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SNAP LAKE

2013 Aquatic Effects Monitoring Program Design Plan

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REPORT

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PLAIN LANGUAGE SUMMARY

The original Aquatic Effects Monitoring Program (AEMP) for the Snap Lake Mine (the Mine) was designed and implemented in 2005. The Water Licence for the Mine requires De Beers Canada Inc. (De Beers) to review and update the AEMP in 2012 and every four years thereafter. The AEMP Re-Evaluation Report, previously submitted to the Mackenzie Valley Land and Water Board (MVLWB), provides a detailed review of the existing AEMP. The present 2013 AEMP Design Plan builds on that Report to recommend changes to the existing AEMP program based on results and findings to date. Key changes, described below, are as follows: a conceptual site model (a visual representation of the food web in Snap Lake in relation to potential Mine-related effects) was developed; a new reference lake was identified; monitoring stations were reorganized to include downstream lakes; the sampling schedule was adjusted; and, a Response Framework for assessing the overall results of AEMP monitoring was developed based on a Weight of Evidence assessment.

Conceptual Site Model

The conceptual site model includes the following food web components that could be affected by the Mine, and which are also assessed in the AEMP: the small planktonic organisms living in the open water (phytoplankton – small plants; zooplankton – small animals); the small organisms living in the near-shore area (n – small attached plants called epilithic algae and small animals without backbones called invertebrates living on rocks); the organisms living in the sediments (animals without backbones called invertebrates such as snails, clams, worms, and insect larvae); and, the fish. Although dust and uncontrolled runoff can potentially affect this food web, the primary potential effect is from the treated effluent. There are two possible effects from the treated effluent: nutrient enrichment (more food); or, chemical contamination (resulting in toxicity).The conceptual site model provides the basis for refining the AEMP to provide necessary information for management to keep the water safe to drink and the fish present and safe to eat.

New Reference Lake

Northeast Lake is currently the reference lake for the AEMP. A reference lake is a lake that is reasonably similar to what Snap Lake was like before the Mine, and is not affected by the Mine. By monitoring a reference lake, De Beers can assess whether changes in Snap Lake are due to the Mine, or due to natural factors. More than one reference lake provides a better basis upon which to determine whether changes to Snap Lake are natural or Mine-related. Lake 13 has been recommended as a second reference lake. It was approved by the MVLWB on March 28, 2013; it was added to the 2013 AEMP.

Reorganization of Monitoring Stations

The 2005 AEMP Design Plan focused on the effects of treated effluent on Snap Lake as it mixed with the natural lake waters. Presently, treated effluent is relatively evenly mixed throughout the main body of Snap Lake, and is now found in the lakes immediately downstream of Snap Lake. Accordingly, changes in Snap Lake can be assessed by fewer monitoring stations. Also, the AEMP was streamlined to the extent possible, by sampling the same monitoring stations by each component (water and sediment quality, plankton, and benthos).

Adjustment of Sampling Schedule

Some AEMP components were being monitored too often, some not often enough based on the results of monitoring through to 2012. Accordingly, the frequency of monitoring of the different components has been

adjusted. It is proposed that water quality, plankton, and fish tasting (a part of traditional knowledge) be monitored every year, while sediment quality, benthic invertebrates, fish health, fish community, and metals in fish be monitored every three years.

AEMP Response Framework

The AEMP Response Framework, which also incorporates a Weight of Evidence assessment of AEMP findings, provides a systematic approach for responding to the results of the AEMP. Potential responses are identified, with responses required if unacceptable changes or trends pointing to such trends are detected. The specific responses will depend on the type and seriousness of any effect(s) determined from the AEMP results.

SUMMARY OF THE PROPOSED MONITORING PLAN BY AEMP COMPONENT

Water Quality Monitoring

The objective of water quality monitoring is to determine whether changes in water quality caused by the Mine could be detrimental to aquatic communities in Snap Lake. This monitoring compares concentrations of substances in lake water with Environmental Assessment Report (EAR) predictions, Water Licence limits, and AEMP benchmarks (concentrations above which potential effects could occur).

The number and locations of water quality stations in Snap Lake were chosen so that there would be sufficient data to calculate the average total dissolved solids (TDS) concentrations for Snap Lake and to support future water quality modelling. The stations were also chosen to provide the data required for sediment, plankton, and benthic invertebrate monitoring. Water quality monitoring will continue at nine existing water quality stations in the main basin of Snap Lake and at four existing stations in the northwest arm of the lake. Six stations will be discontinued. The reorganized stations will reduce duplication, while still providing “early warning” of any effects.

A water quality station in a tributary of Snap Lake will be added to the AEMP program. This station will provide information about natural inflows to Snap Lake and potential acidification due to air emissions. Reconnaissance sampling, including treated effluent plume delineation, will be completed downstream of Snap Lake in Lake 1, Lake 2, and in Lac Capot Blanc.

For the 2013 AEMP Design Plan, one water quality sample will be collected at each of the Snap Lake stations at the depth of maximum conductivity, or mid-depth if no conductivity gradient is present. Specific conductivity measurements, which are a direct measurement of TDS, will be made at 1-m intervals at each station, including stations close to the artificial reef and near the water intake.

The diffuser stations in Snap Lake will continue to be monitored monthly to provide early-warning water quality data. Other stations in Snap Lake and the two reference lakes will be sampled for selected parameters four times per year: April/May, July, August, and September. The January program will be discontinued because data have shown that the “worst-case” chemistry usually occurs in late winter and because sampling in January is often postponed due to health and safety concerns. Sampling at the existing station 25 km downstream of Snap Lake (i.e., at King Lake) will be carried out once a year in April/May. Metals will be monitored monthly at the diffuser stations and in April/May and September at the other stations.

Toxicity sampling and testing will continue at the three Snap Lake diffuser stations twice per year, once during ice-covered conditions in April/May and once during open-water conditions in September. Beginning in 2013, sampling for another toxicity test, the Rainbow Trout embryo/alevin/fry test, will be added. This sampling is anticipated to be conducted weekly over a three-month period beginning in July (i.e., during the duration of this long-term toxicity test).

Sediment Quality Monitoring

The objective of the sediment quality monitoring is to determine whether sediment quality in Snap Lake can support a healthy benthic invertebrate community. This monitoring compares concentrations of substances in the sediment with AEMP benchmarks (concentrations above which potential effects could occur).

Sediment quality in the main basin of Snap Lake will be assessed and compared to the two reference lakes. The number of monitoring stations in the main basin of Snap Lake will be reduced to seven, and there will be three stations in the northwest arm of Snap Lake.

Sediment quality monitoring at the diffuser station will continue to be carried out once a year to serve as an early warning of possible changes in sediment quality within Snap Lake. Monitoring at the other sediment stations will be reduced from once a year to once every three years.

Samples will continue to be collected from the top 5 centimetres (cm) of sediment for all stations. However, samples will also be collected from the top 2 cm at the diffuser station to assess Mine-related changes over time.

Plankton Monitoring

The objective of the plankton monitoring is to determine whether plankton communities have been affected by changes in water quality in Snap Lake. This monitoring also compares plankton communities with EAR predictions.

Plankton sampling will be carried out in Snap Lake, Northeast Lake, and Lake 13. The sampling locations will be the same as those for water quality sampling. Sampling will take place each year in July, August, and September.

Benthic Invertebrates

The objective of benthic invertebrate monitoring is to determine whether benthic invertebrate communities have been affected by changes in water and sediment quality in Snap Lake. This monitoring also compares benthic invertebrate communities with EAR predictions.

Sampling locations will be located in water that is 10 to 15 metres (m) deep. This is the same depth used in the AEMP to date. The sampling locations will be the same as those for water quality sampling with the following exceptions. In the northwest arm of Snap Lake, one station will be at a different location because the water quality station is deeper than 15 m. Sampling will be conducted every three years. In the main basin, SNAP15 will be monitored in place of water quality station SNP02-20e because SNP02-20e is deeper than the maximum depth of 15 m required for benthic invertebrate sampling. Station SNAP07 will be added to the monitoring program to monitor the benthic invertebrate community near the outlet of Snap Lake. This station will be monitored in place of water quality station SNAP08 because SNAP08 is shallower than the minimum depth required for benthic invertebrate sampling.

Fish Health

The objective of the fish health survey is to determine whether treated Mine effluent is having a significant effect on the growth, reproduction, survival, and condition of fish in Snap Lake. Comparisons are made to EAR predictions.

In 2012, the AEMP fish health survey was changed from a large-bodied Lake Trout and Round Whitefish program to a small-bodied Lake Chub program. The change was made because of concerns about the effect of sampling-related mortality on Lake Trout and Round Whitefish populations in Snap Lake. For the 2013 AEMP Design Plan, fish health will be assessed with lethal and non-lethal surveys of Lake Chub to assess growth, reproduction, and condition.

Fish will be collected from the main basin of Snap Lake, Northeast Lake, and Lake 13, from the same stations and from similar habitat types in Snap Lake as in previous AEMP studies. The sample size for the lethal survey will increase from 30 to 40 fish for each of adult males, adult females, and juveniles. This increase in sample size is a compromise between acceptable levels of fish mortality and better data for statistical analyses. Sampling will continue immediately following ice-out in early to mid-July at the peak pre-spawning period for Lake Chub, and will be carried out every three years.

Comparisons will be made between Snap Lake and the reference lakes. Comparisons will also be made among fishing methods to see whether the fishing method affects the total number of fish caught, and whether it affects the difference between the numbers of males and females caught.

Fish Community

The objective of fish community monitoring is to determine whether changes in water quality in Snap Lake are affecting the makeup of the fish community and, if so, whether the effects are greater than those predicted in the EAR.

Fish community monitoring will measure fish abundance and will determine the species make-up of the fish communities in Snap Lake, Northeast Lake, and Lake 13. It will also measure fish size, mortality, maturity, age at maturity, juvenile survival and growth rate, and the rate of reproduction for individual species within the community such as Lake Trout and Round Whitefish and their age structure.

The field program will take place after ice-out, every 3 years for about 21 consecutive days, with 7 days on each of the three lakes. The program will follow the Broad Scale Fish Community Monitoring method (BsM), a widely-accepted sampling method developed by the Ontario Ministry of Natural Resources and endorsed by Fisheries and Oceans Canada. Large-mesh and small-mesh gillnets having a range of mesh sizes will be used to target a broad range of fish sizes and species. Gill nets will be set at a number of depths within each lake and the BsM method will be used to capture approximately two percent of the fish in each lake.

Fish Tissue Metals

The objective of monitoring fish tissue metal concentrations is to determine whether the treated Mine effluent has increased fish tissue metal levels to the extent that this would limit their use or safe consumption by humans or wildlife. Fish usability can be affected by flavour and odour, and by tissue metals concentrations that are above consumption guidelines.

Fish will be collected from the main body of Snap Lake, Northeast Lake, and Lake 13. Sampling will take place every three years, starting in 2015. This sampling frequency strikes a balance between the need for monitoring and the mortality caused by monitoring.

Lake Chub tissues will be analyzed for metal concentrations as part of the fish health study. Lake Trout and Round Whitefish collected during the fish community program will similarly be analyzed for tissue metal concentrations. The Lake Chub results will be used as an early warning of potential changes to tissue quality of Lake Trout and as part of the interpretation of the fish health study. An increase in metal concentrations in Lake Trout or Round Whitefish will be used as an early warning of potential changes in fish usability.

Fish Tasting Program

The main objective of the Snap Lake fish tasting program is to obtain feedback from community members about Lake Trout and Round Whitefish taste, texture, general condition, and health.

The fish tasting program was developed in 2004 in response to Aboriginal concerns that the Mine could adversely affect the texture and taste of fish in Snap Lake. De Beers has conducted annual fish tasting events since 2005. The fish tasting program is an informal annual gathering of members of Aboriginal organizations and De Beers staff at the Mine site to determine whether the flavour and texture of cooked Snap Lake fish are acceptable.

The fish for the fish tasting program will be captured in the main basin of Snap Lake. The sampling locations will be chosen by Aboriginal fishermen based on traditional knowledge of fish habitat preferences and on past fish health program sampling success. If possible, fish will be caught from the same vicinity each year. Community members will be invited to angle and set nets for a period of no more than two days during September.

AEMP Response Framework

The AEMP Response Framework provides a systematic approach for responding to the findings of the AEMP. The level of change in Snap Lake that is not acceptable, based on the EAR, would occur when the water might not be safe to drink, and fish might not be plentiful and safe to eat.

Leading up to such unacceptable change are various “Action Levels”. Potential responses are identified for each Action Level, with increasing responses required if unacceptable changes become more likely. A “Low Action Level” is identified if there are few changes based on the monitoring but the changes are approaching EAR predictions.

The specific responses to be taken will depend on the type and seriousness of effect(s) determined from the AEMP. If an Action Level is exceeded, De Beers is required to contact the Board within 30 days and to prepare a plan to respond, the “AEMP Response Plan,” for review and approval.

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ACRONYMS AND GLOSSARY

Elements

Ag	silver
Al	aluminum
As	arsenic
B	boron
Ba	barium
Be	beryllium
Bi	bismuth
C	carbon
Cd	cadmium
Co	cobalt
Cr	chromium
Cr(VI+)	hexavalent chromium
Cs	cesium
Cu	copper
Fe	iron
Hg	mercury
Li	lithium
Mn	manganese
Mo	molybdenum
N	nitrogen
Ni	nickel
P	phosphorus
Pb	lead
S	sulphur
Sb	antimony
Se	selenium
SiO_2	silicon dioxide
SO_2	sulphur dioxide
Sr	strontium
Tl	thallium
Ti	titanium
U	uranium
V	vanadium
Zn	zinc

Acronyms

AB	Alberta
AEMP	Aquatic Effects Monitoring Program
ALS	ALS Laboratory Group
ANCOVA	analysis of covariance
ANOVA	analysis of variance
APHA	American Public Health Association
BC	British Columbia
BCMOE	British Columbia Ministry of the Environment
BOD	biochemical oxygen demand
BsM	Broad-scale Fish Community Monitoring
BTEX	benzene, toluene, ethylene, xylene
CA	California
CCME	Canadian Council of Ministers of the Environment
CCMS	collision cell inductively coupled plasma-mass spectrometry
CPUE	catch-per-unit-effort
CT	Connecticut
CV	coefficient of variation
DC	District of Columbia
DDW	laboratory-distilled de-ionized water
De Beers	De Beers Canada Inc.
DFO	Fisheries and Oceans Canada
DIC	dissolved inorganic carbon
DL	detection limit
DO	dissolved oxygen
DOC	dissolved organic carbon
dw	dry weight
E. coli	*Escherichia coli*
e.g.	for example
EAF	embryo/alevin/fry
EAR	Environmental Assessment Report
EEM	Environmental Effects Monitoring
ELS	early life stage
et al.	and others
FF	far-field area
FL	Florida
Flett	Flett Research Ltd.
GF/C	Glass Fibre type C Filter

GIS	geographic information system
Golder	Golder Associates Ltd.
GSI	gonadosomatic index
HydroQual	HydroQual Laboratories
i.e.	that is
IC	ice cover
IC25 / IC50	inhibition concentration (to 25% / 50% of test organisms)
ICP-MS	inductively coupled plasma-mass spectrometry
ISQG	interim sediment quality guideline
K	condition factor based on carcass weight
K-S	Kolmogorov-Smirnov
LC25 / LC50	lethal concentration (to 25% / 50% of test organisms)
LSI	liver somatic index
max	maximum
Maxxam	Maxxam Analytics Inc.
MB	Manitoba
MDS	Multiparameter Display System
MF	mid-field area
mL	Millilitre
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVLWB	Mackenzie Valley Land and Water Board
n	number of stations sampled / number of samples
n/a	not applicable
NAD	North American Datum
NC	North Carolina
NEL	Northeast Lake
NF	near-field area
NH	New Hampshire
NMDS	non-metric multidimensional scaling
NWA	northwest arm
NWT	Northwest Territories
NY	New York
OH	Ohio
ON	Ontario
PEL	probable effect level
pers. comm.	personal communication
PIT	passive integrated transponder
P-value	statistical probability

QA	quality assurance
QC	quality control
QS	Quick Sample (YSI 600)
RPD	relative percent difference
SD	standard deviation
SE	standard error
SNP	Surveillance Network Program
SQG	sediment quality guideline
SR	studentized residual
SYSTAT	SYSTAT Software Inc.
TDN	total nitrogen, total dissolved nitrogen
TDP	total dissolved phosphorus
TDS	total dissolved solids
the Mine	Snap Lake Mine
TOC	total organic carbon
TP	total phosphorus
TWTP	temporary water treatment plant
UK	United Kingdom
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WQG	water quality guideline
WTP	permanent water treatment plant

Units of Measure

%	percent
‰	parts per thousand
% dw	percent dry weight
α	alpha
β	beta
<	less than
>	greater than
±	plus or minus
≤	less than or equal to
≥	greater than or equal to
°C	degree Celsius
µg/g ww	micrograms per gram wet weight
µm	micrometre

µS/cm	microSiemens per centimetre
cm	centimetre
CFU/100 mL	colony forming units per 100 millilitres
g	gram
h	hour
kg	kilogram
kg/year	kilograms per year
km	kilometre
L	litre
m	metre
m^2	square metre
mg	milligram
mg/kg	milligrams per kilogram
mg/kg dw	milligrams per kilogram dry weight
mg/L	milligrams per litre
mm	millimetre
mm^3/m^3	cubic millimetres per cubic metre
v/v	volume of solute per volume of solvent

Glossary

acidification	The decrease of acid neutralizing capacity in water, or base saturation in soil, caused by natural or anthropogenic processes. Acidification is exhibited as the lowering of pH.
acute	A stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
alkalinity	A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. Alkalinity is expressed as an equivalent of calcium carbonate. Its composition is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.

autotroph	An organism that produces complex organic compounds (such as carbohydrates, fats, and proteins) from simple inorganic molecules using energy from light (by photosynthesis) or inorganic chemical reactions (chemosynthesis). They are the producers in a food chain, such as plants on land or algae in water.
background	An area not influenced by chemicals released from the site under evaluation.
baseline	A surveyed or predicted condition that serves as a reference point to which later surveys are coordinated or correlated.
bathymetry	Measurement of the depth of a waterbody.
benthic invertebrates	Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of waterbodies such as lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species, such as caddisfly larvae, that spend at least part of their lifestages dwelling on bottom sediments in the waterbody. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.
biochemical oxygen demand (BOD)	An empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and contaminated waters.
Biota	Living organisms and vegetation.
chlorophyll *a*	The primary photosynthetic pigment contained in the phytoplankton (primary producers).
chronic	The development of adverse effects after extended exposure to a given substance. In chronic toxicity tests, the measurement of a chronic effect can be reduced growth, reduced reproduction or other non-lethal effects, in addition to lethality. Chronic should be considered a relative term depending on the life span of the organism.
colonial	Individuals of the same species clustered together to form a group.
conductivity	A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.

Fisheries and Oceans Canada (DFO)	Responsible for policies and programs in support of Canada's economic, ecological and scientific interests in oceans and inland waters; for the conservation and sustainable utilization of Canada's fisheries resources in marine and inland waters; for leading and facilitating federal policies and program on oceans; and for safe effective and environmentally sound marine services responsive to the needs of Canadians in a global economy.
detection limit (DL)	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
diatom	A group of algae that are encased within a frustule made of silica; a component of phytoplankton.
diffuser	A device used to disperse an effluent plume to a waterbody.
diffuser station	Stations located less than 200 metres from the Snap Lake diffuser.
dissolved oxygen (DO)	Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L).
ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location. A community of organisms and its environment functioning as an ecological unit. For the purposes of assessment, the ecosystem must be defined according to a particular unit and scale.
effluent	Stream of water discharging from a source.
Ekman grab	Cube-shaped mechanical device with spring-loaded jaws at the bottom that is lowered to the bottom of a waterbody and triggered to close to collect a sample of the bottom substrate.
electrofishing	A live fish capture technique in which negative (anode) and positive (cathode) electrodes are placed in the water and an electrical current is passed between the electrodes. Fish are attracted (galvano-taxis) to the anode and become stunned (galvano-narcosis) by the current, allowing fish to be collected, measured, and then released.
euphotic	The upper surface layer of a waterbody where sufficient light penetrates to allow photosynthesis to occur.

eutrophication	The over fertilization of a body of water, which generally results in increased plant growth and decay. This ultimately leads to an increase in simple algae and plankton over more complex plant species, resulting in a decrease in water quality. Causes of eutrophication can be anthropogenic or natural.
far-field (FF)	Stations located in the southern portion of the south basin of Snap Lake, and in the northeast and southeast arms of Snap Lake.
fish	Fish as defined in the Fisheries Act, includes parts of fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.
geographic information system (GIS)	Computer software designed to develop, manage, analyze, and display spatially referenced data.
global positioning system (GPS)	A system of satellites, computers and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.
groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
habitat	The place or environment where a plant or animal naturally or normally lives or occurs.
histology	The microscopic study of tissues.
homogeneity	The quality of being similar or comparable in kind or nature.
hydrology	The science of waters of the Earth: their occurrence, distribution, and circulation; their physical and chemical properties; and, their reaction with the environment, including living beings.
ice-covered conditions	The period of time, during the year, when waterbodies are covered in ice.
littoral zone	The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.
mesotrophic	Trophic state classification for lakes characterized by moderate productivity and nutrient inputs (particularly total phosphorus).

method blank	A laboratory grade, pure water sample that is subjected to all laboratory procedures. Used to detect the possibility of cross-contamination between samples in the laboratory.
microcystin-LR	Microcystin-LR is among the most frequent and most toxic microcystin that frequently occur in cyanobacterial genera. Microcystin-LR is considered in the World Health Organization Guidelines for drinking-water quality.
mid-field (MF)	Stations located in the northern half of the south basin of Snap Lake.
mixing zone	The region in which the initial dilution of a discharge occurs.
near-field (NF)	Stations located in the north basin of Snap Lake.
northwest arm (NWA)	The arm of Snap Lake located north of the De Beers Snap Lake Mine.
nutrients	Substances (elements or compounds), such as nitrogen or phosphorus, that are necessary for the growth and development of plants and animals.
oligotrophic	Trophic state classification for lakes characterized by low productivity and low nutrient inputs (particularly total phosphorus).
open-water conditions	The period of time during the year when waterbodies are relatively free of ice.
open-water season	Same as above
outlier	A data point that falls outside of the statistical distribution defined by the mean and standard deviation.
***P*–value**	Statistical probability value used to determine the significance of a relationship or difference.
pelagic	Open water area within a lake.
pH	The degree of acidity (or alkalinity) of soil or solution, expressed as the negative logarithm of hydrogen ion concentration. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of 1 pH unit represents a 10-fold change in hydrogen ion concentration.
plankton	Small, often microscopic, plants (phytoplankton) and animals (zooplankton) that live in the open water column of non-flowing water bodies such as lakes. They are an important food source for many larger animals.
plume	The area or volume of detectable effluent in a waterbody.

polygon	Representations of an area consisting of a plane figure bounded by straight edges.
probable effect level (PEL)	Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely but not certain.
quality assurance (QA)	Management and technical practices designed so that the data generated are of consistent high quality. They include standardization and review by field and office personnel of procedures used in the collection, transport, and analysis of samples.
quality control (QC)	Internal techniques used to measure and assess data quality, including samples that are used to detect and reduce systematic and random errors that may occur during field sampling and laboratory procedures.
relative abundance	The proportional representation of a species in a sample or a community.
rotifer	A large class (Rotifera) of the pseudocoelomate phylum Aschelminthes; a component of zooplankton.
Secchi depth	A measure of water clarity, measured by lowering a 20-cm diameter disk (Secchi disk) with alternating black and white coloured quadrants. The shallowest depth at which the disk is no longer visible is the Secchi depth. High Secchi depth readings indicate clearer water that allows sunlight to penetrate to greater depths. Low readings indicate turbid water, which can reduce the passage of sunlight to bottom depths. Limited light penetration can be a factor in diminished aquatic plant growth beneath the surface, thus reducing the biological reaeration at lower depths.
sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.
sedimentation	The process of deposition of suspended matter carried by water, wastewater or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material.
sentinel species	Species that can be used as an indicator of environmental conditions.

