IC20	51	16.93	113.3
IC25	84.95	17.48	249.8
IC40	290.5	7.634	3215
IC50	596.3	4.152	85650

Regression Parameters

Parameter	Estimate	Std Error	95% LCL	95% UCL	t Stat	P-Value	Decision(α:5%)
A	0.3065	0.01335	0.2804	0.3327	22.96	<0.0001	Significant Parameter
C	0.5638	0.3469	-0.1161	1.244	1.625	0.1126	Non-Significant Parameter
D	596.3	901.3	-1170	2363	0.6616	0.5123	Non-Significant Parameter

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Model	0.017429	0.017429	1	14	0.0006	Significant
Lack of Fit	0.011168	0.001595	7	1.371	0.2534	Non-Significant
Pure Error	0.034907	0.001164	30			
Residual	0.046075	0.001245	37			

Residual Analysis

Attribute	Method	Test Stat	Critical	P-Value	Decision(α:5%)
Variances	Bartlett Equality of Variance	7.507	16.92	0.5844	Equal Variances
	Mod Levene Equality of Variance	0.8987	2.211	0.5384	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9806	0.9447	0.7131	Normal Distribution
	Anderson-Darling A2 Normality	0.2045	2.492	0.9155	Normal Distribution

Hyalella 14-d Survival and Growth Sediment Test — **Nautilus Environmental**

Analysis ID:	12-2159-0124	**Endpoint:**	Mean Dry Biomass-mg	**CETIS Version:**	CETISv1.8.4
Analyzed:	07 Nov-12 15:16	**Analysis:**	Nonlinear Regression	**Official Results:**	Yes

Mean Dry Biomass-mg Summary — **Calculated Variate**

C-mg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	4	0.3143	0.263	0.363	0.02105	0.04211	13.4%	0.0%
0.2595		4	0.2835	0.255	0.312	0.01203	0.02407	8.49%	9.79%
0.516		4	0.3097	0.285	0.334	0.0103	0.0206	6.65%	1.43%
0.951		4	0.3012	0.24	0.371	0.02763	0.05527	18.35%	4.14%
1.925		4	0.2995	0.239	0.326	0.02041	0.04083	13.63%	4.69%
3.7		4	0.281	0.248	0.334	0.0185	0.03699	13.16%	10.58%
7.495		4	0.2693	0.243	0.29	0.009938	0.01988	7.38%	14.32%
15.35		4	0.3097	0.281	0.326	0.01007	0.02014	6.5%	1.44%
30.2		4	0.2348	0.196	0.277	0.02013	0.04025	17.15%	25.3%
63.6		4	0.2425	0.228	0.269	0.009329	0.01866	7.69%	22.83%

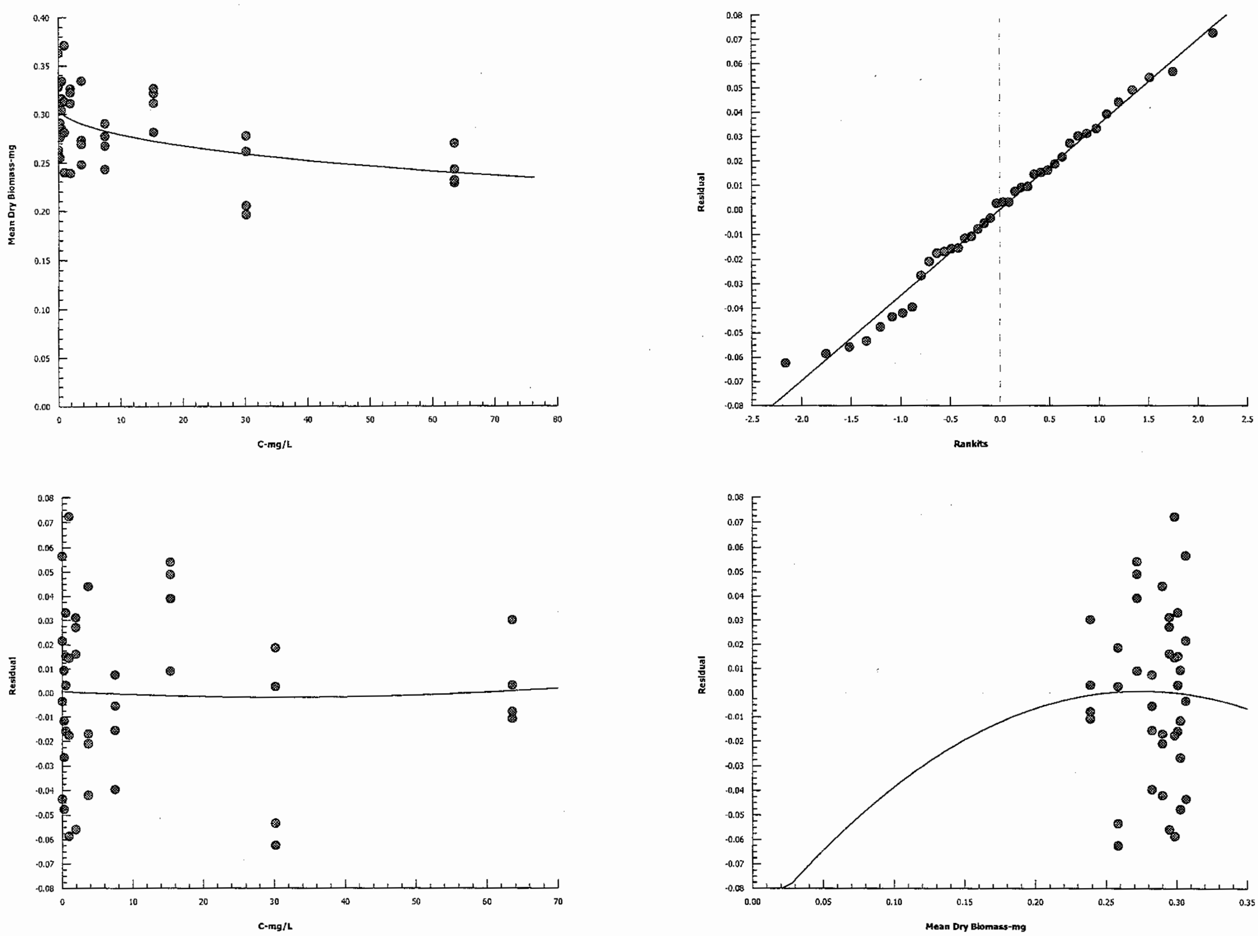
Mean Dry Biomass-mg Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	0.328	0.363	0.263	0.303
0.2595		0.312	0.291	0.276	0.255
0.516		0.334	0.316	0.304	0.285
0.951		0.313	0.281	0.371	0.24
1.925		0.326	0.322	0.239	0.311
3.7		0.248	0.273	0.269	0.334
7.495		0.267	0.243	0.29	0.277
15.35		0.3209	0.326	0.311	0.281
30.2		0.277	0.196	0.205	0.261
63.6		0.228	0.231	0.242	0.269