Simpson's diversity index	One of several indices used to measure diversity. In ecology, it can be used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the relative abundance of each species. The Simpson index represents the probability that two randomly selected individuals in the habitat will not belong to the same species.
specific conductivity	A measure of how well water conducts electricity.
spring freshet	A spring thaw event resulting from melting snow and ice on rivers.
standard deviation (SD)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
standard error (SE)	A measure of the statistical accuracy of an estimate, equal to the standard deviation of the theoretical distribution of a large population of such estimates. It is calculated as the standard deviation divided by the square root of the sample size.
taxa	Plural of taxon, see below.
taxon	A group of organisms at the same level of the standard biological classification system; the plural of taxon is taxa.
total dissolved solids (TDS)	The total concentration of all dissolved solids found in a water sample.
total Kjeldahl nitrogen (TKN)	The sum of organic nitrogen, ammonia, and ammonium.
total organic carbon (TOC)	Total organic carbon is composed of both dissolved and particulate forms. Total organic carbon is often calculated as the difference between total carbon (TC) and total inorganic carbon. Total organic carbon has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
total suspended solids (TSS)	The amount of suspended substances in a water sample. Solids, found in wastewater or in a stream that can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
toxicity	The inherent potential or capacity of a material to cause adverse effects to a living organism.

Traditional Knowledge	Knowledge and understanding of traditional resource and land use, harvesting, and special places.
trophic	Of or relating to feeding or nutrition.
trophic level	A functional classification of organisms in an ecosystem according to feeding relationships, from primary producers through herbivores (primary consumers) and carnivores (secondary and tertiary consumers).
turbidity	An indirect measure of suspended particles, such as silt, clay, organic matter, plankton and microscopic organisms, in water.
under ice	The period of year when the lakes are partially or completely covered with ice.
vertical profile	An in situ measurement consisting of taking readings of physical parameters or samples at certain depth increments in the water column of a lake.
waterbody	Any location where water flows or is present, whether or not the flow or presence of water is continuous seasonal, intermittent, or occurs only during a flood.
watercourse	Riverine systems such as creeks, brooks, streams, and rivers.
watershed	The entire catchment area of runoff containing a single outlet.
young-of-the-year (YOY)	Fish at age 0, within the first year after hatching.
zooplankton	Small, sometimes microscopic, animals that live in the water column of non-flowing waterbodies such as lakes and mainly eat primary producers (phytoplankton).

1.0 INTRODUCTION

1.1 Background

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (the Mine), a diamond mine located approximately 220 kilometres (km) northeast of Yellowknife, Northwest Territories. The Mine is 30 km south of MacKay Lake and 100 km south of Lac de Gras, where the Diavik and Ekati diamond mines are located (Figure 1.1-1).

An Environmental Assessment Report (EAR) for the Mine (De Beers 2002a) was submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) in February 2002. The Mine received approval from the Minister of Indian and Northern Affairs in October 2003, based on a decision report (MVEIRB 2003) and recommendation from the MVEIRB. In 2004, De Beers negotiated an Environmental Agreement and received the required Water Licence, Land Use Permit, Land Leases, and *Fisheries Act* Authorization to begin construction and operation of the Mine.

The Mine has been operating under the terms and conditions of a Class A Water Licence issued for the Mine in 2004 (Licence #MV2001L2-0002; MVLWB 2004). In June 2011, the Mine submitted an application to renew the Water Licence, and Hearings were subsequently held in December 2011. The Water Licence was renewed for a period of eight years, effective June 14, 2012 (Licence #MV2011L2-0004; MVLWB 2013a).

The Aquatic Effects Monitoring Program (AEMP) is a requirement of the Water Licence, Part G (MVLWB 2013a). The goal of the AEMP is to address potential Mine-related effects to the aquatic ecosystem of Snap Lake in a scientifically defensible and cost-effective manner. The first AEMP Design Plan was submitted in 2004. The current scope of the AEMP is based on the 2005 AEMP Design Plan submitted to the Mackenzie Valley Land and Water Board (MVLWB) in June 2005. The June 2005 AEMP incorporated comments and recommendations made by the Snap Lake Working Group. The MVLWB formed the Snap Lake Working Group to review environmental monitoring and management plans for the Mine. Membership included community organizations and regulatory agencies. The MVLWB approved the AEMP with conditions in July 2005.

Following the six years of monitoring (i.e., 2005 to 2010), De Beers was required to submit a summary of the findings of the AEMP undertaken to date, and then based on these findings, provide an update to the 2005 Design Plan for July 2010. In 2010, at the time the summary of findings and design update were scheduled for submission to the MVLWB, Snap Lake Mine was in the process of renewing their Land Use Permit and Water Licence. Thus, the Board approved an extension for submission to September 2010. De Beers submitted a 5-Year AEMP Review and Conceptual AEMP Update for review (De Beers 2010a). A technical session on the AEMP was held in September 2010 in Yellowknife to present the results of the review. Review comments were provided. In June 2011, De Beers submitted updated water quality predictions as part of the Water Licence renewal submission. As required by the new Water Licence, a summary of AEMP findings was submitted to the Board September 2012 as the Aquatic Effects Re-Evaluation Report (De Beers 2012a).

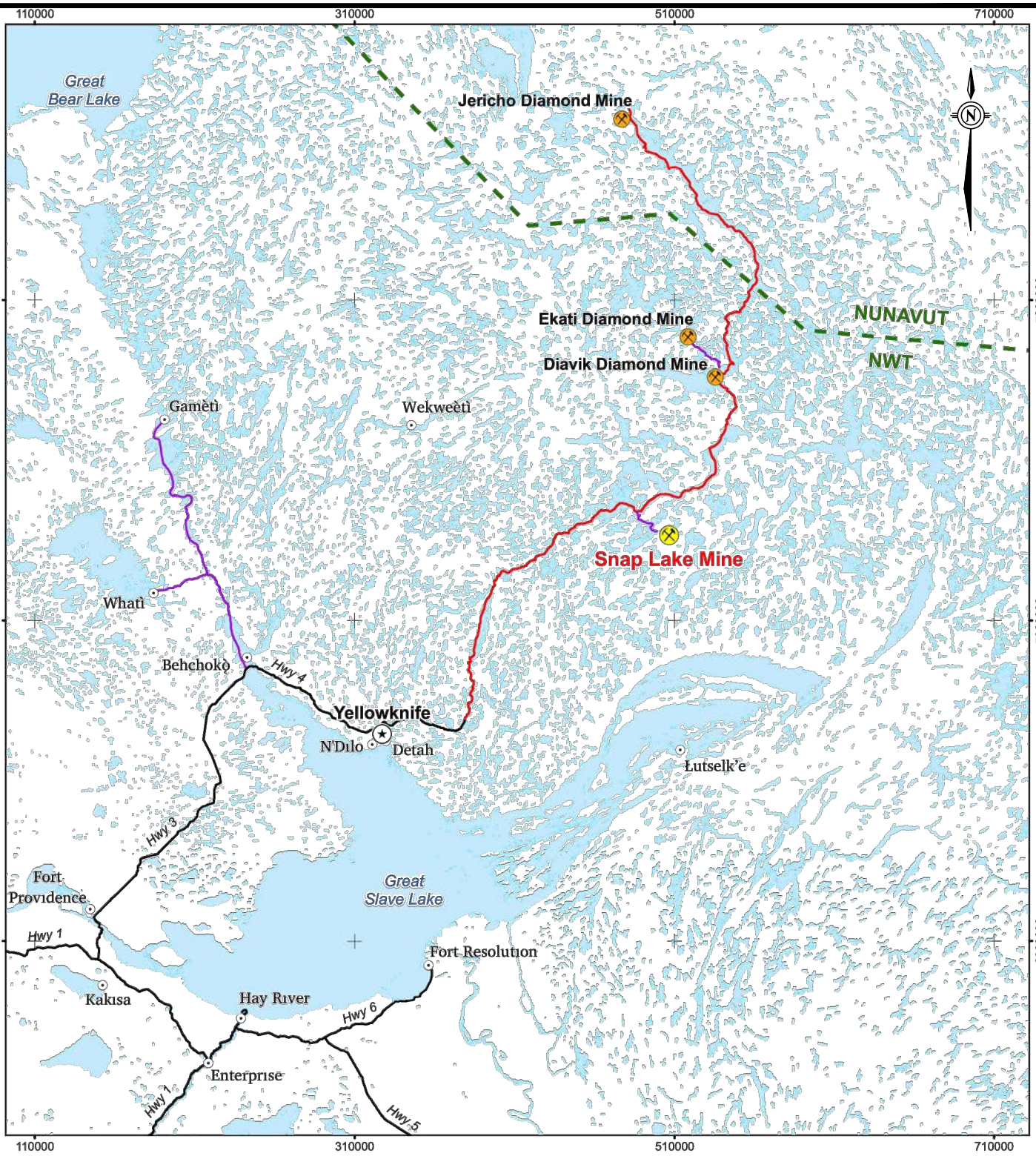
As stated in Part G Item 3 of the current Water Licence, De Beers is to submit an update to the AEMP Design Plan for approval in 2012 and every four years thereafter. The intent of updating the AEMP Design Plan is to provide De Beers the opportunity to make modifications according to the findings of the previous years of monitoring. The draft 2013 AEMP Design was submitted to the MVLWB in November 2012 (De Beers 2012b).

The monitoring portion of the Draft 2013 AEMP Design Plan, was approved by the MVLWB on March 28, 2013 (MVLWB 2013b), with conditions. At that time, the MVLWB requested further work be done on Sections 6 and 7 (Weight-ofEvidence and Response Framework). On March 28, 2013, the MVLWB directed De Beers to resubmit a revised Section 6 and 7 for approval (MVLWB 2013c).

A technical session was held on May 29, 2013 to review Section 6 and 7 of the AEMP. De Beers submitted a revised version of Section 6 (AEMP Response Framework) and Section 7 (Weight-of-Evidence) of the 2013 AEMP Design Plan on July 31, 2013 (De Beers 2013a). Review comments on the document were provided by the MVLWB to De Beers, and responses to comments and recommendations were provided to the MVLWB by October 1, 2013.

On November 29, 2013, the MVLWB approved Sections 6 and 7 of the 2013 AEMP Design Plan as submitted by De Beers on July 31, 2013, conditional on the commitments made by De Beers, along with the incorporation of the revisions listed in the approval letter being completed and submitted (MVLWB 2013d). As such, De Beers is required to submit an updated and final 2013 AEMP Design Plan.

This present 2013 AEMP Design Plan presents the final version of the design and includes the revisions recommended by the MVLWB in its March 28, 2013 and November 29, 2013 approvals.



LEGEND

- SNAP LAKE MINE
- EXISTING MINE
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING WINTER ROAD
- TIBBITT-TO-CONTWOYTO WINTER ROAD
- WATERCOURSE
- WATERBODY
- TERRITORIAL/PROVINCIAL BOUNDARY

REFERENCE

Base data source: The Atlas of Canada
Datum: NAD83 Projection: UTM Zone 12

PROJECT: De Beers Canada Snap Lake Mine

TITLE

LOCATION OF SNAP LAKE MINE

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C001	
DESIGN	TD	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	12/10/2012	FIGURE: 1.1-1		
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

L:\2012\1337\12-1337-0002\1100\Report_C\Fig1.1-1_12133700021100C001_Location of Snap Lake Mine.dwg Nov 01, 2012 - 10:01am

1.2 Report Objectives

The main objective of the 2013 AEMP Design Plan is to describe how water, sediment, and biological monitoring studies (plankton, benthic invertebrates, fish health, fish community, fish tissue chemistry, fish tasting) will be conducted. A secondary objective of this AEMP Design Plan is to address the requirements specified in Part G, Item 3 of the Water Licence (Table 1.2-1).

1.3 Report Organization

The 2013 Design Plan is organized as follows:

- Section 1 – Introduction.
- Section 2 – Conceptual site model.
- Section 3 – Summary of the AEMP study design including: study area description; key question approach; potential zone of influence; location, number and type of sampling sites; and, sampling frequency.
- Section 4 – Detailed methods for each monitoring component of the AEMP (sampling analysis plan).
- Section 5 – Detailed methods for special studies to support the AEMP.
- Section 6 – Weight of Evidence (WOE) approach.
- Section 7 – AEMP Response Framework.
- Section 8 – Description of AEMP reporting.
- Section 9 – Conformity.
- Section 10 – List of references.

Table 1.2-1 2013 AEMP Design Plan Requirements Specified in Part G, Item 3 of the Water Licence

Item	Location in Report
a) a conceptual site model that describes the pathways of potential effects from the Project to the aquatic ecosystem and their relationships to the ecological characteristics within the receiving environment. The conceptual site model should be based on updated effect predictions and other information from the Aquatic Effects Re-Evaluation Report; it should also clearly define testable hypotheses for the AEMP as well as a justification of assessment and measurement endpoints;	Section 2
b) a description of the AEMP sampling and analysis plan required to satisfy the objectives of Part G, Item 1 and incorporate the specific monitoring requirements listed in Schedule 6, Item 1. The sampling analysis and plan shall include: i. the variables, sample media, monitoring protocols, and Quality Assurance/Quality Control (QA/QC) procedures; ii. statistical design criteria, including a description of sampling frequencies for each parameter that ensure both accurate characterization of short-term variability, the collection of sufficient data to establish long-term trends, and a method to conduct trend analysis; iii. a description of procedures to analyze and interpret data collected for each component including a procedure to integrate the results of individual monitoring components such as a Weight of Evidence analysis; iv. the QA/QC procedures which will ensure that any future changes in monitoring protocols will be calibrated to initial monitoring protocols and data sets so that continuity, consistency, validity, and applicability of monitoring results will be maintained. This program shall also explicitly describe the measures that will be taken to identify and address any information deficiencies; v. a complete description of how the Sampling Plan for TDS, Calcium and Chloride, as approved under licence MV2001L2-0002 has been incorporated into the AEMP; vi. a description of how relevant SNP monitoring will be incorporated into the AEMP; and vii. a description of the area to be monitored including maps showing all sampling and reference locations as well as the overall predicted zone of influence of the Project (i.e., predicted zone of influence of mining operations, mineral exploration, or any other disturbance activities).	Sections 3, 4, and 5;
c) a description of the approaches to be used to evaluate and adjust the AEMP;	Section 6
d) a summary of how Traditional Knowledge has been collected and incorporated into the AEMP, as well as a summary of how Traditional Knowledge will be incorporated into further studies relating to the AEMP;	Sections 4.9 and 4.10
e) a description of an AEMP Response Framework that will link the results of the AEMP to those actions necessary to ensure that Project-related effects on the Receiving Environment remain within an acceptable range. The Response Framework shall include: i. definitions, with rationale, for Significance Thresholds and tiered Action Levels applicable to the aquatic Receiving Environment of the Project; and ii. for each action level: a. a description of the rationale including, but not limited to, a consideration of the predictions and conclusions of the Environmental Assessment as well as AEMP results to date; b. a description of how exceedances of Action Levels will be assessed; and c. a general description of what types of actions may be taken if an Action Level is exceeded.	Section 7
f) a description of the Annual AEMP Report format;	Section 8
g) a plain language description of the program objectives, methodology, and interpretive framework; and,	Executive Summary
h) a summary of changes to AEMP design since the last approved design and a rationale for the changes.	Sections 3 and 4, Appendix B

AEMP = Aquatic Effects Monitoring Program; SNP = Surveillance Network Program; TDS = total dissolved solids.

2.0 CONCEPTUAL SITE MODEL

2.1 Introduction

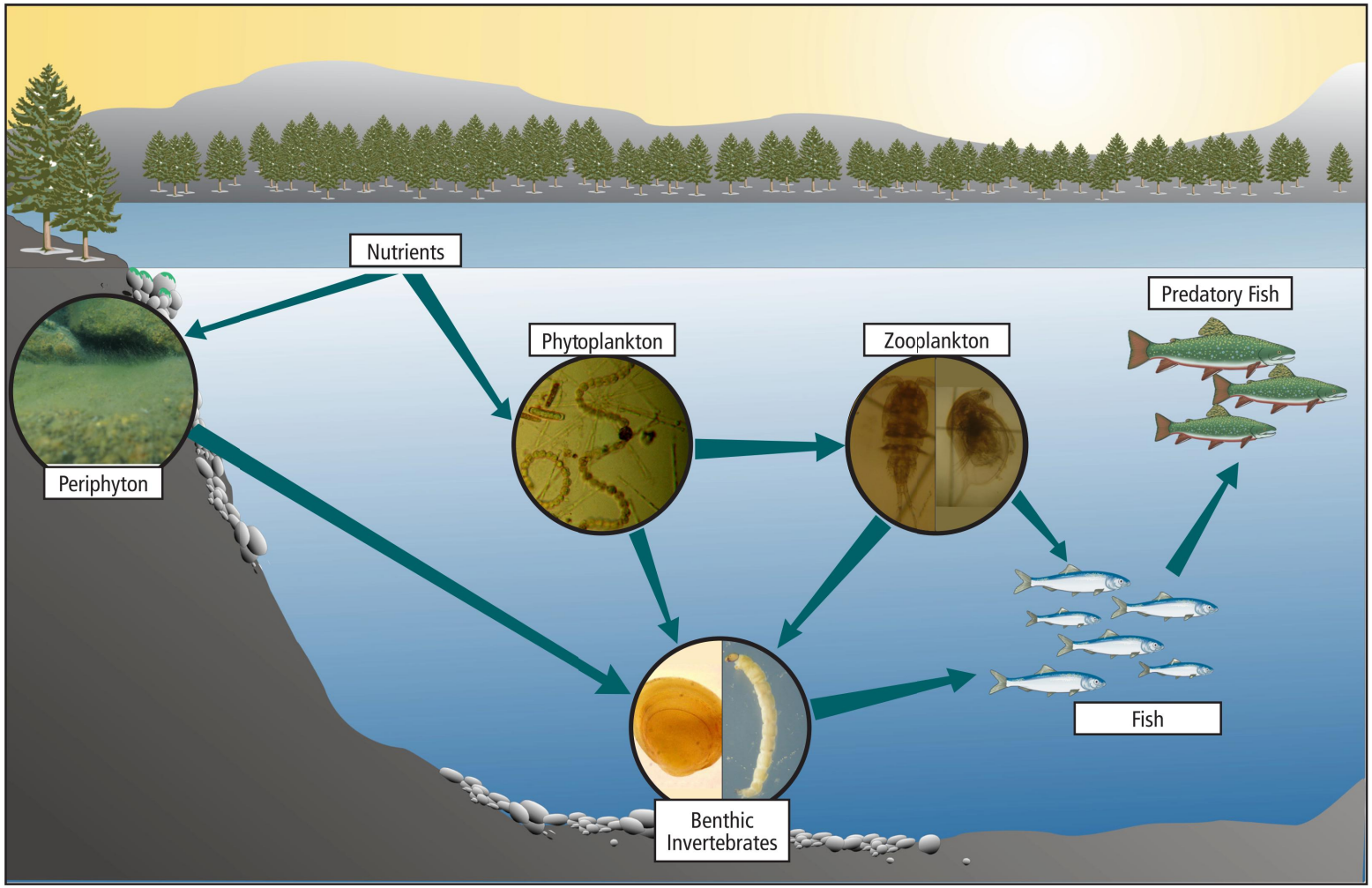
Conceptual site models illustrate potential interactions of stressors of potential concern, exposure pathways, and receptors of potential concern.

The conceptual site model and the stressors of potential concern were identified on the basis of the following:

- project description of mine activities from the EAR and the Water Licence (MV2011L2-0004);
- the predictions of the EAR for aquatic and environmental health;
- the 2011 predictions of treated effluent quality and water quality in Snap Lake (Golder 2011a; De Beers 2012a);
- the 2011 prediction of treated effluent volume (De Beers 2011a);
- recommendations from the AEMP Re-evaluation (De Beers 2012a); and,
- input from regulators on the AEMP Conceptual Design Update (De Beers 2010a).

2.2 Snap Lake Aquatic Ecosystem

A general diagram of the aquatic receiving environment in Snap Lake is presented in Figure 2.2-1. At the base of the Snap Lake food-web, phytoplankton in lake water and algae growing on shoreline rocks use nutrients and carbon sources in the lake water for growth, and provide food to benthic invertebrates and zooplankton. Zooplankton feed directly on phytoplankton, while benthic invertebrates feed on the epilithic algae and decaying organic material (dead plankton or sloughed-off epilithic algae that settle to the lake bottom. Fish feed on zooplankton and benthic invertebrates, and predatory fish feed on smaller fish. Although not shown on this diagram, wildlife also use Snap Lake water and biota as drinking water and as a food source. The EAR predicted negligible effects to wildlife from pathways related to water. Potential effects to wildlife are monitored under the Wildlife Effects Monitoring Program, and are not considered herein.



PROJECT

DE BEERS CANADA
SNAP LAKE MINE

TITLE

CONCEPTUAL SITE MODEL SCHEMATIC FOOD-WEB FOR SNAP LAKE

Golder Associates

PROJECT No.	12-1337-0002		FILE No.	121337000211100C017
DESIGN	TD	10/10/2012	SCALE AS SHOWN	REV. 0
CADD	JEF	12/10/2012	FIGURE: 2.2-1	
CHECK	TD	30/10/2012		
REVIEW	PC	30/10/2012		

2.3 Stressors of Potential Concern

Figure 2.3-1 shows the stressors of potential concern, and corresponding pathways and receptors. In the EAR, five stressors of potential concern were identified and were carried forward in the 2005 AEMP:

Chemical Stressors

- treated effluent (nutrients, TDS, and metals); and,
- air quality changes (acid deposition) around the Mine site.

Physical Stressors

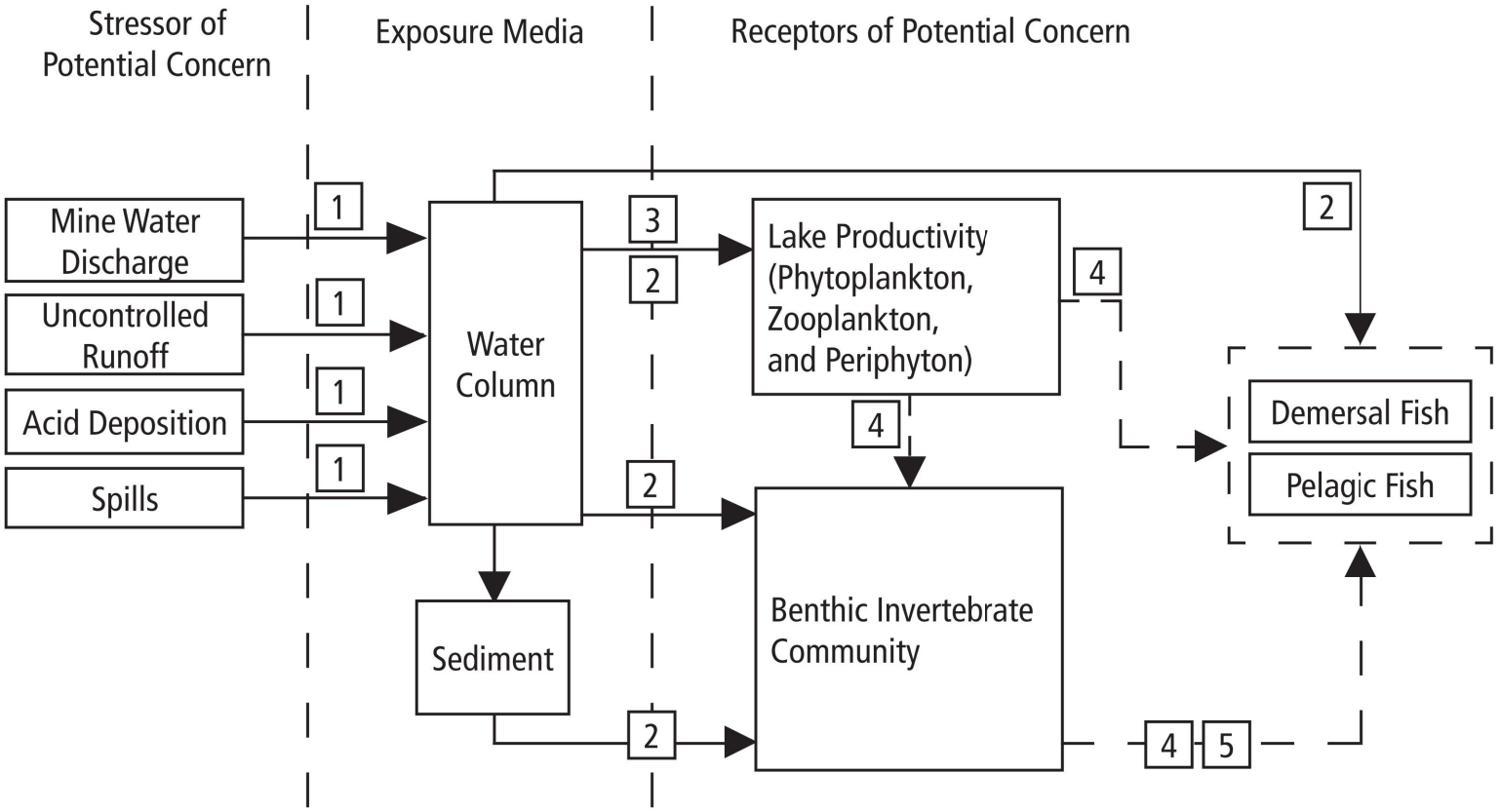
- underground blasting effects on fish health and habitat;
- in-lake habitat alteration during construction; and,
- sediment release from uncontrolled runoff.

In the AEMP Re-evaluation, it was recommended that further monitoring of effects due to physical stressors be discontinued. In 2011, De Beers re-evaluated its mine plan and concluded that current and future blast operations should meet regulatory limits on overpressures in water in relation to blasting. Thus, it appears that at present there is no need to monitor effects in relation to blasting (De Beers 2012a). Suspended sediment monitoring will continue under the SNP as part of the Water Licence requirements and data will be reviewed in the water quality component of the AEMP; however, no additional monitoring will be done within the AEMP because no fish habitat or aquatic issues in relation to sediment release have occurred. Monitoring of alterations to fish habitat were completed under a *Fisheries Act* Authorization; no further habitat monitoring is required in the AEMP specific to construction activities (De Beers 2012a).

The refined Mine-related stressors of potential concern relevant to the 2013 Snap Lake AEMP are:

- total dissolved solids (TDS) and its constituent ions;
- a number of metals;
- the nutrients phosphorus (P) and nitrogen (N); and,
- acidifying substances.

The major source of TDS, associated ions, and metals to Snap Lake is groundwater that enters the mine workings, which is collected and directed to the water treatment plant, and is discharged to Snap Lake following treatment. Additional potential minor sources of these substances are seepages, spills, uncontrolled runoff, and dust deposition.



Notes:

1. Loading of TDS, nutrients, metals and acidifying substances
2. Potential direct toxicity or physical habitat change (sedimentation and dissolved oxygen)
3. Potential nutrient enrichment, or altered balance of nutrients
4. Potential indirect effects due to change in food supply
5. Potential change in tissue chemistry

PROJECT

De Beers Canada
SNAP LAKE MINE

TITLE

CONCEPTUAL SITE MODEL
RELEVANT EXPOSURE PATHWAYS

Golder Associates

PROJECT No.	12-1337-0002		FILE No.	121337000211100C018
DESIGN	TD	10/10/2012	SCALE AS SHOWN	REV. 0
CADD	JEF	12/10/2012	FIGURE: 2.3-1	
CHECK	TD	30/10/2012		
REVIEW	CP	30/10/2012		

The sources of nutrients in Snap Lake are:

- Nitrogen (N): explosives residues, which are dissolved in groundwater seeping into the mine and runoff waters in contact with mined materials and, to a lesser extent, treated sewage and potentially, direct seepages to the lake and spills; and,
- Phosphorus (P): mainly treated sewage, and potentially surface runoff.

The source of acidifying substances is deposition of sulphate and nitrate resulting from emissions of sulphur dioxide and nitrogen oxides. The EAR determined that acid deposition is a concern primarily for small inland lakes and small streams, and less so for Snap Lake because the discharge to Snap Lake contributes additional alkalinity, making it less acid sensitive over time.

Based on the review of sources and pathways in the EAR (De Beers 2002a), and on the clear relationships shown by AEMP data between concentrations of chemicals of potential concern in lake water and their concentrations and loading rates in treated Mine effluent, the primary exposure route for receptors of potential concern in Snap Lake is via the treated Mine effluent discharge.

Receptors of Potential Concern

Receptors of potential concern are the following broad components of the Snap Lake ecosystem:

- primary producers (epilithic algae and phytoplankton communities);
- secondary producers (zooplankton and benthic invertebrate communities);
- demersal and pelagic fish; and,
- humans (through resource use).

Wildlife and birds are not receptors of potential concern because the EAR determined that effects due to the treated Mine effluent, and other aquatic pathways of exposure (snow, dust, lichen, fish tissue) were negligible. Monitoring of wildlife for potential effects due to non-aquatic stressors such as noise or habitat disturbance, occurs through the Wildlife Effects Monitoring Program.

2.4 Pathways

The pathways by which the above-identified sources may influence the aquatic ecosystem are both direct and indirect. Direct pathways involve a direct influence on a receptor, for example, direct toxicity to fish as a result of the elevated concentration of an ion or a metal. Indirect pathways often include several levels of receptors; for example, sediment input causing a reduction in benthic invertebrate density, thereby reducing the amount of food available for fish, is a scenario that includes both benthic invertebrate and fish receptors.

The major exposure pathway relevant to the AEMP is direct contact of aquatic organisms with TDS and associated ions, metals, and nutrients in surface water in Snap Lake (Figure 2.3-1). Depending on the receptor and the relative concentrations of different chemical stressors, different types of effects may occur in Snap Lake. Epilithic algae, phytoplankton, and zooplankton are directly exposed to the water column and may be affected by direct toxic effects of TDS and its constituent ions and metals or, in the case of algae, by the growth-stimulating effect of nutrients (N and P) and micronutrients (some components of TDS).

Potential effects of increased concentrations of TDS and its constituent ions, and metals in lake water or sediments, are largely negative. Zooplankton provide a food supply for pelagic fish, particularly younger life stages and, therefore, any degradation of the zooplankton community resulting from a decreased algal food supply could have a potential indirect effect on the fish community. The benthic invertebrate community is indirectly exposed to sediment porewater and may be directly exposed to the water column during epibenthic grazing on the sediment surface. The benthic invertebrate community provides a key food supply for demersal and pelagic fish and, therefore, any degradation of the benthic invertebrate community could have a potential indirect effect on the fish community. Demersal and pelagic fish are directly exposed to the water column and may be affected by direct toxic effects from TDS and its constituent ions.

Increased supply of nutrients resulting in enhanced algal growth in the phytoplankton communities would provide an increased food supply to zooplankton, which in turn would result in increased food for fish species or life stages that feed on zooplankton. In addition, enhanced epilithic algal growth and increased settling rates of organic detritus on the lake bottom from enhanced phytoplankton, epilithic algae, and zooplankton biomass would provide more food for benthic invertebrates, and ultimately for fish.

Altered balance of nutrients (e.g., increased N, but not P) could affect the aquatic food web through changes in algal biomass and edibility. A substantial change in the N to P molar ratio can cause phytoplankton community shifts. This in turn can result in a change in food quantity available for zooplankton, because algae in different major groups differ in their degree of edibility or palatability for zooplankton. A decline in zooplankton edibility may result from an increased proportion of inedible or unpalatable algal taxa resulting from an altered balance in nutrients, thereby resulting in decreased zooplankton biomass and a subsequent decline in the availability of food for fish. Conversely, an altered balance of nutrients may also stimulate the growth of edible algal species, ultimately resulting in an increased quantity of food for fish.

In contrast to the largely positive effects of nutrient enrichment through increased food supply, increased nutrient concentrations may also result in lower dissolved oxygen (DO) concentrations in deep parts of Snap Lake. Deep water sediments of Snap Lake are highly organic, with a typical total organic carbon (TOC) content of approximately 20 percent (%) under baseline conditions. Likely major sources of organic carbon to deep water sediments are settling of decaying phytoplankton and zooplankton, and sloughing of epilithic algae from shoreline areas. Further increases in periphytic and planktonic algal growth from nutrient enrichment could result in increased TOC in bottom sediments and associated sediment oxygen demand, resulting in reduced deep water DO concentration, which in turn may affect benthic invertebrates and fish. Reduced DO would have a direct effect on invertebrates (altered community and potentially reduced biomass), and a direct physiological effect and indirect food-mediated effect on fish.

Acid deposition and a subsequent drop in pH in inland lakes and small streams may result in direct adverse physiological effects on aquatic organisms, and ultimately result in the simplification of the aquatic ecosystem through loss of sensitive species.

2.5 Hypotheses

The preceding discussion describes how inputs of nutrients, metals, and major ions to Snap Lake could result in enrichment and/or toxicity with the potential to cause impairment of the biological communities in Snap Lake. These pathways can be summarized into two overall hypotheses on the potential impact to Snap Lake from Mine operation:

- *Toxicological Impairment Hypothesis*: Toxicity to aquatic organisms could occur due to substances of toxicological concern (primarily metals[1] and TDS) released to Snap Lake.
- *Nutrient Enrichment Hypothesis*: Eutrophication could occur due to the release of nutrients (primarily phosphorus and nitrogen, and, for some species, TDS) to Snap Lake.

These hypotheses are evaluated in this AEMP using a WOE approach (Section 6).

2.6 Assessment and Measurement Endpoints

The terms "*assessment endpoint*" and "*measurement endpoint*" are commonly applied in environmental assessments and monitoring programs and provide concise statements of what environmental issues are being examined in a particular assessment or monitoring program.

Assessment endpoints are characteristics of the aquatic ecosystem that may be affected by the Mine, expressed explicitly as statements of the actual environmental values that are to be protected (Warren-Hicks et al. 1989; Suter 1990; USEPA 1992). Considerations in the selection of assessment endpoints include ecological relevance, policy goals, future land use, societal values, susceptibility, and the ability to define the effects endpoint in operational terms.

The assessment endpoints were used to select appropriate measurement endpoints, which are measurable responses to the stressor that are related to the valued characteristics chosen as the assessment endpoint (Suter 1990). Measurement endpoints may include measures of exposure (e.g., chemical concentrations in water and sediments) and measures of effects (e.g., plankton biomass and community structure). Measurement endpoints are operationally defined and can be assessed using appropriate field and laboratory studies.

The assessment endpoints for the AEMP are based on the Valued Ecosystem Components identified in the EAR, the effect predictions in the EAR, and narrative commitments made by De Beers during the EAR process and through the Environmental Agreement (De Beers 2004). Specifically, De Beers committed that water quality and fish health will remain acceptable in Snap Lake, which can be summarized in the following four value statements:

1. Water is safe to drink;
2. Fish are safe to eat;
3. Sediment quality is maintained; and,
4. The ecological function of Snap Lake (i.e., the “ecosystem services” it provides including fish health and community) is preserved.

[1] The term “metals” includes metalloids (e.g., arsenic) and non-metals (e.g., selenium).

The components of the AEMP are designed to characterize, individually, changes in measures of contaminant and nutrient exposure, potential receiving water toxicity, and any resulting field effects to plankton, benthos, and fish that would affect the assessment endpoints.

The AEMP includes parameters and testing representing the following types of information: water quality (nutrients and chemical contaminants); chronic toxicity at the edge of the treated effluent mixing zone; chlorophyll *a* and zooplankton biomass; sediment quality; benthic invertebrates; and, fish community. These measurement endpoints can be categorized into the following endpoint groups representing similar types of evidence:

- **Exposure:** Measures of the potential exposure of receptors to Mine-related chemicals and nutrients, including surface water, sediment, and body burdens of metals in fish.
- **Field Biological Responses:** Measures of potential ecological changes, including measures of plankton biomass and community structure, benthic invertebrate abundance community structure, and fish abundance, health and edibility.

3.0 STUDY DESIGN

The core component of the AEMP is operational monitoring, which occurs during all phases of the Mine development. The AEMP monitoring components are:

- water quality;
- sediment quality;
- plankton;
- benthic invertebrates; and,
- fish (i.e., fish health, fish community, fish tissue metals, and fish tasting).

The overall objective of the AEMP is to meet the requirements in Part G of the De Beers' Water Licence. Objectives of individual AEMP monitoring components are:

- **Water quality**: to characterize changes in water quality in Snap Lake resulting from the Snap Lake Mine.
- **Sediment quality**: to characterize changes in sediment quality in Snap Lake resulting from the Mine.
- **Plankton**: to evaluate effects of the Snap Lake Mine on phytoplankton and zooplankton community structure, and to monitor for nutrient enrichment effects by measuring phytoplankton composition and biomass, and concentrations of chlorophyll.
- **Benthic invertebrates**: to evaluate effects of the Snap Lake Mine on the benthic invertebrate community in Snap Lake due to changes in water and sediment quality.
- **Fish health**: to evaluate effects of the Snap Lake Mine on fish health in Snap Lake due to changes in water/sediment quality.
- **Fish community**: to evaluate effects of the Snap Lake Mine on the fish community in Snap Lake due to changes in water/sediment quality.
- **Fish tasting**: to determine whether the flavour and texture of the fish in Snap Lake are acceptable to community members.
- **Traditional Knowledge**: to summarize how traditional knowledge was collected and will be incorporated in future AEMP reports.

3.1 Key Question Approach

The Snap Lake AEMP used a key question approach for each core component of the AEMP, as well as for the special studies presented in Section 5. The methods and data analyses for each AEMP component or special study have been designed to address the following key questions.

AEMP Components

Site Characterization and Supporting Environmental Variables

- What are the general conditions of the Mine site and the local environment under which the AEMP is conducted, independent of mining-related activities and considering unanticipated mining events such as spills?
- Is there a habitat difference between Snap Lake and the reference lakes in terms of seasonal water temperature and ice-cover?

Water Quality

- Are concentrations or loads of key water quality parameters in discharges to Snap Lake consistent with EAR predictions and below Water Licence limits?
- Are concentrations of key water quality parameters in Snap Lake below AEMP benchmarks and Water Licence limits?
- Which water quality parameters are increasing over time in Snap Lake and nearby waterbodies, and how do concentrations of these parameters compare to AEMP benchmarks, concentrations in reference lakes, EAR predictions, and subsequent modelling predictions?
- Are spatial and seasonal patterns in water quality in Snap Lake and downstream waterbodies consistent with predictions presented in the EAR and subsequent modelling predictions?
- Is there evidence of acidification effects from the Mine on nearby waterbodies?
- Is water from Snap Lake safe to drink?

Sediment Quality

- Are concentrations of sediment quality parameters above or below sediment quality guidelines (SQGs)?
- Are there differences in sediment quality in Snap Lake relative to reference lakes and, if so, are they related to the Mine?
- Are concentrations of sediment quality parameters increasing over time?

Plankton

- What are the current concentrations of chlorophyll *a* and *c*, and what do these concentrations indicate about the trophic status of Snap Lake, Northeast Lake, and Lake 13?
- What is the current status, in terms of abundance, biomass and composition, of the phytoplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?

- What is the current status, in terms of abundance, biomass and composition, of the zooplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?
- How do observed changes compare to applicable predictions in the EAR?

Benthic Invertebrates

- Is the benthic invertebrate community affected by changes in water and sediment quality in Snap Lake?
- If the benthic invertebrate community is affected, is the change greater than that stated in the EAR?

Fish Health

- Is fish health affected by changes in water and sediment quality in Snap Lake?
- Are changes observed in fish health greater than those predicted in the EAR?

Fish Community

- Will the fish community be affected by the changes in water quality in Snap Lake and will any change be greater than that predicted in the EAR?

Fish Tissue

- Are tissue metal concentrations in fish from Snap Lake increasing relative to baseline?
- Are tissue metal concentrations in fish from Snap Lake increasing relative to reference lakes?

Fish Tasting

- Are the taste and texture of fish captured in Snap Lake acceptable to community members?

Special Studies

Littoral Zone Study

- Can littoral monitoring be conducted in Snap Lake and Northeast Lake, and does the inherent variability in the littoral zone allow the detection of Mine-related changes?
- What are the current ratios of particulate C:N, C:P, N:P, and C:chlorophyll *a*, and what is the current percent algal caron in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Notheast Lake? How do these values compare to baseline and what do these values indicate about Mine-related changes in nutrient status and food quality for invertebrates and fish?
- What is the current status, in terms of relative abundance and relative biomass, of epilithic algal communities in the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of Mine-related effects?

- What is the current invertebrate composition in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect?

Picoplankton Study

- What is the current status, in terms of abundance, of the picoplankton community in Snap Lake, Northeast Lake, and Lake 13, and do these results provide any evidence of Mine-related nutrient enrichment?
- How do any observed changes in the picoplankton community compare to changes observed in the phytoplankton community?

Downstream Lakes

- What is the spatial extent of the treated effluent plume downstream of Snap Lake (i.e., plume delineation)?
- What are the current sediment and water quality characteristics in the three downstream lakes?

Lake Trout Population Estimate

- How many Lake Trout of fishable size (>250 mm FL), are estimated to be in Snap Lake and what is the level of confidence of that estimate?