Hyalella 14-d Survival and Growth Sediment Test | **Nautilus Environmental**

Analysis ID:	12-2159-0124	**Endpoint:**	Mean Dry Biomass-mg	**CETIS Version:**	CETISv1.8.4
Analyzed:	07 Nov-12 15:16	**Analysis:**	Nonlinear Regression	**Official Results:**	Yes

Graphics 3P Log-Logistic EV [Y=A/(1+(X/D)^C)]



Client: Golder

W.O.#: 12192

Hardness and Alkalinity Datasheet

	Alkalinity					Hardness			
Sample ID	Sample Date	Sample Volume (mL)	(mL) 0.02N HCL/H_2SO_4 used to pH 4.5	(mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Total Alkalinity (mg/L$CaCO_3$)	Sample Volume (mL)	Volume of 0.01M EDTA Used (mL)	Total Hardness (mg/L $CaCO_3$)	Technician
MHW Control	May 1/12	50	2.8	2.9	54	50	5.2	104	KJL

Notes:

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

NAUTILUS ENVIRONMENTAL
ATTN: Karen Lee
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 03-MAY-12
Report Date: 11-MAY-12 17:42 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: L1142729

Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Golder
Strontium
Hyal - Day 0
May 3/12

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1142729-1	L1142729-2	L1142729-3	L1142729-4	L1142729-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	03-MAY-12	03-MAY-12	03-MAY-12	03-MAY-12	03-MAY-12
	Sampled Time					
	Client ID	SEDIMENT CONTROL	0.25-SR	0.50-SR	1.0-SR	2.0-SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	0.0242	0.276	0.533	1.04	2.02

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1142729-6	L1142729-7	L1142729-8	L1142729-9	L1142729-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	03-MAY-12	03-MAY-12	03-MAY-12	03-MAY-12	03-MAY-12
	Sampled Time					
	Client ID	4.0-SR	8.0-SR	16.0-SR	32.0-SR	64.0-SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	3.78	7.68	16.3	30.2	67.6

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SPL	Sample was Preserved at the laboratory - total metals

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
MET-TOT-LOW-MS-VA	Water	Total Metals in Water by ICPMS(Low)	EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

TESTING LOCATION (Please Circle)

Nautilus Enviro

(1) British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

L1142729 **Chain of Custody**

Date May 3/12 Page 1 of 1

Sample Collection By:

Report to:		Invoice To:	
Company	(1)	Company	(1)
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	karen@nautilusenvironmental.com	Email	karen@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	Sediment Control	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
2	0.25 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
3	0.50 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
4	1.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
5	2.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
6	4.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
7	8.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
8	16.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
9	32.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										
10	64.0 - Sr	03-May-12			125ml Bottle	1	Strontium - Day 0	x										

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 0. Samples are not preserved.

RELINQUISHED BY (CLIENT)	RELINQUISHED BY (COURIER)
(Signature) Karen (Time) 1700h	(Signature) (Time)
(Printed Name) Karen Lee (Date) May 3/12	(Printed Name) (Date)
(Company) Nautilus Environmental	(Company)

RECEIVED BY (COURIER)	RECEIVED BY (LABORATORY)
(Signature) TN May 3 17:30 22° (Time)	(Signature) (Time)
(Printed Name) (Date)	(Printed Name) (Date)
(Company)	(Company)

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

NAUTILUS ENVIRONMENTAL
ATTN: Karen Lee
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 17-MAY-12
Report Date: 28-MAY-12 18:11 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: L1149217
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Golder
Strontium
Hyal - Day 14
May 17/12

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1149217-1	L1149217-2	L1149217-3	L1149217-4	L1149217-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	17-MAY-12	17-MAY-12	17-MAY-12	17-MAY-12	17-MAY-12
	Sampled Time					
	Client ID	SEDIMENT CONTROL	0.25-SR	0.50-SR	1.0-SR	2.0-SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	0.0543	0.243	0.499	0.862	1.83

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1149217-6	L1149217-7	L1149217-8	L1149217-9	L1149217-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	17-MAY-12	17-MAY-12	17-MAY-12	17-MAY-12	17-MAY-12
	Sampled Time					
	Client ID	4.0-SR	8.0-SR	16.0-SR	32.0-SR	64.0-SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	3.62	7.31	14.4	30.2	59.6

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
MET-TOT-LOW-MS-VA	Water	Total Metals in Water by ICPMS(Low)	EPA SW-846 3005A/6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

TESTING LOCATION (Please Circle)

Chain of Custody

L1149217

(1) British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

Date May 17/12 Page 1 of 1

Sample Collection By:

Report to:		Invoice To:	
Company	(1)	Company	(1)
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	karen@nautilusenvironmental.com	Email	karen@nautilusenvironmental.com

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	Sediment Control	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
2	0.25 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
3	0.50 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
4	1.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
5	2.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
6	4.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
7	8.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
8	16.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
9	32.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										
10	64.0 - Sr	17-May-12			125ml Bottle	1	Strontium - Day 14	x										

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

RELINQUISHED BY (CLIENT)
(Signature) Karen (Time) 1700 h
(Printed Name) Karen Lee (Date) May 17/12
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 14. Samples are not preserved.

RECEIVED BY (COURIER)
(Signature) TN may 17 (Time) 17:05
(Printed Name) 23° (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) (Time)
(Printed Name)

L1149217-COFC

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

Hyalella azteca Sediment Test Summary Sheet

Client: In-House (R&D) Start Date: 05-Jul-12
Work Order No.: n/a Set up by: KJL

Sample Information:

Sample ID: Strontium Study
Sample Date: n/a
Date Received: n/a
Sample Volume: n/a

Test Organism Information:

Species: *H. azteca*
Supplier: Aquatic Biosystems, CO
Date received: 04-Jul-12
Age or size (Day 0): 7-8 Days

NaCl Reference Toxicant Results:

Reference Toxicant ID HA50
Stock Solution ID: NaCl
Date Initiated: 05-Jul-12

96-h LC50 (95% CL): 5.3 (4.6 - 6.0) g/L NaCl

96-h LC50 Reference Toxicant
Mean and 2SD Range: 4.4, 3.0 - 6.3 g/L NaCl CV (%) 21

Test Results:

Sample ID	Survival ± SD (%)			Mean Biomass ~~Average Dry Wt.~~ ± SD (mg)		
Control Sediment	100.0	±	0.0	0.41	±	0.03
30.1 mg/L Sr	100.0	±	0.0	0.38	±	0.05
61.2 mg/L Sr	100.0	±	0.0	0.25	±	0.05
125.0 mg/L Sr	100.0	±	0.0	0.13	±	0.01
242.0 mg/L Sr	0.0	±	0.0	0.00	±	0.00
469.0 mg/L Sr	0.0	±	0.0	0.00	±	0.00

Reviewed by: [signature] Date reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet
Freshwater Sediment Water Quality

Client: In-House (R+D)
Work Order No.: n/a
~~Test Condition:~~ Sample ID: Strontium

Start Date: ~~27-Jun-12~~ KJL July 5/12
Termination Date: ~~11-Jul-12~~ July 19/12
Test Organism: *Hyalella azteca*

Temperature (°C)

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
30	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
60	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
120	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
240	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
480	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Conductivity (µS)

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	343	356	348	365	348	375	348	454	348	423	348	393	348	382
30	423	443	450	468	437	461	455	472	436	479	437	470	438	475
60	504	520	531	536	522	542	514	552	523	560	527	560	522	560
120	662	674	716	715	667	659	680	708	658	730	652	733	722	740
240	963	970	1040	1000	998	1015	1005	1038	1037	1054	1039	1063	1039	1060
480	1555	1567	1672	1599	1673	1617	1678	1671	1690	1706	1675	1726	1644	1707
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments:

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet
Freshwater Sediment Water Quality

Client: In-house (R+D)
Work Order No.: n/a
~~Test Condition:~~ Sample ID: Strontium

Start Date: ~~27-Jun-12~~ KJL July 5/12
Termination Date: ~~11-Jul-12~~ July 19/12
Test Organism: *Hyalella azteca*

Temperature (°C)