Food Web – Stable Isotopes

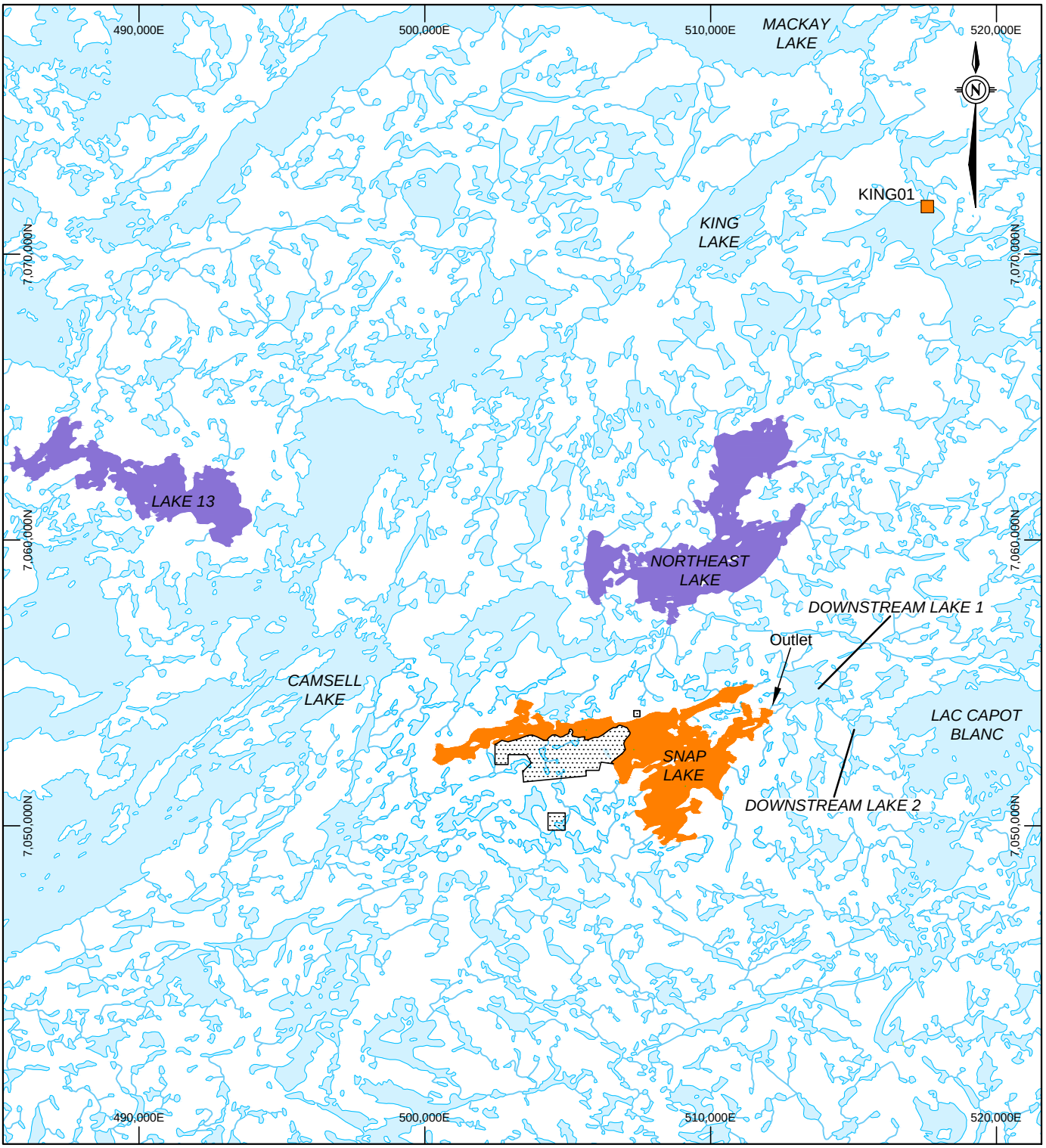
- What eats what in Snap Lake?
- Is the Snap Lake food web planktonically or benthically driven?

A key question for Traditional Knowledge is currently under development pending community consultation (see Section 4.11). In previous years, the fish tasting program was the only Traditional Knowledge program; however, further work is being conducted to develop additional Traditional Knowledge programs.

3.2 AEMP Study Area

The study areas included in the 2013 AEMP Design Plan are Snap Lake, Northeast Lake, Lake 13, and one station downstream of Snap Lake in the Lockhart River system, located upstream of King Lake (Figure 3.2-1, Appendix A). Additional sampling is also proposed as part of the water quality program (Section 4.2) and as a special study (Section 5.3) on the three lakes immediately downstream of Snap Lake (Figure 3.2-1).

Currently, Northeast Lake is sampled as the reference area for each AEMP component. The objective of sampling a reference lake is to assist in determining whether changes in Snap Lake are natural or Mine-related (Golder 2005). The Aquatic Effects Re-evaluation Report recommended the addition of a second reference lake (De Beers 2012a). The intent of a second reference lake is to further understand natural variability.



LEGEND

- WATER QUALITY STATION
- MONITORING AREA
- REFERENCE AREA
- SNAP LAKE MINE FOOTPRINT
- WATERBODY

4 0 4
SCALE KILOMETRES

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.

PROJECT: De Beers Canada — Snap Lake Mine

TITLE

STUDY AREA, 2013 TO 2016

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C003	
DESIGN	TD	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	12/10/2012	FIGURE: 3.2-1		
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

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In 2005, a review of potential reference lakes was conducted. Thirty-three lakes were reviewed on the basis of size, shape, and physical characteristics. Five of the lakes thought to be most similar to Snap Lake were selected as possible reference lakes. Site specific information was collected from these five lakes. The lake identified as most similar to Snap Lake was Northeast Lake; the second most similar lake was Lake 13 (Golder 2005). While Lake 13 is not a perfect match for Snap Lake, it is unlikely that a more similar lake can be found. It is therefore considered reasonable to select the second reference lake based on the previous selection criteria, which were approved by the Board. Thus, Lake 13 is provisionally proposed as the second reference Lake for the Snap Lake AEMP. Sampling details for each AEMP component for Lake 13 are described in Section 4.0.

3.2.1 Predicted Zone of Influence

The predicted zone of influence includes mining operations, areas of mineral exploration, and locations of any other Mine-related activities that may cause a disturbance. The predicted zone of influence for the Mine includes the discharge of treated effluent to Snap Lake due to mining activities, the Mine footprint itself, the winter access road to the Mine, and mineral exploration work that is being conducted on the north shore of Snap Lake (Figure 3.2-2).

In 2012, treated effluent was detected 50 metres (m) from the inlet to Lac Capot Blanc (within 6 km of the Snap Lake diffuser); the EAR predicted that, as a result of mining operations, treated effluent could reach up to 44 km downstream of the Snap Lake diffuser by the end of mine life (Figure 3.2-2).

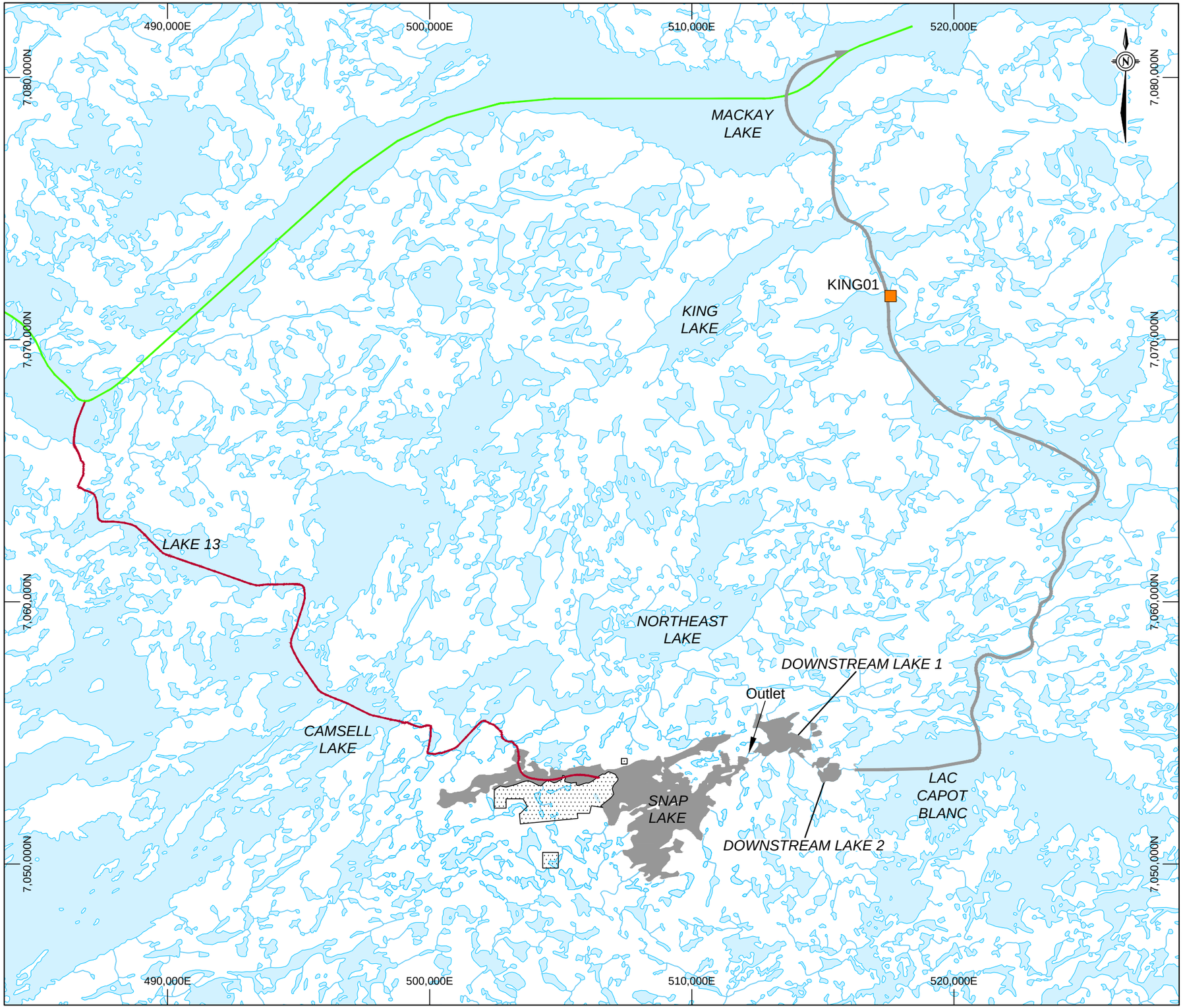
3.3 Sampling Locations

The AEMP Re-evaluation Report (De Beers 2012a) recommended that the focus of the AEMP be shifted from evaluating spatial and seasonal trends in Snap Lake, to monitoring trends over time and changes downstream of Snap Lake. Initially, monitoring stations in Snap Lake were established to detect a spatial gradient within the lake. For the 2013 AEMP Design Plan, monitoring stations have been updated to achieve the following design goals:

- provide as much overlap as possible in sampling stations among components (water quality, sediment quality, plankton, benthic invertebrates, and fish);
- maintain consistency in stations for each component over time (i.e., 2004 to 2012 AEMPs);
- reflect the shift from looking for a spatial gradient within Snap Lake, to assessing the main basin as a whole compared to reference lakes and downstream conditions; and,
- provide sufficient power (i.e., large enough sample size) to be able to detect differences considered ecologically significant.

The Snap Lake 2012 and 2013 AEMP Design Plan sampling stations are presented in Figures 3.3-1 and 3.3-2, respectively; overlap between the two years is presented in Table 3.3-1.

Monitoring stations in the two reference lakes, Northeast Lake and Lake 13, were selected to provide adequate coverage of the lakes, while maintaining consistency in water depth across monitoring stations. No changes have been proposed to the monitoring stations in Northeast Lake for the 2013 Design Plan (Figure 3.3-3). Monitoring stations in Lake 13 were selected based on information gathered during the reference lake selection program (Golder 2005), and additional field information, including bathymetry work that was conducted during summer 2012 (Figure 3.3-4).



LEGEND

- WATER QUALITY STATION
- CURRENT ZONE OF INFLUENCE
- SNAP LAKE MINE FOOTPRINT
- WATERBODY
- PREDICTED ZONE OF INFLUENCE
- WINTER ACCESS ROAD
- TIBBIT-TO-CONTWOYTO WINTER ROAD

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.

3 0 3
Scale:1:150 000 Km

PROJECT

De Beers Canada
Snap Lake Mine

TITLE

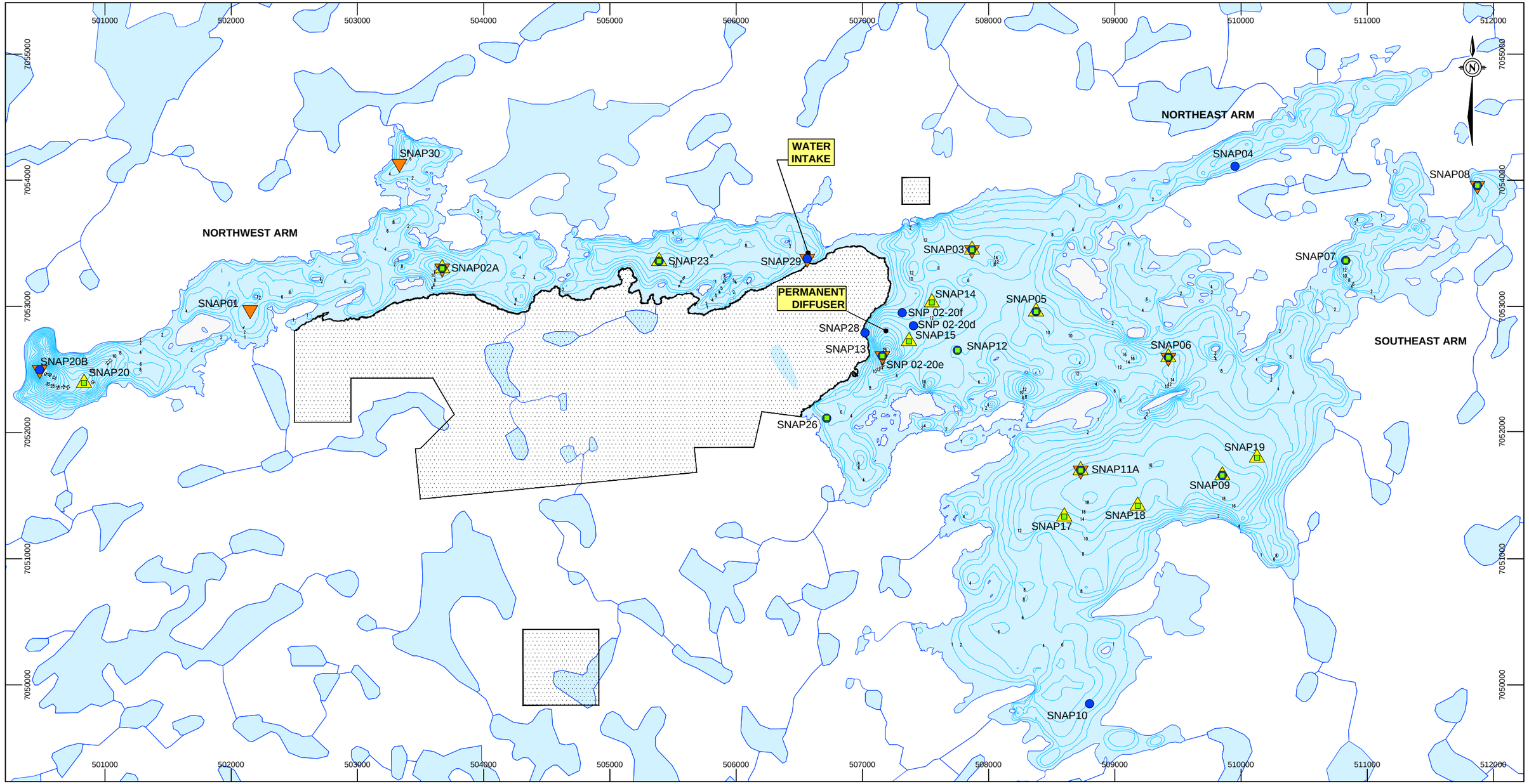
ZONE OF INFLUENCE OF THE SNAP LAKE MINE

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	121337000211000002	
DESIGN	TD	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	12/10/2012	FIGURE: 3.2-2		
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

Nov 01, 2012 – 7:23pm

L:\2012\1337\12-1337-0002\1100\Report_C\Fig3.2-2_121337000211000C002_Zone Of Influence.dwg



LEGEND

- WATER QUALITY MONITORING STATION
- SEDIMENT QUALITY MONITORING STATION
- BENTHIC INVERTEBRATE MONITORING STATION
- PLANKTON MONITORING STATION
- SNAP LAKE MINE FOOTPRINT
- WATERBODY
- DEPTH CONTOUR (m)

REFERENCE

DIGITAL MAP FROM MACKAY LAKE, NORTHWEST TERRITORIES, PRODUCED BY DEPARTMENT OF ENERGY, MINES AND RESOURCES. MAP 75M, ORIGINAL SCALE 1:250,000, NAD 83 UTM ZONE 12.

SNAP LAKE OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

NOTES

1. MAP MOVED TO NAD83 COORDINATE SYSTEM.

PROJECT: De Beers Canada — Snap Lake Mine

TITLE: **MONITORING STATIONS IN SNAP LAKE, 2012 AEMP**

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C004	
DESIGN	TD	2/10/2012	SCALE	AS SHOWN	REV. 0
CADD	JEF	11/10/2012			
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

FIGURE: 3.3-1

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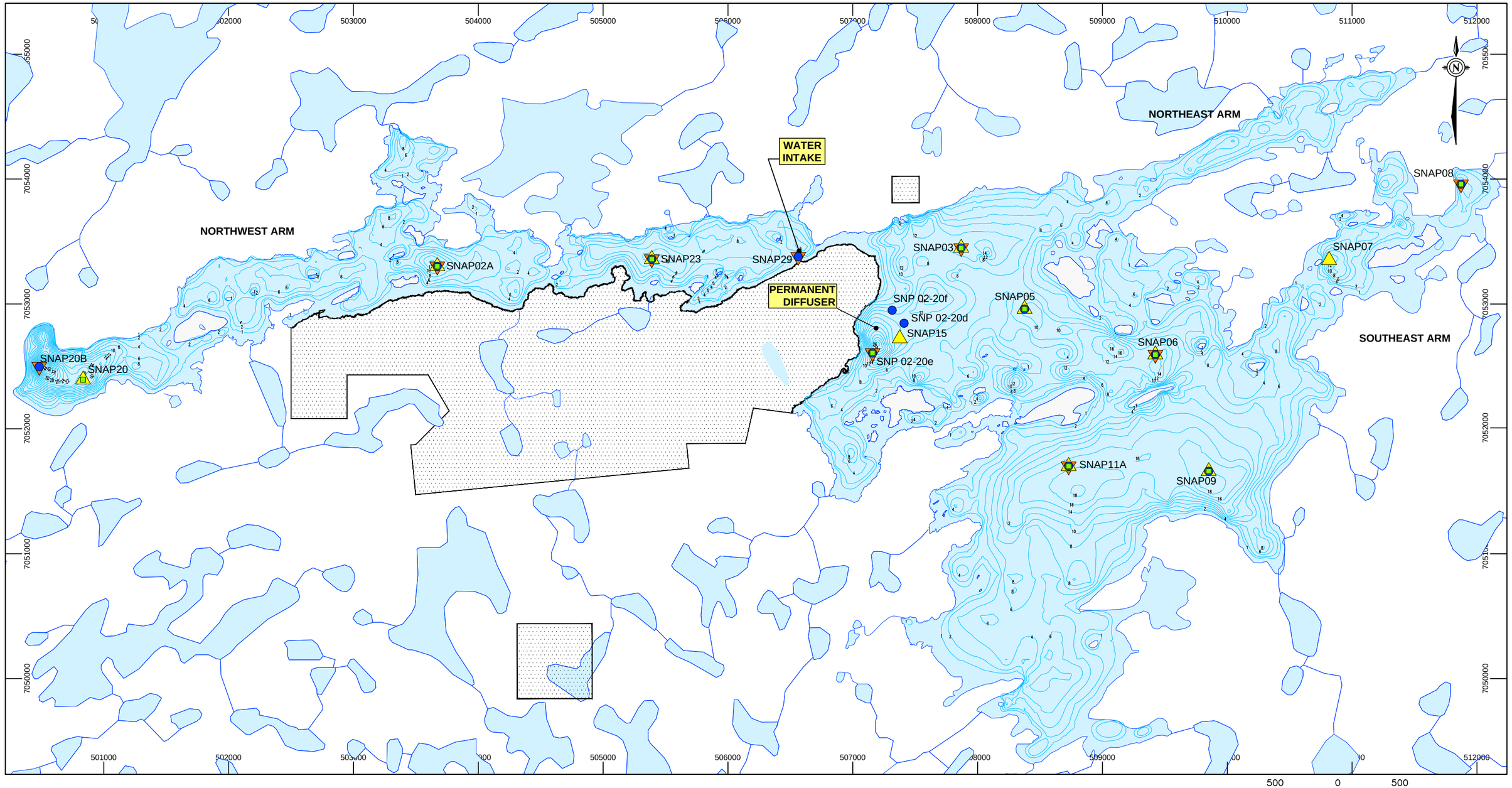

LEGEND

- WATER QUALITY MONITORING STATION
- SEDIMENT QUALITY MONITORING STATION
- BENTHIC INVERTEBRATE MONITORING STATION
- PLANKTON MONITORING STATION
- SNAP LAKE MINE FOOTPRINT
- WATERBODY
- DEPTH CONTOUR (m)

REFERENCE

DIGITAL MAP FROM MACKAY LAKE, NORTHWEST TERRITORIES, PRODUCED BY DEPARTMENT OF ENERGY, MINES AND RESOURCES. MAP 75M, ORIGINAL SCALE 1:250,000, NAD 83 UTM ZONE 12.