Sample ID (mg/L Sr)	Day 7 new	Day 8 old	Day 8 new	Day 9 old	Day 9 new	Day 10 old	Day 10 new	Day 11 old	Day 11 new	Day 12 old	Day 12 new	Day 13 old	Day 13 new	Day 14 old
Control	24.0	23.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	23.5	23.5	24.0	23.5	23.5
30	24.0	23.0	23.5	24.0	24.0	24.0	24.0	24.0	24.0	23.5	23.5	24.0	24.0	23.5
60	24.0	23.0	23.5	24.0	24.0	24.0	24.0	23.5	24.0	23.5	23.0	24.0	24.0	23.5
120	24.0	23.5	23.5	24.0	24.0	24.0	24.0	23.5	24.0	23.0	23.0	23.5	24.0	23.0
240	24.0	23.5	23.5	24.0	24.0	24.0	24.0	23.5	24.0	23.5	22.0	23.5	24.0	23.5
480	24.0	23.5	23.5	24.0	24.0	24.0	24.0	23.5	24.0	24.0	22.0	23.5	24.0	23.5
Technician Initials	KJL	KJL	KJL	[illegible]	[illegible]	[illegible]	[illegible]	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Conductivity (µS)

Sample ID (mg/L Sr)	Day 7 new	Day 8 old	Day 8 new	Day 9 old	Day 9 new	Day 10 old	Day 10 new	Day 11 old	Day 11 new	Day 12 old	Day 12 new	Day 13 old	Day 13 new	Day 14 old
Control	349	374	~~356~~ ①	403	351	400	352	394	350	385	351	380	348	380
30	437	482	~~356~~	497	433	500	449	487	447	478	440	475	436	472
60	519	573	~~495~~	582	516	578	545	589	531	575	529	575	524	575
120	691	743	701	763	705	765	714	~~785~~ ②	701	760	698 ~~834~~	762	696	767
240	1030	1065	1061	1099	1026	1071	1060	1104	1033	1070	~~963~~	1076	1036	1096
480	1697	1718	1645	1720	1706	1727	1706	1704	1718	1725	1671	1729	~~1706~~	1725
													1683	
Technician Initials	KJL	KJL	KJL	[illegible]	[illegible]	[illegible]	[illegible]	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments: ① cont - 348, 30 - 444, 60 - 533 ② 765

Reviewed by: [signature]
Date Reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet
Freshwater Sediment Water Quality

Client: In-House (R+D)
Work Order No.: n/a
~~Test Condition~~: Sample ID: Strontium

Start Date: ~~27-Jun-12~~ KJL July 5/12
Termination Date: ~~11-Jul-12~~ July 19/12
Test Organism: *Hyalella azteca*

Dissolved Oxygen (mg/L)

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	7.0	7.5	8.0	7.6	8.0	7.6	8.0	7.8	8.2	7.8	8.2	7.7	7.9	7.8
30	7.0	7.6	8.0	7.7	8.1	7.5	8.0	7.8	8.3	7.9	8.1	7.6	7.6	7.7
60	6.9	7.6	8.1	7.7	8.1	7.6	8.0	7.9	8.3	7.9	8.1	7.6	7.7	7.6
120	6.9	7.6	8.2	7.6	8.1	7.7	8.0	7.9	8.3	8.0	8.1	7.6	7.7	7.7
240	7.0	7.7	8.0	7.7	8.1	7.7	8.0	7.9	8.3	7.9	8.2	7.5	7.9	7.6
480	6.9	7.7	7.9	7.7	8.0	7.6	8.0	7.8	8.0	7.9	8.2	7.6	8.0	7.7
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

pH

Sample ID (mg/L Sr)	Day 0	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 old
Control	7.8	7.9	8.0	7.6	8.0	7.9	~~7.9~~ 8.0	8.0	8.0	7.9	8.0	8.0	8.0	7.9
30	7.6	7.9	7.9	7.6	7.8	7.9	8.0	8.0	7.9	7.9	7.9	8.0	8.0	7.9
60	7.6	7.9	7.9	7.7	7.8	7.9	8.0	7.9	7.9	7.9	7.9	7.9	8.0	7.8
120	7.5	7.9	7.9	7.7	7.8	7.9	8.0	7.9	7.9	7.9	7.8	7.9	8.0	7.8
240	7.6	7.8	7.8	7.7	7.8	7.9	8.0	7.9	7.9	7.9	7.8	7.9	7.9	7.7
480	7.6	7.6	7.7	7.7	7.7	7.8	7.9	7.9	7.8	7.8	7.7	7.9	7.8	7.7
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments:

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

Chronic *H. azteca* Sediment Toxicity Test Data Sheet
Freshwater Sediment Water Quality

Client:	In-House (R+D)	Start Date:	~~27-Jun-12~~ KJL July 5/12
Work Order No.:	n/a	Termination Date:	~~11-Jul-12~~ July 19/12
~~Test Condition:~~ Sample ID:	Strontium	Test Organism:	*Hyalella azteca*

Dissolved Oxygen (mg/L)

Sample ID (mg/L Sr)	Day 7 new	Day 8 old	Day 8 new	Day 9 old	Day 9 new	Day 10 old	Day 10 new	Day 11 old	Day 11 new	Day 12 old	Day 12 new	Day 13 old	Day 13 new	Day 14 old
Control	8.0	7.9	8.0	8.0	7.9	7.9	8.0	8.1	8.2	7.7	8.3	8.0	8.2	7.8
30	7.8	7.9	7.8	7.9	7.9	8.0	8.0	8.4	8.2	7.6	8.3	7.9	8.2	7.7
60	7.8	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.2	7.7	8.3	8.0	8.2	7.6
120	8.0	8.0	8.1	8.0	8.0	8.0	8.1	8.0	8.1	7.7	8.2	7.9	8.0	7.7
240	8.1	8.1	8.2	8.0	8.0	8.0	8.1	8.0	8.0	7.8	8.2	8.0	8.1	7.7
480	8.1	8.2	8.2	8.0	8.0	8.0	8.1	8.0	8.0	7.7	8.2	8.0	8.1	7.8
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

pH

Sample ID (mg/L Sr)	Day 7 new	Day 8 old	Day 8 new	Day 9 old	Day 9 new	Day 10 old	Day 10 new	Day 11 old	Day 11 new	Day 12 old	Day 12 new	Day 13 old	Day 13 new	Day 14 old
Control	7.8	7.8	8.0	8.0	8.0	8.0	8.2	8.0	8.1	8.0	7.9	8.0	7.9	8.0
30	8.0	7.8	7.9	8.0	8.0	8.1	8.2	8.0	8.0	8.0	8.0	8.0	7.9	8.0
60	7.9	7.8	7.9	8.0	8.0	8.1	8.1	8.0	8.0	8.0	8.0	8.0	7.9	8.0
120	7.9	7.8	7.9	8.0	8.0	8.1	8.1	8.0	8.0	8.0	7.9	8.0	7.9	8.0
240	7.8	7.8	7.8	8.0	7.9	8.1	8.1	7.9	7.9	7.9	7.9	7.9	7.9	7.9
480	7.7	7.8	7.7	8.0	7.8	8.1	8.0	7.9	7.8	7.9	7.7	7.9	7.8	7.9
Technician Initials	KJL	KJL	KJL	~	~	~	~	KJL	KJL	KJL	KJL	KJL	KJL	KJL

Comments:

Reviewed by: [signature] Date Reviewed: 6 Nov 2012

Nautilus Environmental

H. azteca Sediment Toxicity Test Data Sheet

Freshwater Sediment 14-d Survival and Weight

Client: In-House (R+D)
W.O. #: n/a
Sample ID: Strontium

Start Date: ~~27-Jun-12~~ KJL July 5/12
Termination Date: ~~11-Jul-12~~ July 19/12
Test Organism: *Hyalella azteca*

Sample ID (mg/L Sr)	Pan No.	Rep (orange)	No. alive	No. dead	No. missing	Initials	Pan weight (mg)	Pan + organism (mg)	No. weighed	Initials
Control	1	A	10	0	0	KJL	1013.32	1016.92	10	KJL
	2	B	10	0	0	↓	1027.63	1031.74	10	↓
	3	C	10	0	0	↓	994.10	998.20	10	↓
	4	D	10	0	0	↓	995.71	1000.15	10	↓
30	5	A	10	0	0	KJL	984.89	988.25	10	KJL
	6	B	10	0	0	↓	975.88	979.11	10	↓
	7	C	10	0	0	↓	1014.41	1018.54	10	↓
	8	D	10	0	0	↓	997.22	1001.53	10	↓
60	9	A	10	0	0	KJL	1001.75	1003.50	10	KJL
	10	B	10	0	0	↓	1005.80	1008.34	10	↓
	11	C	10	0	0	↓	1001.54	1004.08	10	↓
	12	D	10	0	0	↓	999.52	1002.57	10	↓
120	13	A	10	0	0	KJL	1022.97	1024.28	10	KJL
	14	B	10	0	0	↓	1017.94	1019.25	10	↓
	15	C	10	0	0	↓	1038.96	1040.18	10	↓
	16	D	10	0	0	↓	1021.69	1023.13	10	↓
240	17	A	0	2	8	KJL	1000.44	—	0	KJL
	18	B	0	0	10	↓	1011.30	—	0	↓
	19	C	0	0	10	↓	1007.90	—	0	↓
	20	D	0	0	10	↓	999.68	—	0	↓

Comments: Reweighed pans: 4- ~~99~~ KJL 1000.02 10- 1008.22

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

H. azteca Sediment Toxicity Test Data Sheet
Freshwater Sediment 14-d Survival and Weight

Client: In-House (R+D)
W.O. #: n/a
Sample ID: Strontium

Start Date: ~~27-Jun-12~~ KJL July 5/12
Termination Date: ~~11-Jul-12~~ July 19/12
Test Organism: *Hyalella azteca*

Sample ID (mg/L Sr)	Pan No.	Rep	No. alive	No. dead	No. missing	Initials	Pan weight (mg)	Pan + organism (mg)	No. weighed	Initials
480	21	A	0	0	10	KJL	1001.97	—	0	KJL
	22	B	0	0	10	↓	1011.80	—	0	↓
	23	C	0	0	10	↓	1043.96	—	0	↓
	24	D	0	0	10	↓	967.22	—	0	↓

Comments:

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

CETIS Summary Report

Report Date: 17 Aug-12 09:25 (p 1 of 1)
Test Code: n/a | 16-6428-1589

Hyalella 14-d Survival and Growth Sediment Test — **Nautilus Environmental**

Batch ID:	07-4674-7996	**Test Type:**	Growth-Survival (~~10d~~)(14 d)	**Analyst:**	
Start Date:	05 Jul-12 15:00	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Mod-Hard Synthetic Water
Ending Date:	19 Jul-12 15:00	**Species:**	Hyalella azteca	**Brine:**	
Duration:	14d 0h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Sample ID:	12-9817-1117	**Code:**	4D6084ED	**Client:**	Golder
Sample Date:	03 May-12	**Material:**	Strontium	**Project:**	
Receive Date:	03 May-12	**Source:**	Golder		
Sample Age:	63d 15h	**Station:**	Strontium		