SNAP LAKE OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

NOTES

1. MAP MOVED TO NAD83 COORDINATE SYSTEM.

PROJECT

De Beers Canada
SNAP LAKE MINE

TITLE

MONITORING STATIONS IN SNAP LAKE, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C006
DESIGN	TD	2/10/2012	SCALE AS SHOWN	REV. 0
CADD	JEF	11/10/2012	FIGURE: 3.3-2	
CHECK	TD	30/10/2012		
REVIEW	PC	30/10/2012		

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Table 3.3-1 2012 AEMP and 2013 AEMP Design Plan Monitoring Stations

		UTM (NAD 83, Zone 12 V)		Approximate Depth (m)	Sampling Stations							
					2012 AEMP				2013 to 2016 AEMP			
		Easting	Northing		WQ	SQ	Plankton	BI	WQ	SQ	Plankton	BI
Snap Lake												
Main Basin	SNP02-20d	507411	7052845	12	x	-	-	-	x	-	-	-
	SNP02-20e	507158	7052607	29	x	x	x	-	x	x	x	-
	SNP02-20f	507316	7052949	15	x	-	-	-	x	-	-	-
	SNAP03	507868	7053448	13	x	x	x	x	x	x	x	x
	SNAP04	509952	7054110	4	x	-	-	-	-	-	-	-
	SNAP05	508376	7052958	14	x	x	-	x	x	x	-	x
	SNAP06	509424	7052594	13	x	x	x	x	x	x	x	x
	SNAP07	510816	7053351	12	x	x	-	-	-	-	-	x
	SNAP08	511872	7053958	9	x	x	x	-	x	x	x	-
	SNAP09	509851	7051660	15	x	x	-	x	x	x	-	x
	SNAP10	508801	7049847	5	x	-	-	-	-	-	-	-
	SNAP11A	508729	7051700	14	x	x	x	x	x	x	x	x
	SNAP12	507753	7052652	8	x	x	-	-	-	-	-	-
	SNAP14	507550	7053033	13	-	x	-	x	-	-	-	-
	SNAP15	507376	7052723	11	-	x	-	x	-	-	-	x
	SNAP17	508599	7051334	10	-	x	-	x	-	-	-	-
	SNAP18	509181	7051419	13	-	x	-	x	-	-	-	-
	SNAP19	510126	7051800	12	-	x	-	x	-	-	-	-
	SNAP26	506718	7052116	6	x	x	-	-	-	-	-	-
	SNAP28	507021	7052790	7	x	-	-	-	-	-	-	-
NWA	SNAP01	502150	7052972	5	-	-	x	-	-	-	-	-
	SNAP02A	503671	7053301	11	x	x	x	x	x	x	x	x
	SNAP20	500834	7052393	14	-	x	-	x	-	x	-	x
	SNAP20B	500483	7052497	35	x	-	x	-	x	-	x	-
	SNAP23	505390	7053358	12	x	x	-	x	x	x	x	x
	SNAP29	506563	7053378	7	x	-	x	-	x	-	x	-
	SNAP30	503332	7054131	9	-	-	x	-	-	-	-	-

Table 3.3-1 2012 AEMP and 2013 AEMP Design Plan Monitoring Stations (continued)

		UTM (NAD 83, Zone 12 V)		Approximate Depth (m)	Sampling Stations							
					2012 AEMP				2013 to 2016 AEMP			
		Easting	Northing		WQ	SQ	Plankton	BI	WQ	SQ	Plankton	BI
Northeast Lake												
	NEL01	508416	7058982	12	x	x	x	x	x	x	x	x
	NEL02	510105	7058927	12	x	x	x	x	x	x	x	x
	NEL03	510247	7058560	10	x	x	x	x	x	x	x	x
	NEL04	510049	7059749	13	x	x	x	x	x	x	x	x
	NEL05	511467	7059537	12	x	x	x	x	x	x	x	x
	NEL06	510765	7058773	27	x	-	-	-	x	-	-	-
Lake 13												
	LK13-01	487001	7063584	12	x	x	x	x	x	x	x	x
	LK13-02	490783	7061866	11	x	x	x	x	x	x	x	x
	LK13-03	492506	7061880	12	x	x	x	x	x	x	x	x
	LK13-04	492967	7061093	10	x	x	x	x	x	x	x	x
	LK13-05	492212	7060992	15	x	x	x	x	x	x	x	x
	LK13-06	492070	7061231	23	x	-	-	-	x	-	-	-
Inland Lakes												
	IL3	504601	7051867	12.3	x	-	-	-	x	-	-	-
	IL4	504834	7051922	10.5	x	-	-	-	x	-	-	-
	IL5	504619	7051373	12.1	x	-	-	-	x	-	-	-
Tributaries												
	S1	506789	7051436	n/a	x	-	-	-	x	-	-	-
	S27	502131	7052562	n/a	x	-	-	-	x	-	-	-

NWA = Northwest Arm; UTM = Universal Transverse Mercator; NAD = North American Datum; m = metre; WQ = water quality; SQ = sediment quality; BI = benthic invertebrates; AEMP = Aquatic Effects Monitoring Program; n/a = not applicable.

505,000E
506,000E
507,000E
508,000E
509,000E
510,000E
511,000E
512,000E
513,000E

7,064,000N
7,063,000N
7,062,000N
7,061,000N
7,060,000N
7,059,000N
7,058,000N
7,057,000N

NEL01
NEL02
NEL03
NEL04
NEL05
NEL06

L:\2012\1337\12-1337-0002\1100\Report_C\Fig3.3-3_12133700021100C007_Monitoring Stns in NE Lake 2013-2016.dwg Nov 01, 2012 - 11:20am

LEGEND

- WATER QUALITY AEMP MONITORING STATION
- SEDIMENT QUALITY AEMP MONITORING STATION
- BENTHIC INVERTEBRATE AEMP MONITORING STATION
- PLANKTON AEMP MONITORING STATION
- WATER QUALITY PROFILE STATION
- DEPTH CONTOUR (m)
- WATERBODY

REFERENCES

DIGITIZED FROM NTS TOPOGRAPHIC MAP 75 M/10 É 1985 HER MAJESTY THE QUEEN IN RIGHT OF CANADA. DEPARTMENT OF ENERGY, MINES AND RESOURCES. PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD27, COORDINATE SYSTEM : UTM ZONE 12.

REFERENCE LAKE OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

NOTES

MAP MOVED TO PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD83, COORDINATE SYSTEM : UTM ZONE 12.

500 0 500
SCALE METRES

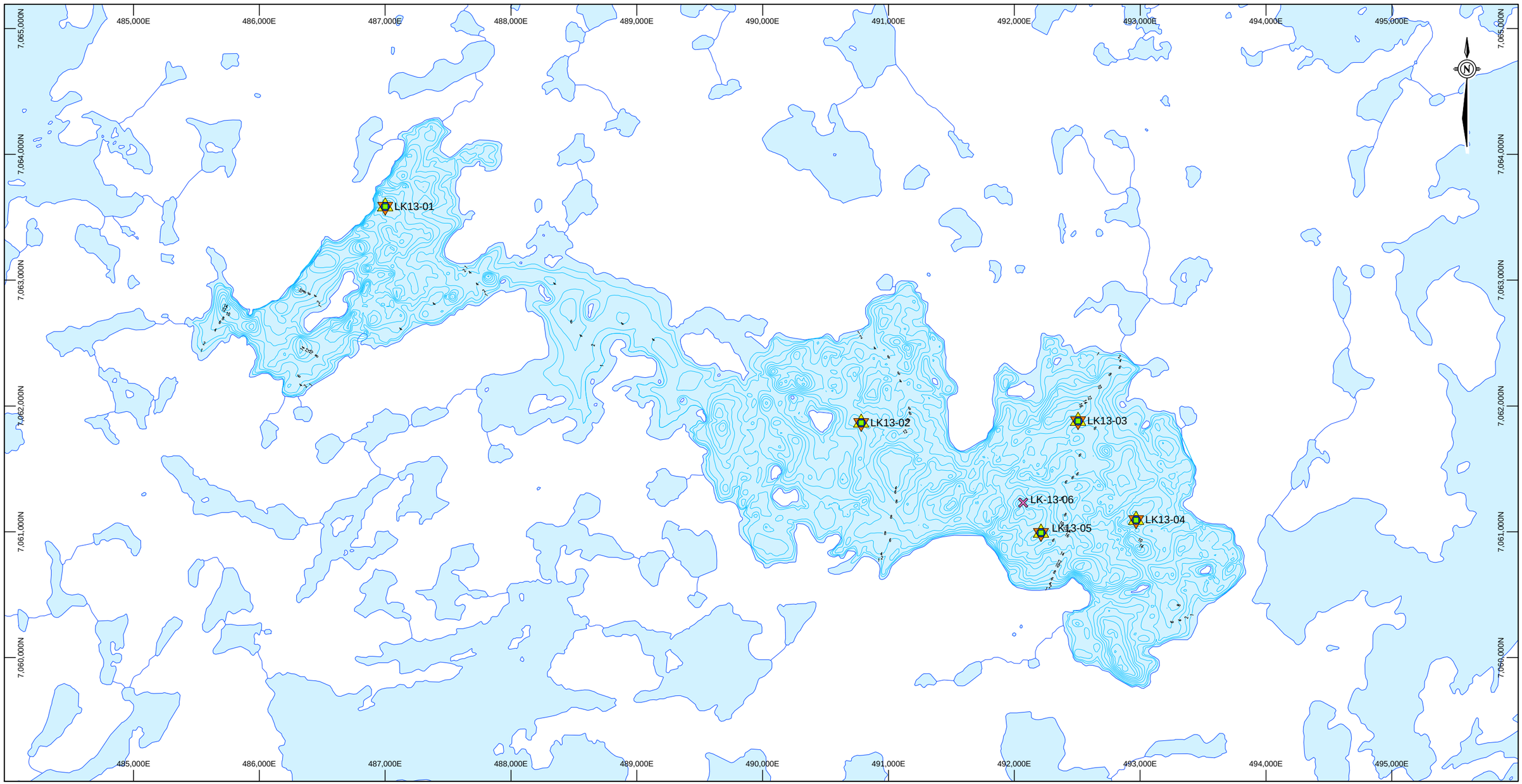
PROJECT
De Beers Canada
Snap Lake Mine

TITLE
MONITORING STATIONS IN NORTHEAST LAKE, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C007	
DESIGN	TD	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	11/10/2012			
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

FIGURE: 3.3-3



LEGEND

- WATER QUALITY MONITORING STATION
- SEDIMENT QUALITY MONITORING STATION
- BENTHIC INVERTEBRATE MONITORING STATION
- PLANKTON MONITORING STATION
- WATER QUALITY PROFILE STATION
- WATERBODY
- DEPTH CONTOUR (m)

REFERENCE

BASE VECTOR DIGITAL CANVEC 1:50K DATA OBTAINED FROM GEOGRATIS ONLINE.

DATUM: NAD83 PROJECTION: UTM ZONE 12

PROJECT
De Beers Canada
Snap Lake Mine

TITLE
MONITORING STATIONS IN LAKE 13, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	121337000211000008	
DESIGN	TD	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	10/10/2012	FIGURE: 3.3-4		
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

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3.4 Sampling Schedule

The monitoring frequency of the 2005 to 2012 AEMP was annual, with the exception of the fish program. Fish health, fish community, and fish tissue monitoring were conducted once every five years. In the 2013 Design Plan, water quality and plankton will continue to be monitored on an annual basis to detect potential early warning changes. The other components of the AEMP (i.e., sediment quality, benthic invertebrates, fish health, fish community, fish tissue) will be monitored at a frequency of once every three years (Table 3.4-1). This represents a decrease in monitoring frequency for sediment quality and benthic invertebrates from the previous annual frequency, and an increase in the frequency of fish surveys from once every five years to once every three years.

Fish tasting, an aspect of Traditional Knowledge, will be conducted on an annual basis to maintain community involvement in the AEMP on an annual basis. Fish habitat monitoring will only be conducted if project activities change such that additional habitat disturbance is possible. The rationale for these changes in frequency is provided in detail in Section 4.

The change in frequency will not affect the reporting schedule specified in the new Water Licence. A full sampling program would take place in 2015, and the annual report would be submitted May 1, 2016. The next AEMP Design Plan for the next four-year cycle would be due October 2016. This schedule allows for a detailed assessment of all components and an evaluation of trends prior to the submission of the next Design Plan. This approach follows the same approach as other national aquatic effects monitoring programs, such as the federal pulp and paper and metal mining Environmental Effects Monitoring (EEM) programs, which use a tiered, three-year cycle approach (Environment Canada 2010, 2012). The sampling schedule over the next four-year AEMP cycle is presented in Table 3.4-2.

Table 3.4-1 Summary of the 2013 AEMP Design Plan

Component	Frequency	Timing	Sampling Depth	Sample Type	Number of Samples per Station	Number of Stations
Water Quality - SNP (Mixing Zone)	Annually	Monthly	Depends on presence of a vertical conductivity gradient	Discrete	1 (depth of maximum conductivity, or mid-depth if no conductivity gradient is present)	Diffuser: 3
Water Quality - AEMP	Annually	1 ice-cover	Depends on presence of a vertical conductivity gradient	Discrete	1 (depth of maximum conductivity, or mid-depth if no conductivity gradient is present)	Main Basin: 6 NWA: 4 NEL:5 Lake 13: 5
		3 open-water				
Water Quality – Inland lake stations	Annually	Monthly during open-water conditions	Surface	Discrete	1	3
Water Quality – Station in major tributary to Snap Lake	Annually	Approximately twice weekly sampling and field measurements during spring freshet;	Surface	Discrete	1	2
		approximately monthly sampling and field measurements during open-water conditions				
Water Quality – Downstream stations	Annually	Quarterly[(a)] sampling and field measurements	Surface	Discrete	1	1
Sediment Quality - SNP	Annually	1 ice-cover	Top 2 cm and top 5 cm	Composite of 3 sediment cores	1 composite at each depth for chemistry	Diffuser: 1
Sediment Quality - AEMP	Once every 3 years	1 open-water	Top 5 cm for TOC, particle size, metals, nutrients	Composite of 3 Ekman grabs	1 composite for chemistry	Main Basin: 6 NWA: 3 NEL: 5 Lake 13: 5
Plankton – Phytoplankton and Chlorophyll *a*	Annually	3 open-water	Depth-integrated (euphotic zone)	Composite of euphotic zone samples	1	Main Basin: 5 NWA: 4 NEL: 5: Lake 13: 5
Plankton - Zooplankton	Annually	3 open-water	Depth-integrated (full water column vertical tow)	Discrete	1	Main Basin: 5 NWA: 4 NEL: 5: Lake 13: 5

Table 3.4-1 Summary of the 2013 AEMP Design Plan (continued)

Component	Frequency	Timing	Sampling Depth	Sample Type	Number of Samples per Station	Number of Stations
Benthic Invertebrates	Once every 3 years	1 open-water	10 to 15 m	Composite of 6 grabs (grabs are kept separate at selected stations)	1 composite (6 discreet at selected stations)	Main Basin: 7 NWA: 3 NEL: 5 Lake 13: 5
Fish Health	Once every 3 years	1 open-water	(not applicable)	Lethal survey: 40 adult male 40 adult female 40 juvenile Non-lethal survey: 100-400 fish	(not applicable)	Snap Lake NEL Lake 13
Fish Community	Once every 3 years	1 open-water	Depth stratified	Represents a composite for the entire lake	Minimum of 31 gill net sets	Composite is assumed to represent the entire lake
Fish Tissue Chemistry	Once every 3 years	1 open-water	(not applicable)	Individual or composite of muscle tissue, liver and kidney	10 Lake Chub, 10 Lake Trout 10 Round Whitefish	Snap Lake NEL Lake 13
Fish Tasting	Annually	1 open-water	(not applicable)	(not applicable)	(not applicable)	Snap Lake

(a) Summary for existing downstream station KING01 only; further recommendations regarding downstream sampling is provided in Section 5.0.

AEMP = Aquatic Effects Monitoring Program; SNP = Surveillance Network Program; NWA = northwest arm; NEL = Northeast Lake; TOC= total organic carbon; cm= centimetre; m = metre; SNP = surveillance network program; AEMP = Aquatic Effects Monitoring Program.

Table 3.4-2 AEMP Sampling Schedule

Component[(a)]	2013		2014		2015		2016	
	IC	OW	IC	OW	IC	OW	IC	OW
Site Characterization and Supporting Environmental Variables	√	√	√	√	√	√	√	√
Supporting Environmental Variables - Trend Analysis					√			
Water Quality – SNP	√	√	√	√	√	√	√	√
Water Quality – AEMP	√	√	√	√	√	√	√	√
Plankton - Total Phosphorus and Total Nitrogen		√		√		√		√
Plankton - Phytoplankton, Zooplankton, Chlorophyll *a* and Chlorophyll *c*		√		√		√		√
Sediment Quality - SNP		√		√		√		√
Sediment Quality – AEMP						√		
Benthic Invertebrates						√		
Fish Health						√		
Fish Community		√				√		
Fish Tasting		√		√		√		√
Annual AEMP Report	√		√		√		√	
AEMP Four-year Re-evaluation Report								√
AEMP 2017 Design Plan								√

(a) See Table 3.4-1 for sampling locations and frequency descriptions

AEMP = Aquatic Effects Monitoring Program; SNP = Surveillance Network Program; IC = Ice-cover conditions; OW = open-water conditions.

3.5 Special Studies

Special studies occur as needed, and include research activities that support effects monitoring. These studies are not part of monitoring activities, as they do not assess changes that may be related to the Mine, but rather focus on development of monitoring methods, further investigation of monitoring findings, or to fill data gaps. The special studies for the 2013 AEMP Design Plan are:

- Littoral Zone Special Study (Section 5.1);
- Picoplankton Special Study (Section 5.2);
- Downstream Lakes Special Study (Section 5.3);
- Lake Trout Population Estimate Special Study (Section 5.4); and,
- Stable Isotope Food Web Analysis Special Study (Section 5.5).

4.0 COMPONENT SAMPLING AND ANALYSIS PLAN

4.1 Site Characterization and Supporting Environmental Variables

4.1.1 Objectives and Scope

The primary objective of the Site Characterization component of the AEMP for the Snap Lake Mine is to provide a description of non-Mine related modifying factors that may affect the Snap Lake ecosystem, and that need to be considered during data interpretation by each AEMP component. This component is new to the 2013 AEMP Design Plan.

Information on the characteristics of the Mine site and its operations, as well as characteristics of the surrounding waterbodies, was generally reported in the EAR (De Beers 2002a) and is updated in annual reports prepared outside of the AEMP:

- Annual SNP reports;
- Acid Rock Drainage and Geochemical Characterization Report for the Water Licence;
- Hydrology Annual Report;
- Air Quality and Meteorological Annual Report for the Environmental Agreement (De Beers 2004); and,
- The annual National Pollutant Release Inventory for the Mine.

Aquatic habitat is not fully characterized and reported under the above reports. Thus, additional information on habitat will be collected (e.g., seasonal water temperature, duration of ice cover, ice thickness, and shoreline to deep water habitat ratio).

The purpose of this component is to incorporate key findings of each of the above reports and programs, and additional information on habitat, to assist in the interpretation of AEMP results by the main AEMP components (i.e., water quality, sediment quality, plankton. benthic invertebrates, fish health, fish community).

The key questions to be addressed by the Site Characterization component are:

- What are the general conditions of the Mine site and the local environment under which the AEMP is conducted, independent of mining-related activities and considering unanticipated mining events such as spills?
- Is there a habitat difference between Snap Lake and the reference lakes in terms of seasonal water temperature and ice-cover?

4.1.2 Sampling Locations

Data will be reported from the sampling locations at the Snap Lake Mine site, Snap Lake, Northeast Lake, and Lake 13, including relevant data from the following monitoring stations: SNP; Acid Rock Drainage and Geochemical Plan; Hydrology; and, Air Quality.

4.1.3 Rationale

Any site is affected by natural factors independent of any anthropogenic influences. Understanding these natural factors is important to determine the effects of anthropogenic influences (Environment Canada 2012). Similarly, unanticipated mining-related events that are not part of normal operations need to be considered (e.g., spills).

4.1.4 Methods

4.1.4.1 Key Question 1: What are the general conditions of the Mine site and the local environment under which the AEMP is conducted, independent of mining-related activities, and considering unanticipated events occurring at the Mine such as spills?

A qualitative summary of this information will be provided. No quantitative analyses of these data are planned.

Site Conditions

The conditions at the Snap Lake Mine site will be characterized by reviewing the following information to be provided by site staff: identification of accidents, malfunctions, or spills relevant to the aquatic environment; any changes to mining operations not outlined in the EAR; the monthly and annual volume of combined treated effluent discharged; and, any uncontrolled runoff containing substances of potential concern (Table 4.1-1).

Hydrology

The hydrological conditions at the Snap Lake Mine site will be characterized by reviewing the following information from the annual hydrology program: date of peak freshet; freshwater discharge volume relative to baseline; and, the lake water levels relative to baseline (Table 4.1-1).

Air Quality

The meteorological and air quality conditions at the Snap Lake Mine site will be characterized by reviewing the following information from the annual air quality and meteorological program: air temperature; wind speed; predominant wind direction; net solar radiation over water; and, solar radiation (Table 4.1-1). The rate of dust deposition data will also be incorporated if the results are available within the timeframe for completing this section of the report.

Meteorological data are collected from a weather station at the Mine. These data will be reviewed to determine whether there are monthly differences in weather conditions during the open-water season that may affect plankton, benthic invertebrates, or fish communities. These data are available from baseline to present; comparisons will be done yearly and in comparison to baseline conditions.

4.1.4.2 Key Question 2: Is there a habitat difference between Snap Lake and the reference lakes in terms of seasonal water temperature and ice-cover?

Information on general habitat conditions of each study lake will be collected as follows: seasonal water temperature; duration of ice cover; ice thickness; and, the shoreline to deep water habitat ratio.

Temperature data loggers (Onset HOBO Water Temp Pro, #H20-001 or equivalent) will be deployed at two stations in each study lake (Snap Lake, Northeast Lake, and Lake 13) to assess seasonal differences in water temperatures. Water temperatures will be recorded from spring until fall, which is the time encompassing the principal period of growth for fish. Consideration will be given to monitoring under-ice if feasible. Loggers will be

set at a shallow station (<1 m deep) and a deep station (10 m deep) in each lake. At each deep station, a logger will be set mid-column and just above the substrate. The temperature data loggers will be set to measure water temperature on an hourly basis (i.e., 24 readings per day).

Data on ice thickness and duration of ice cover are collected during the AEMP water quality field programs. These data will be tabulated as part of the summary of the site conditions.

The ratio of shoreline habitat to deep water will be calculated by geographic information system (GIS).

Table 4.1-1 Types of Information used to Characterize Site Conditions for the Snap Lake AEMP

Type	Parameter	Format	Source
Operational	Accidents, Malfunctions or Spills	Narrative	Site; SNP Annual Report
	Project Description changes	Narrative	Site; SNP Annual Report; National Pollution Release Inventory Report
	Volume of Treated Effluent Discharged	m^3/day	Site; SNP Annual Report (SNP 02-17 and SNP 02-17b)
	Any runoff quality of concern	Narrative; chemistry and volume data	Annual Acid Rock Drainage Report and Geochemical Inspection
Hydrology	Peak Freshet	Date	Annual Hydrology Report
	Freshwater discharge volume relative to baseline	m^3/day from 1999 to current year; numeric and plot	
	Regional and Local Water Levels relative to baseline	m^3/day from 1999 to current year for each study lake[(a)]; numeric and plot	
Air Quality	Air Temperature	Min, mean, max, median per month and annually	Annual Meteorological and Air Quality Report
	Wind Speed	Min, mean, max, median per month and annually	
	Wind Direction	Narrative	
	Net Solar Radiation Over Water	Min, mean, max, median per month and annually	
	Solar Radiation	Min, mean, max, median per month and annually	
	Dust Deposition	mg/100 cm^2/month	
Habitat	Water Temperature	Min, mean, max, median per month and per open water season for each lake in shallow area and deep area	Plot and statistical comparison in each annual AEMP
	Shoreline to Deep Water Ratio	Ratio for main basin where study locations focussed	GIS Map for 2013 AEMP Annual Report
	Date of Ice-off	Date from site staff observations of Snap Lake; may not have ice off for other study lakes.	AEMP Annual Report
	Days of Ice Cover vs. Open Water	Number of days of each	AEMP Annual Report
	Ice thickness	Mean thickness for each lake for each winter season	AEMP Annual Report

(a) Hydrology is not monitored on Lake 13.

m^3/day = cubic metres per day; mg = milligrams; cm^2 = square centimetres; min = minimum; max = maximum; SNP= Surveillance Network Program; % = percentage; EAR = Environmental Assessment Report; GIS = geographic information system; AEMP = Aquatic Effects Monitoring Program.

4.1.5 Data Analyses

Data analyses for the site, air, and hydrology conditions will be limited to narrative statements and comparisons between months and annually as appropriate (Tables 4.1-1 and 4.1-2).

Mean, median, maximum, and minimum temperature per day will be calculated for each logger and each lake. Median and maximum temperatures will be compared with a Mann-Whitney U-test (i.e., a nonparametric t-test).

Table 4.1-2 Overview of Analysis Approach for Site Characterization Key Questions

Key Question	Overview of Analysis Approach
1. What are the general conditions of the Snap Lake Mine site and the local environment under which the AEMP is conducted, independent of mining-related activities and considering unanticipated mining events such as spills?	Tabular summary of site conditions and interpretation of such relative to each AEMP component by that component.
2. Is there a habitat difference between Snap Lake and the reference lakes in terms of seasonal water temperature and ice-cover?	Statistical analysis will be used to determine whether there are statistically significant differences in median temperatures between study lakes and ice cover.

The data summaries within the Site Characterization section will be used by the main AEMP components to aid in the interpretation of their specific data, i.e., to determine whether any changes are potentially mine-related or a result of natural factors.

4.1.6 QA/QC Procedures

Quality Assurance (QA) and Quality Control (QC) procedures govern all aspects of the AEMP including field methods, laboratory analysis, data management and analysis, and reporting. The QA/QC procedures currently implemented for the AEMP (De Beers 2012c) have been effective for assessing potential sample contamination, field precision, and accuracy associated with the environmental data collected. Results from the QA/QC assessments are used to make adjustments, when necessary, to the program to improve data quality. No additional QA/QC specific to this component is necessary.

4.2 Water Quality

4.2.1 Objectives and Scope

The primary objectives of the water quality component of the AEMP for the Snap Lake Mine are to:

- characterize and interpret water quality in Snap Lake for the purpose of identifying any Project-related effects;
- verify and update the EAR predictions (De Beers 2002a);
- support and inform management decisions made by Mine personnel (i.e., the Response Framework); and,
- recommend any necessary and appropriate changes to the water quality component of the AEMP for future years.

Specific Water Licence conditions applying to the water quality component of the Aquatic Effects Monitoring Plan (AEMP) for the Snap Lake Project (the Project) in the Water Licence MV2011L2-0004 [Part G, Schedule 6, Item 1 of MVLWB (2012a)] are:

a) *Monitoring for the purpose of measuring Project-related effects on the following components of the Receiving Environment:*
   i. *water quality;*

b) *Monitoring the following as indicators of nutrient enrichment in Snap Lake:*
   i. *total phosphorus, dissolved phosphorus and orthophosphate, nitrate, nitrite, ammonia and Kjeldahl nitrogen.*

c) *Monitoring to verify or assess the Environmental Assessment predictions relating to the trophic and dissolved oxygen status of Snap Lake including monitoring of:*
   i. dissolved oxygen concentrations in profiles at deep portions (i.e., >8 m) of Snap Lake with monitoring occurring monthly from February through May (i.e., under ice) and in late summer; and
   iii. *concentrations of total phosphorus, orthophosphate, and dissolved phosphorus in mine effluent on a regular basis and in Snap Lake under ice in March and early summer*

Analyses and interpretation of water quality data focus on answering the following six key questions:

- Are concentrations or loads of key water quality parameters in discharges to Snap Lake consistent with EAR predictions and below Water Licence limits?
- Are concentrations of key water quality parameters in Snap Lake below AEMP benchmarks and Water Licence limits?
- Which water quality parameters are increasing over time in Snap Lake and nearby waterbodies, and how do concentrations of these parameters compare to AEMP benchmarks, concentrations in reference lakes, EAR predictions, and subsequent modelling predictions?

- Are spatial and seasonal patterns in water quality in Snap Lake and downstream waterbodies consistent with predictions presented in the EAR and subsequent modelling predictions?
- Is there evidence of acidification effects from the Mine on nearby waterbodies?
- Is water from Snap Lake safe to drink?

4.2.2 Sampling Locations

The water quality component of the Snap Lake AEMP will sample Snap Lake, three inland lakes, two tributaries (Figure 4.2-1), two reference lakes, Northeast Lake (Figure 3.3-3) and Lake 13 (Figure 3.3-4), and one downstream station (Figure 4.2-2). Sample station locations are provided in Table 3.3-1.

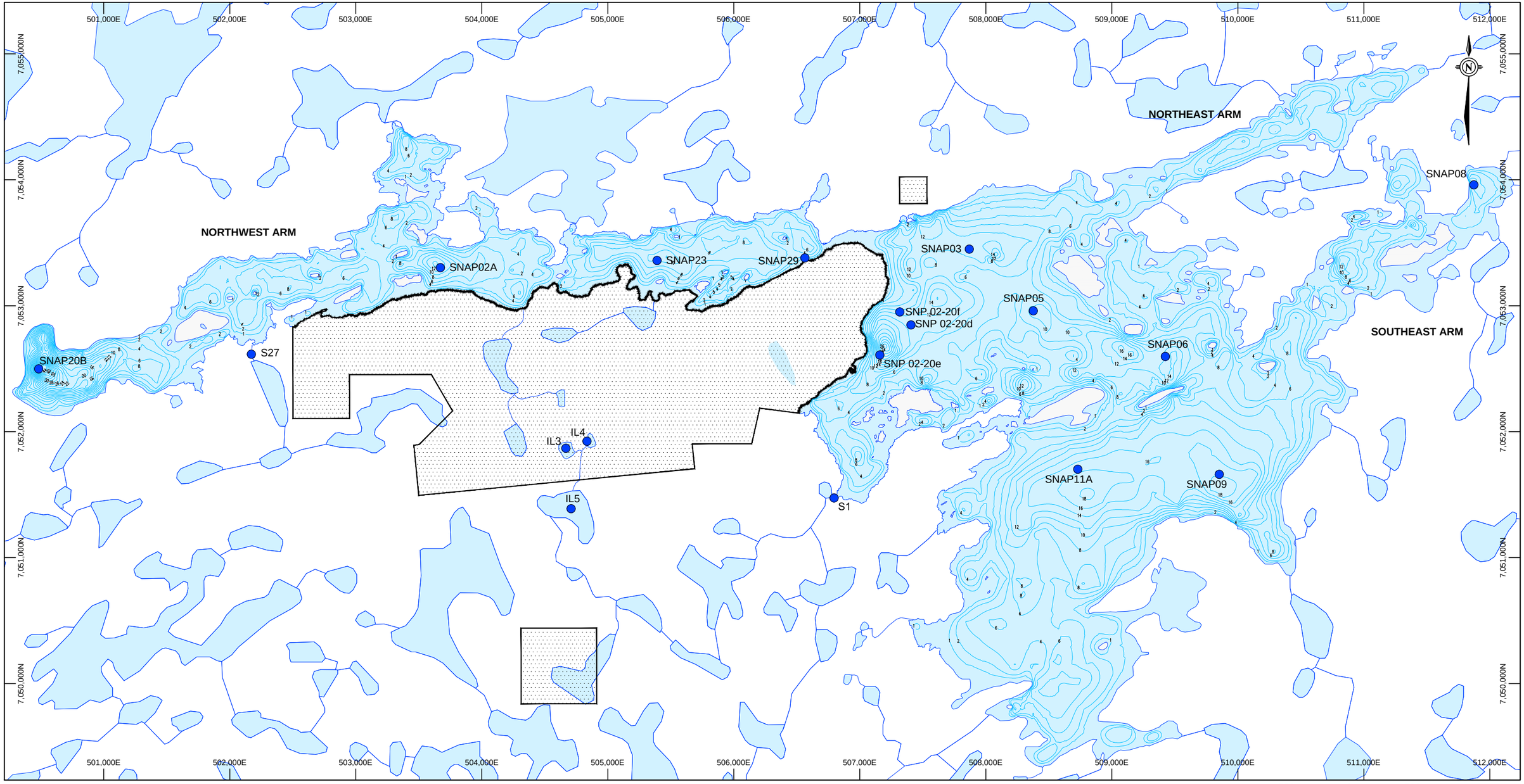
Water quality stations in Snap Lake are:

- Main Basin: SNP02-20d, SNP02-20e, SNP02-20f, SNAP03, SNAP05, SNAP06, SNAP08, SNAP09, and SNAP11A; and,
- Northwest Arm: SNAP29, SNAP23, SNAP02A, and SNAP20B.

Other sampling stations are:

- Northeast Lake (first reference lake): NEL01, NEL02, NEL03, NEL04, NEL05, and NEL06;
- Lake 13 (second reference lake): LK13-01, LK13-02, LK13-03, LK13-04, LK13-05, and LK13-06;
- Downstream waterbody: KING01;
- Inland Lake stations: IL3, IL4, and IL5; and,
- Tributaries: S1 and S27.

Main basin stations SNP02-20d, SNP02-20e, and SNP02-20f, located in the lake at the edge of the mixing zone, are monitored as part of the Surveillance Network Program (SNP) under the operational Water Licence (2013a). Water quality data collected from these stations will be summarized and incorporated into the AEMP, to assist with answering the key questions listed in Section 4.2.1, as well as to provide early warning for potential changes or effects related to the Mine in support of the Response Framework (Section 6.0). Further information on the design rationale is provided in Section 4.2.3.



LEGEND

- WATER QUALITY MONITORING STATION
- DEPTH CONTOUR (m)
- WATERCOURSE
- WATERBODY
- SNAP LAKE MINE FOOTPRINT

REFERENCES

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 OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

SNAP LAKE PLANTSITE DRAWING OBTAINED FROM CLIENT. DATE: JUNE 12, 2012. "SNAPLAKE-08_STATMAP_2012". DRAWN BY Nampcy Solutions Ltd.

NOTES

MAP MOVED TO PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD83, COORDINATE SYSTEM : UTM ZONE 12.

PROJECT

De Beers Canada
SNAP LAKE MINE

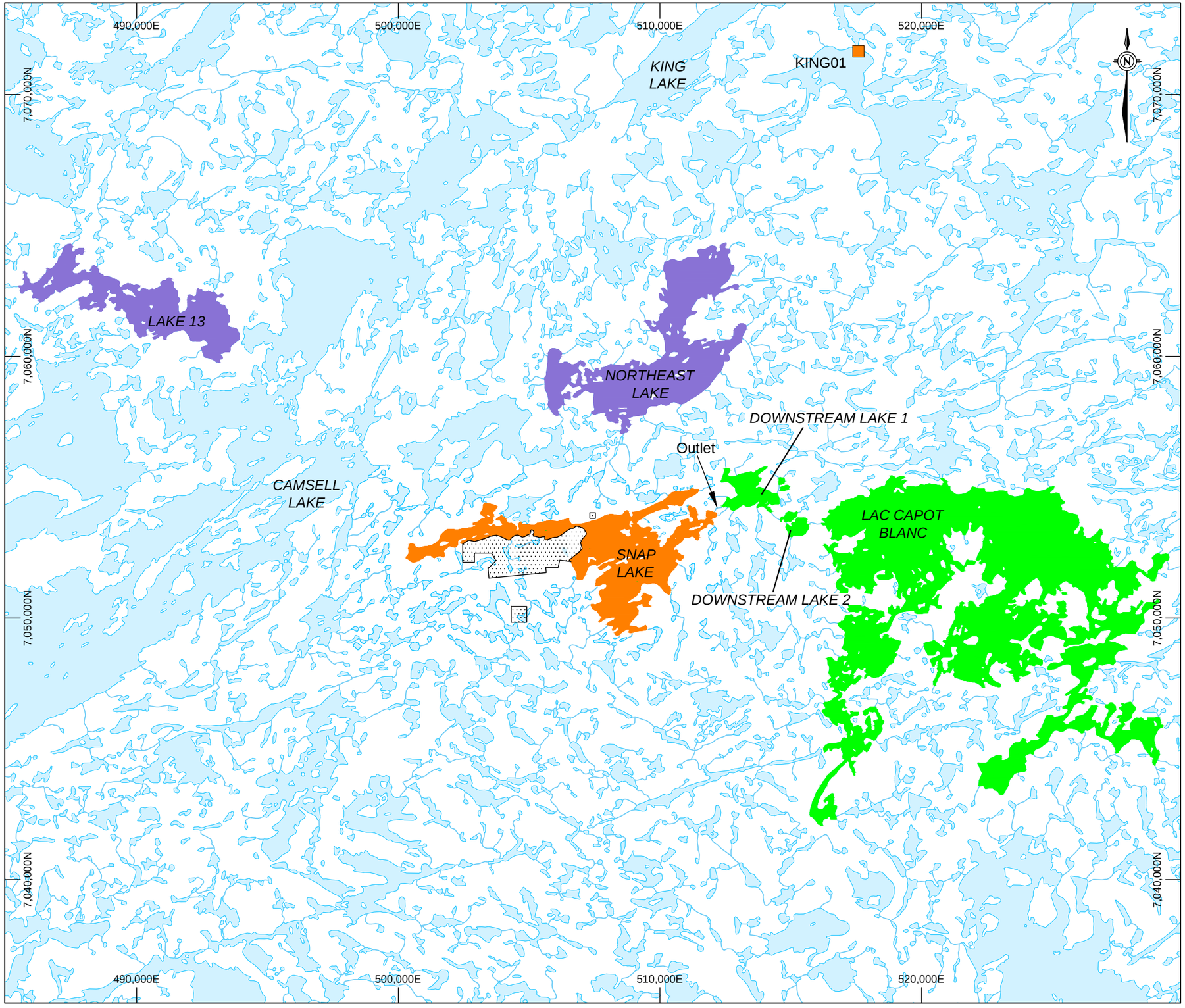
TITLE

WATER QUALITY MONITORING STATIONS IN SNAP LAKE, INLAND LAKES AND TRIBUTARIES, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	121337000211100C009	
DESIGN	TH	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	10/10/2012	FIGURE: 4.2-1		
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

L:\2012\1337\12-1337-0002\1100\Report_C\ Drawing file: Fig4.2-1_121337000211100C009_WQ Stn Inland Lakes and trib.dwg Nov 01, 2012 - 1:26pm



LEGEND

- AEMP WATER QUALITY STATION
- MONITORING AREA
- REFERENCE AREA
- SNAP LAKE MINE FOOTPRINT
- TARGETED DOWNSTREAM MONITORING AREA
- WATERBODY

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.

3 0 3
Scale:1:150 000 Km

PROJECT

De Beers Canada
Snap Lake Mine

TITLE

DOWNSTREAM WATER QUALITY MONITORING STATIONS, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C010	
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CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

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4.2.3 Design Rationale

Historical water quality data from Snap Lake indicate that the treated effluent is becoming evenly mixed throughout the main body of the lake and that, as predicted, its influence is becoming evident in lakes downstream of Snap Lake. The 2005 AEMP Design Plan was intended to identify spatial patterns as treated effluent mixed throughout Snap Lake. At that time, investigation into temporal trends was minimal as it was the early stage of Mine operations. The Re-evaluation Report (De Beers 2012a) and past AEMP annual reports (e.g., De Beers 2011b, 2012b) recommended that the focus of the AEMP be shifted from evaluating spatial and seasonal trends in Snap Lake to monitoring trends over time and changes downstream of Snap Lake. Therefore, refinements to the water quality component of the 2005 AEMP Design Plan are recommended based on understanding of past trends and current status of water quality in the lake, knowledge of key parameters, and predicted changes in Snap Lake and downstream. The 2013 AEMP Design Plan is a balance between adjusting effort required to adequately monitor future conditions within Snap Lake, and expanding the program to an additional reference lake and downstream of Snap Lake.

The 2013 AEMP Design Plan is intended to meet the objectives listed in Section 4.2.1. Consideration was given to the Water Licence, 2005 design rationale (De Beers 2005a), as well as the TDS, Calcium, and Chloride Sampling Plan (De Beers 2005b). At times, the water quality program design presented herein deviates from requirements in the aforementioned documents. Where differences occur, the rationale for such deviation is presented.

A summary of the design changes to the water quality component of the AEMP is provided below, focussed on highlighting additions to the overall AEMP study design for all components as described in Section 3.0. A table comparing the 2005 and 2013 AEMP Design Plans, and Water Licence requirements along with supporting information for design changes is provided in Appendix B.

4.2.3.1 Reductions in the Water Quality Component

Stations in the Main Basin

As part of the 2005 AEMP Design Plan (De Beers 2005a), water quality stations within Snap Lake were classified as diffuser, near-field, mid-field, far-field, and northwest arm stations. Stations were classified into these five areas according to their geographical location relative to the diffuser outlet. Such classifications are no longer required as the spatial gradient within the main basin of Snap Lake is minimal (De Beers 2012a). In the future, stations in Snap Lake will be referred to as “main basin” and “northwest arm” stations.

Nine stations in the main basin and four stations in the northwest arm of Snap Lake are included in the water quality component of the 2013 AEMP Design Plan and will continue to be monitored (Table 4.2-1). Stations SNAP04, SNAP07, SNAP10, SNAP12, SNAP26, and SNAP28 will be discontinued. The number and selection of stations retained in the main basin was based on the following considerations:

- retaining an adequate number of stations to calculate the whole-lake average for TDS concentration;
- providing appropriate spatial coverage, thereby supporting future water quality modelling;
- integrating with other components (sediment, plankton, benthic invertebrates, fish), for which the water quality component generates supporting data; and,
- eliminating redundancies in the program while retaining the ability to provide “early warning” of potential effects.

Annex A, Section D of the Water Licence specifies that the whole-lake average TDS concentration be calculated using 15 stations from the main basin, rather than the 9 referred to above. An assessment was completed to estimate the number of samples in the main basin above which further sampling would yield little additional information (Appendix B; Section 2.0). The standard error (SE) of the mean TDS value converges at approximately nine stations, indicating minimal gain in precision by sampling more stations. At nine stations, the SE ranged from 0.9% to 2.3% of the mean value based on 2011 data, and the coefficient of variation ranged from 2.7% to 6.8%, compared to ranges of 1.0% to 1.5% and 3.7% to 5.8% for 15 stations, respectively. In addition, the 2011 whole-lake average, minimum, and maximum values were also similar when calculated using 15 stations[2] and 9 stations (Appendix B). These results indicate a reasonable level of precision for the purposes of the AEMP and illustrate that the gain in precision from 9 to 15 stations is negligible. Whole-lake average TDS values will continue to be calculated using the method presented by De Beers (2005b) and MVLWB (2012a), only with fewer stations. Further details are provided in Section 4.2.5.3.