Point Estimate Summary

Analysis ID	Endpoint	Level	mg/L	95% LCL	95% UCL	TU	Method
02-9408-6394	10d Survival Rate	EC50	176.8	159.2	196.2		Binomial/Graphical

10d Survival Rate Summary

C-mg/L	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	4	1	1	1	1	1	0	0	0.0%	0.0%
30.1		4	1	1	1	1	1	0	0	0.0%	0.0%
61.25		4	1	1	1	1	1	0	0	0.0%	0.0%
125		4	1	1	1	1	1	0	0	0.0%	0.0%
242		4	0	0	0	0	0	0	0		100.0%
469		4	0	0	0	0	0	0	0		100.0%

10d Survival Rate Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	1	1	1	1
30.1		1	1	1	1
61.25		1	1	1	1
125		1	1	1	1
242		0	0	0	0
469		0	0	0	0

Hyalella 14-d Survival and Growth Sediment Test — Nautilus Environmental

Analysis ID:	08-0161-7154	Endpoint:	Mean Dry Biomass-mg	CETIS Version:	CETISv1.8.4
Analyzed:	07 Nov-12 15:23	Analysis:	Nonlinear Regression	Official Results:	Yes
Batch ID:	07-4674-7996	Test Type:	Growth-Survival (10d) (14 d)	Analyst:	
Start Date:	05 Jul-12 15:00	Protocol:	EC/EPS 1/RM/33	Diluent:	Mod-Hard Synthetic Water
Ending Date:	19 Jul-12 15:00	Species:	Hyalella azteca	Brine:	
Duration:	14d 0h	Source:	Aquatic Biosystems, CO	Age:	
Sample ID:	12-9817-1117	Code:	4D6084ED	Client:	Golder
Sample Date:	03 May-12	Material:	Strontium	Project:	
Receive Date:	03 May-12	Source:	Golder		
Sample Age:	63d 15h	Station:	Strontium		

Non-Linear Regression Options

Model Function	X Transform	Y Transform	Weighting Function	PTBS Function
3P Log-Logistic EV [Y=A/(1+(X/D)^C)]	None	None	Normal [W=1]	Off [Y*=Y]

Regression Summary

Iters	Log LL	AICc	BIC	Adj R2	Optimize	F Stat	Critical	P-Value	Decision(α:5%)
9	68.7	-130.2	-127.9	0.9523	Yes	2.114	3.16	0.1341	Non-Significant Lack of Fit

Point Estimates

Level	mg/L	95% LCL	95% UCL
IC5	21.79	N/A	31.85
IC10	30.24	19.3	38.5
IC15	37.03	27.7	45.09
IC20	43.15	34.28	51.36
IC25	48.95	40.28	57.38
IC40	66.33	57.67	75.65
IC50	79.24	69.87	89.87

Regression Parameters

Parameter	Estimate	Std Error	95% LCL	95% UCL	t Stat	P-Value	Decision(α:5%)
A	0.4081	0.01696	0.3748	0.4413	24.06	<0.0001	Significant Parameter
C	2.281	0.3221	1.649	2.912	7.081	<0.0001	Significant Parameter
D	79.24	6.371	66.75	91.72	12.44	<0.0001	Significant Parameter

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Model	0.632523	0.632523	1	461.2	<0.0001	Significant
Lack of Fit	0.007504	0.002501	3	2.114	0.1341	Non-Significant
Pure Error	0.021297	0.001183	18			
Residual	0.028801	0.001371	21			

Residual Analysis

Attribute	Method	Test Stat	Critical	P-Value	Decision(α:5%)
Variances	Mod Levene Equality of Variance	3.822	2.773	0.0155	Unequal Variances
Distribution	Shapiro-Wilk W Normality	0.9704	0.9169	0.6771	Normal Distribution
	Anderson-Darling A2 Normality	0.3954	2.492	0.3763	Normal Distribution

Mean Dry Biomass-mg Summary — Calculated Variate

C-mg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	4	0.4063	0.36	0.444	0.01732	0.03465	8.53%	0.0%
30.1		4	0.3758	0.323	0.431	0.02709	0.05417	14.42%	7.51%
61.25		4	0.247	0.175	0.305	0.02684	0.05368	21.73%	39.2%
125		4	0.132	0.122	0.144	0.004526	0.009052	6.86%	67.51%
242		4	0	0	0	0	0		100.0%
469		4	0	0	0	0	0		100.0%