Stations SNAP04 and SNAP10 were added to the AEMP in 2004 to provide more complete coverage of TDS gradients in Snap Lake and support the calculation of whole-lake average TDS (De Beers 2005b). These stations are located in the northeast arm (i.e., SNAP04) and southeast arm (i.e., SNAP10) of Snap Lake, previously referred to as “far-field” TDS stations. Because the lake is now well mixed, sampling at SNAP04 and SNAP10 is redundant, as chemistry is similar to other areas in Snap Lake (Appendix B and De Beers 2012a). Similarly, sampling at SNAP07 is not required, as the outlet of Snap Lake (i.e., SNAP08) will continue to be monitored and will provide appropriate spatial coverage in that area. The Snap Lake water quality model does not require either of these stations for calibration (Golder 2011a).

The Water Licence requires TDS samples be collected from areas in close proximity to fisheries compensation works (i.e., SNAP05, SNAP12 [close to the artificial reef], SNAP29 [water intake], and SNAP28 [treated minewater outlet]). For the 2013 AEMP Design Plan, stations SNAP05 and SNAP29 will be retained, but SNAP12 and SNAP28 will be discontinued. SNAP05 and SNAP12 are in close proximity to one another and concentrations of TDS, the parameter of interest at the two stations, are similar (Appendix B; Section 3.0). Although station SNAP12 (i.e., approximately 8 m deep) is shallower than SNAP05 (i.e., approximately 14 m deep), DO profiles and nitrate concentrations are also similar for the depths that overlap. Therefore, SNAP05 is considered an adequate surrogate for SNAP12 and continued sampling of both locations would be redundant and unnecessary.

Station SNAP28 is located at the embankment of the minewater outlet, within the diffuser mixing zone (Figure 4.2-1). Three diffuser stations are located in the vicinity of SNAP28, providing adequate spatial coverage in that area. TDS concentrations at SNAP28 are consistent with those at the diffuser stations (Appendix B; Section 3.0). Recently, sampling at SNAP28 has been logistically challenging during ice-cover due to historical open-water areas near the diffuser and the resultant delineation of a “no go” zone due to unsafe ice conditions. Therefore, due to the logistical challenges and the overlap with the diffuser stations data, sampling at SNAP28 will be discontinued.

2 Fifteen stations during the open-water season and 14 stations sampled during the ice-covered season were used in the evaluation. Data from station SNAP28 were not available during ice-cover due to unsafe ice conditions in this area.

Sampling Depth

Previously, water samples were collected from three sampling depths at the diffuser stations (i.e., SNP02-20d, SNP02-20e, and SNP02-20f). At other locations in the main basin, either one or three samples were collected depending on the presence of a vertical conductivity gradient (De Beers 2012c). One sample from the depth of maximum conductivity is sufficient to capture the maximum concentration of treated effluent, effectively "worst-case" concentrations (De Beers 2012a and Appendix B; Section 4.0). This is consistent with requirements in the Water Licence for diffuser stations: *"samples at surface, at one metre above bottom, and at the depth of maximum conductivity shall be analyzed for if no conductivity peak is observed, a sample shall be taken at mid-depth between surface and bottom."*

For Snap Lake stations near the fisheries compensation works (i.e., SNAP05, SNAP12 [close to the artificial reef], SNAP29 [water intake], and SNAP28 [treated minewater outlet]), the Water Licence requires that TDS samples be collected at 1-m depth intervals. Under the 2013 AEMP Design Plan, specific conductivity, a direct measurement of the TDS in the water column, will be measured at SNAP05 and SNAP29 at 1-m intervals instead of TDS. This procedure is consistent with the 2005 AEMP Design Plan. For reasons outlined above, SNAP12 and SNAP28 will be discontinued.

Sampling Frequency

The 2005 AEMP Design Plan specified that all stations within Snap Lake and Northeast Lake, and the station downstream of Snap Lake (KING01), be monitored quarterly for all field and selected laboratory parameters (De Beers 2005a). Quarterly monitoring was completed twice during ice-covered conditions (i.e., January and April), and twice during open-water conditions (i.e., July and September). For the 2013 AEMP Design Plan, with the exception of the diffuser stations which will continue to be monitored monthly, stations in Snap Lake and the two reference lakes will be sampled for selected parameters in April/May, July, August, and September. The January program will be discontinued. This program reduction is based on the seasonal assessment completed as part of the Re-evaluation Report (De Beers 2012a), which indicated that TDS concentrations in April were, on average, approximately 15 milligrams per litre (mg/L) higher than the January/February values (Appendix B; Section 5.0). Concentrations are typically highest in late winter due to lack of mixing and natural inflows. Therefore, to capture "worst-case" chemistry in the lake, samples will be collected during the late-winter program only (April/May). Monthly collection of water quality samples and field water quality profiles at the diffuser stations will continue to provide early-warning water quality data.

Sampling frequency at KING01 will be reduced, as no increasing trends have been observed and ongoing effort is focussed on the current location of the plume in the lakes immediately downstream of Snap Lake. Sampling at KING01 will occur annually in April/May, rather than quarterly, to capture the period when peak concentrations tend to occur at this site (Appendix B; Section 7.0)

The effect of reducing DO measurement frequency on evaluating DO changes over winter was investigated as part of developing the 2013 AEMP Design Plan. The Water Licence requires measurement of DO concentrations as profiles at deep portions (i.e., >8 m) of Snap Lake, monthly from February through May (i.e., under ice) and in late summer. As shown in the Re-evaluation Report, increases rather than reductions in bottom DO concentrations have been observed in Snap Lake since 2004 (De Beers 2011c, 2012a). The increase in bottom DO concentrations during ice-covered conditions near the diffuser may result from the release of oxygenated treated effluent from the diffuser near the lake bottom. Profiles of DO at each station throughout the winter program were similar (Appendix B; Section 6.0); therefore, reducing the frequency of under-ice measurements is justified.

The frequency of sampling for metal concentrations in Snap Lake and the need for dissolved metals analysis were re-evaluated as part of developing the 2013 AEMP Design Plan. Maximum concentrations of some metals have on occasion exceeded water quality guidelines (WQGs), EAR benchmarks, or EAR predictions in Snap Lake between 2004 and 2011; however, whole-lake average (i.e., lake-wide) concentrations for these metals have remained below guidelines and predictions (De Beers 2012a). Most of the elevated metals results were attributable to sample contamination or in-lake processes rather than treated effluent exposure, because there were no temporal trends for these parameters and concentrations were not correlated with conductivity (an indicator of the treated Mine effluent). The modelling update indicated that, while concentrations of some metals are predicted to increase, they will remain below available benchmarks throughout the operational period (Golder 2011a). Similarly, concentrations of most metals are not predicted to exceed benchmarks in the treated effluent. Consequently, the modelling update report recommended reducing the frequency and spatial coverage of metals monitoring, until such time as any potential risks are indicated at the point of discharge (Golder 2011a).

In the 2005 AEMP Design Plan, metals were monitored monthly at the diffuser stations and quarterly throughout Snap Lake. In the 2013 AEMP Design Plan, the frequency of metals analysis at the diffuser stations is unchanged, but monitoring for metals at the remaining stations will occur in April/May and September only. Similar to the recent AEMPs, total metals will be analyzed, while a dissolved metals sample will be collected, preserved, and archived, and only analyzed if a total metal result is above a WQG.

4.2.3.2 Additions to the Water Quality Component

New Stations

Five stations will be added in Lake 13 to allow additional comparisons with reference lake water quality and to provide supporting information for other components (sediment, plankton, benthic invertebrates, and fish). A sixth station (LK13-6) will be profiled for DO to provide a deep-water reference station comparison. The northwest arm was previously used for this purpose; however, recent data indicate that the treated effluent is now evident throughout the northwest arm (De Beers 2012a,c). Locations presented in Table 4.2-1 were sampled during the 2012 reference lake special study. Station locations will be finalized following thorough review of the data obtained in 2012. Similar to LK13-6, station NEL06 in Northeast Lake will be added to measure DO concentrations at depths comparable to the deeper stations in Snap Lake.

Further reconnaissance sampling will be completed downstream of Snap Lake in downstream Lake 1, Lake 2, and Lac Capot Blanc. Long-term station locations will be finalized following review of the data obtained during the 2012 downstream lakes special study. The downstream water quality monitoring effort will also include a plume delineation component using conductivity as a tracer, similar to procedures used in 2011 and 2012 (De Beers 2012c).

Watercourse station S27, which is located in a tributary of Snap Lake, will be added to the AEMP program. This station is monitored to provide an estimate of natural watershed loadings to Snap Lake and to assess the potential for acidification due to air emissions. Monitoring of this stream was outlined as an EAR commitment; however, past monitoring has been sporadic. This station will be added formally to the 2013 AEMP Design Plan, but will be revisited as part of the air emissions re-assessment, to be completed in 2013.

Parameters Analyzed

Monitoring of microcystin-LR (amino acids lysine and arginine) concentrations will be completed as part of the water quality component. In the event of elevated microcystin-LR concentrations, the plankton component will assess potential cause(s) by evaluating the result in light of phytoplankton community composition and biomass.

As per the Water Licence, in addition to the chronic toxicity tests with invertebrate and algal species that are currently performed twice yearly on water samples from the three diffuser stations, an early life stage (ELS) toxicity test with Rainbow Trout will be performed once per year on a composite diffuser station water sample. The specified ELS toxicity test is an embryo/alevin/fry (EAF) test that is expected to last at least 70 days, and will therefore require weekly collection and shipment of large sample volumes for at least 10 weeks. Logistics, timing and feasibility associated with conducting this EAF toxicity test are currently being investigated.

4.2.4 Methods

4.2.4.1 Sampling Frequency

Depending on sampling area, stations will generally be monitored four times per year, monthly, or twice weekly (Table 4.2-1). The ice-covered season is defined as November to June of the following year (e.g., November 2012 to June 2013). The open-water season is defined as July to October (e.g., July 2013 to October 2013). Delineation of seasons is consistent with previous AEMP surveys. Since January 2007, surveys in June, October, November, and December have not been conducted, because ice conditions were often unsafe; however, in the event of ice conditions being safe, sampling will be conducted (De Beers 2007a).

4.2.4.2 Collection of Supporting Field Measurements

Field measurements of DO, pH, water temperature, and conductivity will be collected using a YSI 650 Multiparameter Display System (MDS) (or equivalent) water quality meter with a YSI 600 Quick Sample (QS) multi parameter water quality probe (or equivalent). A 30-m cable will be used with the YSI meter for depth profiles. Field water quality profiles will be collected every 1 m. Station number, UTM coordinates, date, time of collection, and weather will also be recorded at each station. A summary of the field water quality profile measurements recorded at the Snap Lake stations and the downstream station is provided in Table 4.2-2.

Other field data collected are ice thickness during ice-covered conditions and Secchi depth during open water conditions. Ice thickness will be measured at each station using an ice-thickness gauge before sampling, and Secchi depths will be measured using a 20-centimetre (cm) diameter Secchi disk, consistent with the method described in Wetzel (2001).

Table 4.2-1 Water Quality Monitoring Frequency

Area	Sampling Stations	Frequency	Months
Snap Lake – Main Basin	SNP02-20d; SNP02-20e; and SNP02-20f[(a)]	monthly as conditions allow[(a)]	All[(b)]
	SNAP03; SNAP05; SNAP06; SNAP08; SNAP09; and SNAP11A	four times per year (once during ice-covered and three times during open water conditions)	April/May July[(c)] August[(c)] September
Snap Lake - Northwest Arm	SNAP20B; SNAP02A; SNAP23 and SNAP29		
Northeast Lake	NEL01; NEL02; NEL03; NEL04; NEL05; and NEL06	four times per year	April/May July[(c)] August[(c)] September
Lake 13	LK13-01; LK13-02; LK13-03; LK13-04; LK13-05; and LK13-06	four times per year	April/May July[(c)] August[(c)] September
Inland lake stations	IL3; IL4; and IL5	monthly during open-water conditions	July, August, September
Tributaries	S1 and S27	approximately twice weekly during spring freshet	June[(d)]
		approximately monthly during open-water conditions	July, August, September
Downstream station[(e)]	KING01	Annually	April/May

(a) Monitored as part of the Surveillance Network Program (SNP); Water Licence specifies SNP samples at this location be collected monthly.

(b) Monthly when ice conditions allow. Sampling may not occur during break-up (June) and freeze-up (i.e., October and November).

(c) Reduced parameter suite collected (Table 4.2-4). July and August programs will provide supporting information for biological components (i.e., plankton and benthic invertebrates).

(d) Timing of freshet may vary.

(e) Additional downstream stations to be established as further information becomes available through ongoing reconnaissance fieldwork (Section 5.0).

Table 4.2-2 Summary of Field Parameters Monitored at Each AEMP Station

Category	Station	Parameter
1-m depth profile intervals from surface to 1 m above the lake bottom, or 0.5-m intervals if the depth is less than 5 m deep	all Snap Lake, Northeast Lake and Lake 13 stations	water temperature; dissolved oxygen[(a)]; pH; and conductivity
Single (spot) measurements	all Snap Lake, Northeast Lake and Lake 13 stations	total water depth; ice thickness and evidence of any open-water areas during ice-covered conditions; Secchi depth during open-water conditions; wind and weather conditions during all sampling events
Single (spot) measurements	downstream station (KING01), station S1, S27, and Inland Lake stations (IL3, IL4 and IL5)	water temperature; dissolved oxygen; pH; conductivity; wind and weather conditions

(a) Water will be collected for Winkler titrations to confirm field measurements of dissolved oxygen (Section 4.2.6).

m = metre.

4.2.4.3 Sample Collection and Analyses

Water Quality Sampling

Water will be sampled according to standard water quality methods (Environment Canada 1983, 2012). These methods represent accepted procedures for collecting water samples, conducting field measurements, recording field notes, calibrating instruments, and maintaining quality assurance (QA) and quality control (QC) functions

(De Beers 2008a). Further details are provided below on sampling depths, open-water and ice-cover season sampling methods, as well as toxicity sample collection.

Water from specific sampling depths will be collected using a Teflon Kemmerer sampler for metals samples and a polyvinyl chloride Kemmerer sampler for all other samples. At all stations, samples will be collected from the depth of maximum conductivity, or mid-depth if no conductivity gradient is present.

Surface-water grab samples will be collected at watercourse stations S1 and S27 and at inland lake stations IL3, IL4, and IL5 during open-water conditions. Grab samples will also be collected year-round at AEMP downstream station KING01. Surface water grab samples will be collected at approximately 0.2 m below the surface.

During the ice-covered season, a gasoline-powered ice auger will be used to drill a hole in the ice, and then the Kemmerer samplers will be lowered through the hole into the water column to collect water samples. Water from the Kemmerer samplers will be poured into 4-litre (L) laboratory-grade sampling containers instead of individual sampling bottles. This procedure reduces complications associated with attempting to fill several small bottles in temperatures well below freezing and reduces the chances of contamination in the field. A portion of the 4-L bottle will be filtered, and individual sample bottles will then be filled once the field crew returns to the De Beers environmental laboratory at the end of the sampling day. A similar process will be conducted during the open-water season.

Before shipping the samples to analytical laboratories, a subset of the water samples will require filtering and preserving. The subset includes samples collected for dissolved organic phosphorus, total dissolved phosphorus, dissolved metals, and hexavalent chromium analyses. These samples will be filtered in the De Beers environmental laboratory at the Mine site using a Geopump2 filter unit, laboratory-grade silicon tubing, and 0.45-micrometre (µm) Waterra filters, which are certified high capacity in-line groundwater sampling capsules. Preservatives, supplied by the laboratory to which the samples are being sent, will be added to samples, as required, following standard protocols for specific parameters (APHA 2012).

Toxicity Sampling

Toxicity samples will be collected from Snap Lake at the three diffuser stations twice per year and submitted for chronic toxicity testing using a water flea species, *Ceriodaphnia dubia*, and an algae species, *Pseudokirchneriella subcapitata*. Water samples for toxicity testing will be collected using the same methods as the other water quality samples. To meet the requirements outlined in the Water Licence, sampling will occur once during ice-covered conditions (April/May) and once during open-water conditions (September). Samples will be collected at the depth of maximum conductivity, or mid-depth if no conductivity gradient is observed. A 6-L sample volume will be collected at each diffuser station and split into three separate 2-L containers. Splitting each sample among three containers prior to shipping is a *Ceriodaphnia* test method requirement that allows the laboratory to take samples from unopened containers for daily renewals as the test progresses. Samples for chronic toxicity tests will need to be cooled to 1°C to 7°C prior to shipping, and then packed in coolers with freezer packs to maintain temperatures through transit. Samples will be shipped as soon as possible, as the maximum holding time for initiating the tests is three days after collection.

Beginning in 2013, water samples will be collected for an additional chronic toxicity test, the Rainbow Trout EAF test, required under the Water Licence. This EAF test will be performed once per year, and one test will be performed using composite water samples collected from the three diffuser stations. The EAF test specified in the Water Licence is the longest duration of three options[3] for the Rainbow Trout ELS test, and is expected to last for at least 70 days. For 2013, a separate 7-d E (embryo) test will be conducted concurrently to provide information about the relative sensitivity of the three ELS test durations, for consideration regarding using a shorter duration and more logistically feasible test in future years (Environment Canada 1998). For the EAF test, consistent (i.e., same day of week) weekly water sample collection at the diffuser stations will be required for at least 10 to 12 consecutive weeks. Sampling for the EAF test therefore requires a three month period of safe access to the Snap Lake diffuser stations, either during winter when ice cover is solid or during the open-water summer period. Due to field safety concerns, sampling for the EAF will begin in July once safe open-water conditions have been established. This test requires daily renewal of test solutions, using water samples that are collected weekly. The Rainbow Trout ELS test uses 120 L of sample per week; to allow for possible delays in sample collection and shipping we recommend that 140 L of sample be collected each week. Larger sample volumes may be needed during the later stages of the EAF test, once the fish have hatched and passed the swim-up stage of development. If a 7-d E test is to be performed concurrently, an additional 120 L of sample will be collected during the first sampling event.

4.2.4.4 Laboratory Analyses

The water quality parameters, applicable sampling stations, and monitoring frequency of different parameter groups are summarized in Table 4.2-3.

Water Quality Analyses

The majority of water samples will be submitted to ALS Laboratory Group (ALS) in Edmonton, Alberta (AB). Samples for ultra-low level mercury and methyl mercury analyses will be submitted to Flett Research Ltd. (Flett) in Winnipeg, Manitoba (MB). Flett was selected for the ultra-low level mercury analyses because this laboratory can provide the low detection limits (DLs) required for comparison to applicable guidelines and/or EAR predictions. Samples for *Escherichia coli* (*E. coli*) analysis will be sent to Taiga Environmental Laboratory in Yellowknife, NWT, to meet required holding times. Maxxam Analytics Incorporated (Maxxam) in Burnaby, BC, will be used for inter-laboratory comparisons of sample results. Microcystin-LR samples will be submitted to HydroQual Laboratories (HydroQual) in Calgary, AB.

The parameter groups are defined in Table 4.2-3 and the analytical services provided by each laboratory are listed below:

3 Environment Canada (1998) describes three options for the Rainbow Trout ELS test: an E (embryo) test that assesses embryo viability during a 7-d exposure from fertilization; an EA (embryo-alevin) test that lasts approximately 30 days, from fertilization until 50% of control fish have hatched; and, an EAF (embryo-alevin-fry) test that lasts approximately 70 days, from fertilization until 30 days after 50% of the surviving control alevins exhibit swim-up behaviour.

- ALS in Edmonton: conventional and physical parameters, measured and calculated TDS and major ions, nutrients[4], and ultra-low total and dissolved metals by collision cell inductively coupled plasma mass spectrometry[5], total oil and grease by infrared analysis, and biochemical oxygen demand (BOD);
- Flett in Winnipeg: ultra-low level total mercury and methyl mercury, as per United States Environmental Protection Agency procedures (USEPA 1998) and total mercury (as per USEPA 2002);
- Taiga Environmental Laboratory in Yellowknife, NWT: *E. coli*;
- Maxxam in Burnaby (for inter-laboratory split samples): conventional and physical parameters, measured and calculated TDS and major ions, nutrients, ultra-low total and dissolved metals by collision cell inductively coupled plasma-mass spectrometer, hexavalent chromium, organics, BOD; and,
- HydroQual in Calgary: Microcystin-LR samples will be sent to HydroQual for analysis.

Chronic Toxicity Tests

Chronic toxicity tests with the water flea, *Ceriodaphnia dubia*, and algae, *Pseudokirchneriella subcapitata*, will be performed by HydroQual (Calgary, AB), consistent with previous years' toxicity testing. The Rainbow Trout ELS testing will be performed either by HydroQual or by Nautilus Environmental (Burnaby, BC), depending in part on availability of Rainbow Trout gametes. On-site testing is also a possibility that will be considered, given the extensive requirements for large volumes of water collected over the long duration of this test.

The three-brood *Ceriodaphnia dubia* test involves exposing water fleas to Snap Lake water for approximately seven days to assess potential effects on survival and reproduction (Environment Canada 2007a). A series of seven test concentrations (typically 100%, 50%, 25%, 12.5%, 6.25%, 3.1%, and 1.6%) plus a negative (clean) control are tested. The point estimates[6] calculated are the LC25 and LC50 for survival, and the IC25 and IC50 for reproduction.

The 72-h algae test with *Pseudokirchneriella subcapitata* involves exposing algal cells to Snap Lake water in a microplate to assess potential effects on algal growth (Environment Canada 2007b). A series of seven test concentrations (typically 91%, 46%, 23%, 11%, 5.7%, 2.8%, and 1.4%)[7] plus a negative (clean) control are tested. The point estimates calculated are the IC25 and IC50 for inhibition of algal growth.

4 The laboratory to be used for phosphorus nutrient analyses is unknown and will be chosen dependent on results from the 2012 nutrient study and subsequent follow-up quality control investigation (Section 4.2.6.4).

5 In 2011, ALS replaced their existing ICP-MS instrumentation with a collision cell inductively coupled plasma-mass spectrometer (CCMS) for ultra-low total and dissolved metals analyses. ALS have evaluated, and now adopted, collision cell technology as the standard for all future ICP-MS equipment purchases because of the quality and reliability of the data (Crowther 2011, pers. comm.). As such, ultra-low total and dissolved metals samples for the AEMP will be analyzed by CCMS.