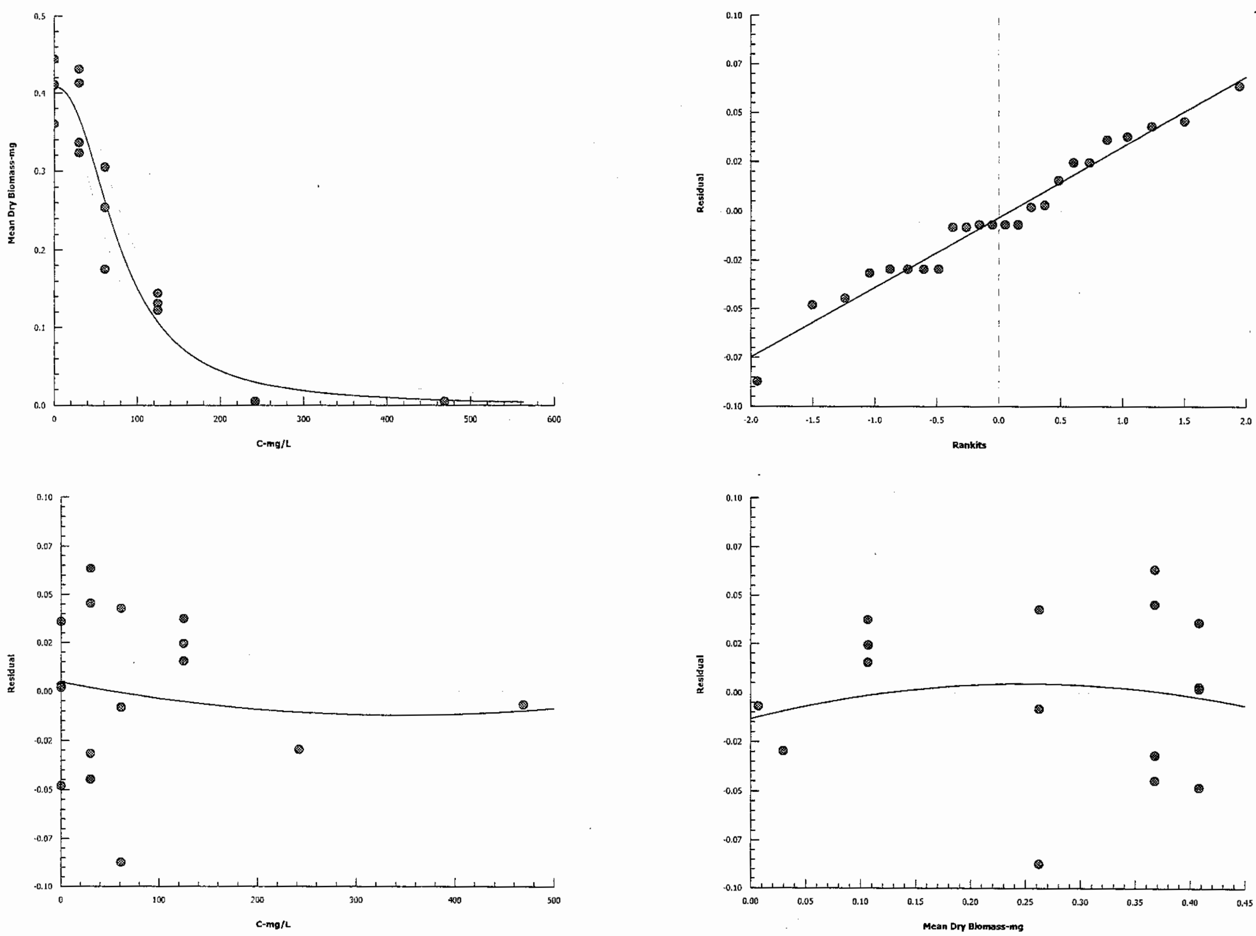
Hyalella 14-d Survival and Growth Sediment Test — **Nautilus Environmental**

Analysis ID:	08-0161-7154	**Endpoint:**	Mean Dry Biomass-mg	**CETIS Version:**	CETISv1.8.4
Analyzed:	07 Nov-12 15:23	**Analysis:**	Nonlinear Regression	**Official Results:**	Yes

Mean Dry Biomass-mg Detail

C-mg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Negative Control	0.36	0.411	0.41	0.444
30.1		0.336	0.323	0.413	0.431
61.25		0.175	0.254	0.254	0.305
125		0.131	0.131	0.122	0.144
242		0	0	0	0
469		0	0	0	0

Graphics — 3P Log-Logistic EV [Y=A/(1+(X/D)^C)]



Client: In-House (R+D)

W.O.#: n/a

Hardness and Alkalinity Datasheet

	Alkalinity						Hardness			
Sample ID	Sample Date	Sample Volume (mL)	(mL) 0.02N HCL/H_2SO_4 used to pH 4.5	(mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Total Alkalinity (mg/L$CaCO_3$)		Sample Volume (mL)	Volume of 0.01M EDTA Used (mL)	Total Hardness (mg/L $CaCO_3$)	Technician
MHW Hyal	July5/12	50	3.0	3.1	58		50	5.0	100	KEB

Notes:

Reviewed by: [signature]

Date Reviewed: 6 Nov 2012

ALS

NAUTILUS ENVIRONMENTAL
ATTN: Karen Lee
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 05-JUL-12
Report Date: 12-JUL-12 12:27 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: **L1173792**
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Round 2
Sr analysis
Hyalella
July 5, 2012
Day 0

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1173792-1	L1173792-2	L1173792-3	L1173792-4	L1173792-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	05-JUL-12	05-JUL-12	05-JUL-12	05-JUL-12	05-JUL-12
	Sampled Time					
	Client ID	CONTROL-SR	30-SR	60-SR	120-SR	240-SR
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	0.0258	31.7	63.5	127	246

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1173792-6				
	Description	WATER				
	Sampled Date	05-JUL-12				
	Sampled Time					
	Client ID	480-SR				
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	479				

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
MET-TOT-ICP-VA	Water	Total Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

TESTING LOCATION (Please Circle)

(1) British Columbia
8664 Commerce Court
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

Chain of Custody

Date Jul 5/12 Page 1 of 1

L117379 2-COFC

Sample Collection By:

Report to:	(1)	**Invoice To:**	(1)
Company		Company	
Address		Address	
City/State/Zip		City/State/Zip	
Contact		Contact	
Phone		Phone	
Email	karen@nautilusenvironmental.com	Email	karen@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium									Receipt Temperature (°C)
1	Control - Sr	05-Jul-12			125ml Bottle	1	Strontium - Day 0	x									
2	30 - Sr	05-Jul-12			125ml Bottle	1	Strontium - Day 0	x									
3	60 - Sr	05-Jul-12			125ml Bottle	1	Strontium - Day 0	x									
4	120 - Sr	05-Jul-12			125ml Bottle	1	Strontium - Day 0	x									
5	240 - Sr	05-Jul-12			125ml Bottle	1	Strontium - Day 0	x									
6	480 - Sr	05-Jul-12			125ml Bottle	1	Strontium - Day 0	x									
7																	
8																	
9																	
10																	

PROJECT INFORMATION		**SAMPLE RECEIPT**	
Client:		Total No. of Containers	
PO No.:		Received Good Condition?	
Shipped Via:		Matches Test Schedule?	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day 0. Samples are not preserved.

RELINQUISHED BY (CLIENT)
(Signature) Karen (Time) 1700h
(Printed Name) Karen Lee (Date) Jul 5/12
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) TN (Time) 17:20
(Printed Name) July 5 (Date)
(Company) 23°

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

ALS

NAUTILUS ENVIRONMENTAL
ATTN: Karen Lee
8664 Commerce Court
Imperial Square Lake City
Burnaby BC V5A 4N7

Date Received: 19-JUL-12
Report Date: 25-JUL-12 15:54 (MT)
Version: FINAL

Client Phone: 604-420-8773

Certificate of Analysis

Lab Work Order #: **L1181583**
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Round 2
Sr analysis
Hyalella
July 19, 2012
Day 14

Can Dang
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

		Sample ID	L1181583-1	L1181583-2	L1181583-3	L1181583-4	L1181583-5
		Description	WATER	WATER	WATER	WATER	WATER
		Sampled Date	19-JUL-12	19-JUL-12	19-JUL-12	19-JUL-12	19-JUL-12
		Sampled Time					
		Client ID	CONTROL - SR	30 - SR	60 - SR	120 - SR	240 - SR
Grouping	**Analyte**						
WATER							
Total Metals	Strontium (Sr)-Total (mg/L)		0.0867	28.5	59.0	123	238

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1181583-6				
	Description	WATER				
	Sampled Date	19-JUL-12				
	Sampled Time					
	Client ID	480 - SR				
Grouping	**Analyte**					
WATER						
Total Metals	Strontium (Sr)-Total (mg/L)	459				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SPL	Sample was Preserved at the laboratory - Total Metals

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
MET-TOT-ICP-VA	Water	Total Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotblock or microwave oven (EPA Method 3005A). Instrumental analysis is by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BC, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Nautilus Environmental

L1181583

TESTING LOCATION (Please Circle)

1 (1) **British Columbia**
~~8664 Commerce Court~~
Burnaby, British Columbia, Canada V5A 4N3
Phone 604.420.8773
Fax 604.357.1361

Chain of Custody

Date Jul 19/12 Page 1 of 1

Sample Collection By:

Report to:	(1)	**Invoice To:**	(1)
Company		**Company**	
Address		**Address**	
City/State/Zip		**City/State/Zip**	
Contact		**Contact**	
Phone		**Phone**	
Email	karen@nautilusenvironmental.com	**Email**	karen@nautilusenvironmental.com

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	Total Strontium										Receipt Temperature (°C)
1	Control - Sr	19-Jul-12			125ml Bottle	1	Strontium - Day 14	x										
2	30 - Sr	19-Jul-12			125ml Bottle	1	Strontium - Day 14	x										
3	60 - Sr	19-Jul-12			125ml Bottle	1	Strontium - Day 14	x										
4	120 - Sr	19-Jul-12			125ml Bottle	1	Strontium - Day 14	x										
5	240 - Sr	19-Jul-12			125ml Bottle	1	Strontium - Day 14	x										
6	480 - Sr	19-Jul-12			125ml Bottle	1	Strontium - Day 14	x										
7																		
8																		
9																		
10																		

(ANALYSES REQUIRED)

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		**Total No. of Containers**	
PO No.:		**Received Good Condition?**	
Shipped Via:		**Matches Test Schedule?**	

SPECIAL INSTRUCTIONS/COMMENTS: Hyalella sediment test. Day ~~7~~ 14 Samples are not preserved.

RELINQUISHED BY (CLIENT)
(Signature) [signature] (Time) 1700h
(Printed Name) Karen Lee (Date) Jul 19/12
(Company) Nautilus Environmental

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) [signature] July 19 (Time) 17:50
(Printed Name) (Date) temp 22.7
(Company)

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.