6 The LC25 and LC50 are the concentrations of sample that are estimated to cause 25% or 50% lethality, respectively, to the test organisms. The IC25 and IC50 are the concentrations of sample that are estimated to cause 25% or 50% inhibition, respectively, in a sublethal endpoint such as reproduction or growth.

7 Because of the small test solution volumes used in this microplate test, once the algal inoculum and nutrient medium have been added the highest concentration tested is actually 91%.

The EAF test with Rainbow Trout involves exposing newly fertilized embryos to Snap Lake water for approximately 70 days as they develop, hatch as alevins, absorb their yolk sacs, and develop into fry (Environment Canada 1998). The EAF test lasts for 30 days after at least 50% of control fish show swim-up behaviour (i.e., absorb their yolk sac and begin feeding). A series of five test concentrations (typically 100%, 50%, 25%, 12.5%, and 6.25%) plus a negative (clean) control are tested. The test endpoints are alevin viability, and survival and dry weight (dw) of fry.

Table 4.2-3 Summary of Water Quality Parameters, Stations, and Sampling Frequency

Parameter Categories	Parameter	Snap Lake – Diffuser Stations	Snap Lake – Main Basin and NWA	Reference Lakes (Northeast Lake and Lake 13)	Inland Lake Stations	Tributary Stations	Downstream Station
		SNP02-20d; SNP02-20e; SNP02-20f	Main Basin: SNAP03; SNAP05; SNP06; SNAP08; SNAP09; SNAP11A. NWA: SNAP02A; SNAP23; SNAP20B; SNAP29	NEL01; NEL02; NEL03; NEL04; NEL05; NEL06[a] LK13-01, LK13-02, LK13-03, LK13-04, LK13-05, LK13-06[a]	IL3; IL4; IL5	S1; S27	KING01
Field Measurements/Profiles	Field pH, specific conductivity, dissolved oxygen and temperature	monthly (at 1-m intervals from surface to bottom)	April/May, July, August, September (at 1-m intervals from surface to bottom)	April/May, July, August, September (at 1-m intervals from surface to bottom)	monthly during open-water conditions (surface)	twice weekly during spring freshet and monthly during open-water conditions	April/May
Physical and conventional parameters, TDS and major ions	total suspended solids; pH; turbidity; conductivity, TDS (calculated and measured); calcium; magnesium; sodium; chloride; sulphate; bicarbonate; carbonate; fluoride; potassium; hydroxide; reactive silica (as SiO_2); hardness; alkalinity; acidity; ion balance	monthly[b]	April/May, July, August, September	April/May, July, August, September	monthly during open-water conditions	twice weekly during spring freshet and monthly during open-water conditions	April/May
Nutrients	total and dissolved phosphorus; total organic carbon; ortho-phosphate as P; total and dissolved organic phosphorus; total and dissolved inorganic phosphorus total ammonia (as nitrogen [N]); nitrate (as N); nitrite (as N); nitrate/nitrite (as N); total Kjeldahl nitrogen (as N)	monthly[b]	April/May, July, August, September	April/May, July, August, September	monthly during open-water conditions for nitrogen nutrients[c]	weekly during spring freshet and monthly during open-water conditions for nitrogen nutrients[b]	April/May
Metals	total and dissolved metals (Al; Sb; As; Ba; Be; Bi; B; Cd; Cs; Cr; $Cr^{(VI+)}$ (total only); Co; Cu; Fe; Pb; Li; Mn; Hg; Mo; Ni; Se; Ag; Sr; Tl; Ti; U; V; Zn)	monthly[b]	April/May, September[d]	April/May, September[d]	not applicable	weekly during spring freshet and monthly during open-water conditions[d]	April/May[d]
Other parameters	methyl mercury and biochemical oxygen demand (BOD)	monthly[b]	not applicable; except BOD at SNAP08	not applicable	not applicable	not applicable	not applicable
Organics	BTEX (benzene; toluene; ethylene; xylene); total oil and grease; total extractable hydrocarbons; total volatile hydrocarbons F1 (without BTEX) and F2 (without BTEX	monthly[b]	not applicable	not applicable	not applicable	not applicable	not applicable
Biological	*Escherichia coli*	monthly[b]	not applicable	not applicable	not applicable	not applicable	not applicable
	Microcystin-LR	not applicable	January, April, July, August, September at SNAP29[e] only	not applicable	not applicable	not applicable	not applicable
Toxicity	*Ceriodaphnia dubia; Pseudokirchneriella subcapitata*	twice per year (April/May, September)	not applicable	not applicable	not applicable	not applicable	not applicable
	Early life stage (embryo/alevin/fry) with Rainbow Trout	Once per year (July to September), on composite diffuser station sample	not applicable	not applicable	not applicable	not applicable	not applicable

(a) Field measurements/profiles only.

(b) Monthly when ice conditions allow. Sampling may not occur during break-up (June) and freeze-up (i.e., October and November).

(c) Nitrogen nutrients = total ammonia (as nitrogen [N]); nitrate (as N); nitrite (as N); nitrate/nitrite (as N); total Kjeldahl nitrogen (as N).

(d) Samples will be analyzed for total metals; dissolved metals sample will be archived and only analyzed if a total metal is above an AEMP benchmark.

(e) SNAP29 = Water intake location.

AEMP = Aquatic Effects Monitoring Program; TDS = total dissolved solids; SiO_2, = silicate; P = phosphorus; N = nitrogen; BOD = biochemical oxygen demand; m = metre; NWA = northwest arm; SNP= Surveillance Network Program; BTEX = benzene, toluene, ethylbenzene, xylene; Al = aluminum; Sb = antimony; As = arsenic; B = boron; Ba = barium; Be = beryllium; Bi = bismuth; Cd = cadmium; Cr = chromium; $Cr^{(VI+)}$ = hexavalent chromium (total only); Co = cobalt; Cs = cesium; Cu = copper; Fe = iron; Pb = lead; Li = lithium; Mn = manganese; Hg = mercury; Mo = molybdenum; Ni =nickel; Se = selenium; Ag = silver; Sr = strontium; Tl = thallium; Ti = titanium; U = uranium; V = vanadium; Zn = zinc.

4.2.5 Data Analysis

4.2.5.1 Approach

Water quality data analysis is designed to answer the key questions listed in Section 4.2.1. An overview of the analysis approach associated with these four questions is provided in Table 4.2-4. Specific details relevant to data analysis methods to address each key question are provided in Sections 4.2.5.2 to 4.2.5.6.

Table 4.2-4 Overview of Analysis Approach for Water Quality Key Questions

Key Question	Overview of Analysis Approach
1. Are concentrations or loads of key water quality parameters in discharges to Snap Lake consistent with EAR predictions and below Water Licence limits?	Treated effluent discharge to Snap Lake will be compared to EAR predictions and Water Licence limits. Temporal trends in treated effluent concentrations and loads will be investigated. Toxicity of the treated effluent will also be evaluated. Other inputs (e.g., seepage, runoff, spills) will be discussed.
2. Are concentrations of key water quality parameters in Snap Lake below AEMP benchmarks and Water Licence limits?	Average and maximum concentrations of water quality parameters will be compared to AEMP benchmarks and Water Licence limits (TDS). Instances where concentrations are above AEMP benchmarks or limits will be identified and qualitatively assessed for potential Mine-related causes.
3. Which water quality parameters are increasing over time in Snap Lake and nearby waterbodies, and how do concentrations of these parameters compare to AEMP benchmarks, concentrations in reference lakes, EAR predictions and subsequent modelling predictions?	An analysis of temporal patterns in water quality will be completed for dissolved oxygen, total phosphorus, and parameters that are significantly correlated with conductivity in Snap Lake. A statistical test (e.g. Seasonal Kendall or other appropriate test) may be used to quantify the certainty of any potential temporal trends identified from laboratory parameters. Comparisons will be made to the normal range observed prior to treated effluent discharge as well as reference lake concentrations. The potential to exceed AEMP benchmarks, EAR predictions, or updated model results will be assessed for parameters with apparent increasing trends (or decreasing trends as for dissolved oxygen) in Snap Lake. An analysis of temporal patterns in conductivity and total dissolved solids at KING01 (the downstream AEMP station) will be completed.
4. Are spatial and seasonal patterns in water quality in Snap Lake and downstream waterbodies consistent with predictions presented in the EAR and subsequent modelling predictions?	Qualitative assessments of horizontal, vertical, and seasonal patterns in Snap Lake water quality will be completed for field parameters, total dissolved solids, major ions, nutrients, and metals. Where patterns existed, the potential for Mine-related causes is qualitatively assessed. An assessment of the data collected downstream of Snap Lake will be completed to delineate the extent of the treated effluent plume. Conductivity will be used as a tracer of treated effluent exposure.
5. Is there evidence of acidification effects from the Mine on nearby waterbodies?[(a)]	Water quality data from inland lake stations IL3, IL4 and IL5, Stream 1 (Station S1) and Stream 27 (Station S27) will be reviewed to identify any changes in stream water quality related to mining activities, including potential acidification effects, and to document loadings to Snap Lake from this source.
6. Is water from Snap Lake safe to drink?	Water quality data from Snap Lake and station SNP 02-15 (the water intake) will be compared against health-based drinking water guidelines.

(a) The inclusion of Key Question 5 in future annual AEMP will depend on the results of the 2013 acidification re-assessment (Section 4.2.5.6).

EAR = Environmental Assessment Report; TDS = total dissolved solids; AEMP = Aquatic Effects Monitoring Program.

4.2.5.2 Key Question 1: Are concentrations or loads of key water quality parameters in discharges to Snap Lake consistent with EAR predictions and below Water Licence limits?

4.2.5.2.1 Treated Effluent

For treated effluent, temporal plots of discharge volume, parameter concentrations and loadings (from both the permanent and temporary treatment plants, as applicable), comparisons of discharge quality to Water Licence limits and EAR predictions, determination of dilution factors, and a summary of the toxicity test results will be provided. These evaluations are discussed in more detail below.

Comparisons to Water Licence Limits

Parameters with Water Licence limits are total suspended solids, nitrogen compounds (ammonia, nitrate and nitrite), ions (fluoride[8], chloride, and sulphate), metals (aluminum, cadmium, chromium, copper, lead, nickel and zinc), and a metalloid (arsenic) (MVLWB 2013a). For these parameters, the Water Licence specifies both a "maximum concentration in any grab sample" and an "average monthly limit". An average monthly limit is the concentration that cannot be exceeded, determined by averaging the analytical results of six consecutive samples collected at 6-day intervals over a 30-day period. For parameters measured every six days (i.e., physical parameters, major ions, nutrients) a 30-day moving average will be calculated for comparison. For metals, which are analyzed approximately once per month, a monthly value will be used.

The following additional limits apply at end-of-pipe:

- the pH level is to be maintained within the range of 6 to 9 pH units;
- the monthly average limit for extractable petroleum hydrocarbons is 4.6 mg/L for fraction F1 (C6-C10) and 2.1 mg/L for fraction F2 (C11-C16); and,
- the total phosphorus annual load limit is 256 kilograms (kg) per year.

Treated effluent data will be plotted so that direct visual comparisons to Water Licence limits can be made. Daily discharge volumes and loadings rates (kilograms per day) will be calculated and reviewed for trends over time. The total phosphorus (TP) annual load to Snap Lake will be calculated using the permanent water treatment plants (WTP) and temporary water treatment plant (TWTP) treated wastewater discharge. Phosphorus concentration data and coincident flow rate data from the WTPs will be used to calculate flow-weighted average concentrations. The average will then be multiplied by the total volume of permanent and temporary WTP discharge, from November through to October of the following year, to estimate the TP loading during that year. The TP loading to Snap Lake will then be compared to the Water Licence limit of 256 kilograms per year (kg/year). Similar to previous AEMP reports, the total loading to Snap Lake for phosphorus will be calculated using Equation 1:

8 The fluoride limit comes into effect starting January 1, 2015, along with revised nitrate and chloride limits (MVLWB 2013a).

$$\text{Total TP Load}_{WTP} = (FWC_{WTP} \times V_{WTP}) + (FWC_{TWTP} \times V_{TWTP}) \quad \text{Equation 1}$$

where:

FWC_{WTP} = flow-weighted average TP concentration in the permanent WTP;

V_{WTP} = total volume of permanent WTP discharge (November to October of the following year);

FWC_{TWTP} = flow-weighted average TP concentration in the temporary WTP; and,

V_{TWTP} = total volume of temporary WTP discharge (November to October of the following year, if applicable).

Comparisons to Environmental Assessment Report Predictions

A summary will be provided of parameters for which flow-weighted concentrations exceed EAR predictions. Flow-weighted concentrations will be presented to provide values more reflective of average conditions, rather than instantaneous concentrations. Loadings will be calculated for parameters with mass-based units; parameters such as pH (unitless) and conductivity (µS/cm) will be excluded. The combined weighted average used for comparison to EAR predictions will be calculated using Equation 2:

$$FWC_{WTP} = \Sigma(C_{WTPi} \times F_{WTPi}) + \Sigma(C_{TWTPi} \times F_{TWTPi}) / \Sigma(F_{WTPi} + F_{WTPi}) \quad \text{Equation 2}$$

where:

FWC_{WTP} = flow-weighted average concentration from the permanent and temporary WTP (combined);

C_{WTPi} = concentration in the permanent WTP discharge during sampling event i;

F_{WTPi}= daily permanent WTP discharge volume associated with sampling event i;

C_{TWTPi} = concentration in the temporary WTP discharge during sampling event i;

F_{TWTPi}= daily temporary WTP discharge volume associated with sampling event i; and,

i = sampling event.

Biological data for the treated effluent samples, including bacterial counts of *E. coli* and fecal coliforms, will be presented as geometric means. Bacteria reproduce at an exponential rate in domestic waste water. It is not uncommon to have an exceptionally wide range in bacterial coliform counts in some domestic waste water samples, such as 10 colony forming units per 100 millilitres (CFU/100 mL) to 100,000 CFU/100 mL. Compared to an arithmetic mean, the geometric mean is less sensitive to the effects of extreme values. Geometric means will be calculated using Equation 3:

$$GM\ \bar{y} = (y1 \times y2 \times y3 \ldots yn)^{1/n} \quad \text{Equation 3}$$

where:

y = bacterial counts;

n = number of samples; and,

GM $\bar{y}$ = geometric mean.

Toxicity of Treated Effluent

Aquatic toxicity tests have been performed on samples of treated effluent since November 2005. Results of treated effluent toxicity tests will continue to be presented in the annual AEMP reports and reviewed for trends and/or concentration-response relationships (i.e., potential adverse effects increasing at higher concentrations of treated effluent). Adverse effects are considered to occur if there is more than a 25% (for a chronic test) or 50% (for a chronic or acute test) decrease in mean response in 100% (v/v) sample, depending on the endpoint.

Dilution Factors

The permanent diffuser is intended to maximize the potential for initial mixing of the treated effluent discharged to Snap Lake. The diffuser does not influence total loadings to Snap Lake or lake-wide changes in water quality, but it can reduce TDS concentrations and concentrations of other constituents of the WTP discharge, near the outfall. The estimated dilution factors achieved by the permanent diffuser will be calculated using parameter concentrations (i.e., TDS) in the temporary and permanent WTP discharge and parameter concentrations from the annual monitoring program in Snap Lake. Minimum dilution factors for the diffuser will be calculated quarterly (i.e., April/May, July, August and September), using Equation 4:

$$DF = (C_e - C_b)/(C_d - C_b) \qquad \text{Equation 4}$$

where:

DF = minimum dilution factor of the permanent diffuser;

C_e = flow-weighted average TDS concentration of the treated effluent at SNP 02-17b;

C_d = maximum TDS concentration at the three diffuser stations SNP 02-20d, SNP 02-20e, and SNP 02-20f; and,

C_b = background lake concentration, represented by the average TDS concentrations from main basin stations[9] in Snap Lake.

The calculated dilution factors will then be compared with predicted dilution factors in the EAR (De Beers 2002a).

4.2.5.2.2 Other Inputs to Snap Lake

Inputs other than treated effluent (e.g., uncontrolled runoff, seepage, and overland spills) can also negatively affect water quality in Snap Lake, although to a much lesser extent than the treated effluent discharge. Uncontrolled runoff may enter Snap Lake from several sites, which are monitored through the SNP. Trends in runoff and groundwater quality and quantity will be provided in the annual Acid/Alkaline Rock Drainage and Geochemistry Monitoring Report (Golder 2012). Additional water quality data collected in relation to recent untreated releases from the waste rock pile collection sumps (e.g., Spill 11-391/11-398) will be presented in

9 Stations to be included in the calculation will be determined based on the observed spatial gradient for that year. If there is less than a 10% difference between concentrations at the diffuser station and SNAP08, all stations in the main basin will be included. As concentrations in the lake increase, less spatial gradient in the main basin is expected, and more stations in the main basin will be included in the calculation.

separate reports. Where relevant, data from these sources will be summarized or referenced in the site characterization and supporting environmental variables section of the AEMP, and discussed as part of the water quality assessment.

4.2.5.3 Key Question 2: Are concentrations of key water quality parameters in Snap Lake below AEMP benchmarks and Water Licence limits?

Water quality parameters in Snap Lake were predicted to remain below aquatic life (e.g., CCME 1999 with updates) or site-specific benchmarks developed in the EAR, such as those specifically developed for three metals: copper, cadmium, and hexavalent chromium.

Since the time the EAR was prepared, several new Canadian Council of Ministers of the Environment (CCME) aquatic life WQGs have been developed (i.e., fluoride, chloride, and nitrate). These new WQGs have been incorporated into the AEMP water quality data comparisons. As part of the 2013 AEMP Design Plan, water quality data collected in Snap Lake will be compared against "AEMP benchmarks," which refers to a collective list of generic aquatic life WQGs (e.g., CCME 1999 with updates) and EAR benchmarks (De Beers 2002a). The list will evolve as new WQGs are published or revised by the CCME and new information becomes available. Any site-specific benchmarks developed for Snap Lake (e.g., TDS) as part of the AEMP Response Framework will be highlighted as such.

If results are above AEMP benchmarks, an attempt will be made to determine the relevance of the elevated results to aquatic biota. Where appropriate, this will involve additional comparison of average conditions to guidelines, benchmarks and predicted concentrations, or consideration of the information on which the aquatic life WQG was developed. Refer to Section 6.0 for further information on water quality action levels within the Snap Lake Response Framework.

Minimum DO concentrations will be compared to the aquatic life WQG (CCME 1999 with updates). Dissolved oxygen concentrations in late winter in Snap Lake will be compared with values from the same period at reference stations in Northeast Lake and Lake 13.

Whole-Lake Average Concentrations of Total Dissolved Solids

The EAR predicted that water discharged to Snap Lake will increase concentrations of TDS and some major ions, nutrients, and metals in Snap Lake (De Beers 2002a). The maximum whole-lake average concentration of TDS in Snap Lake was predicted to be less than 350 mg/L. Whole-lake average concentrations of TDS, chloride, and calcium will be calculated using data collected at Snap Lake monitoring stations, excluding the northwest arm stations. If TDS concentrations are less than 350 mg/L, a simple mean of the depth-averaged means at all stations will be used to calculate the whole-lake average. If the depth-averaged concentration at any one station is above 350 mg/L and a spatial pattern in TDS concentrations is apparent, then the calculation of whole-lake averages will also account for spatial patterns, following the procedure outlined in the TDS, Calcium, and Chloride Sampling Plan (De Beers 2005b).

Total dissolved solids concentrations can be measured directly by evaporating a known volume of filtered water and measuring the mass of the residue left after evaporation (APHA 2012; Method 2540). Alternatively, TDS concentration can be calculated from the summation of major ions in the sample (APHA 2012; Method 1030). As part of the AEMP, TDS will be included as both measured and calculated values, but only calculated TDS will be used in the assessment (De Beers 2012c, MVLWB 2013a).

4.2.5.3.1 Toxicity Data

Samples will be collected twice per year from the diffuser stations and submitted for toxicity testing. Results for the sublethal endpoints from the chronic toxicity tests, *Ceriodaphnia dubia* reproduction and *Pseudokirchneriella subcapitata* algal growth, will be plotted and reviewed for trends. When possible, toxicity results will be compared to water quality data from treated effluent and diffuser stations sampled on the same day.

4.2.5.4 Key Question 3: Which water quality parameters are increasing over time in Snap Lake and nearby waterbodies, and how do concentrations of these parameters compare to AEMP benchmarks, concentrations in reference lakes, EAR predictions, and subsequent modelling predictions?

Different methods will be used to assess temporal trends in water quality in Snap Lake:

- comparing maximum concentrations in Snap Lake with EAR predictions;
- screening for parameters that are positively correlated with conductivity and then visually evaluating temporal plots for these parameters at selected stations to identify increasing trends;
- using a statistical test to identify increasing trends for selected parameters at selected stations;
- comparing observed temporal trends with model predictions for key parameters; and,
- reviewing vertical profiles of DO concentrations from different areas in Snap Lake over time.

4.2.5.4.1 Comparing with EAR Predictions

Concentrations in Snap Lake will be compared against maximum concentrations predicted in the EAR (De Beers 2002a), and for key parameters (i.e., TDS and nitrate). Temporal plots of observed data will be superimposed on the EAR prediction plots and updated predictions to determine whether values are increasing as expected. If results are above predictions, an attempt will be made to determine the relevance of the elevated results to aquatic biota. Refer to Section 6.0 for further information on water quality action levels within the Snap Lake Response Framework.

4.2.5.4.2 Screening and Visual Evaluation of Temporal Plots

The EAR predicted that discharges of treated effluent from the Mine to Snap Lake would result in increases in concentrations of major ions, nutrients, and some metals throughout the lake, and slight decreases in DO in deep waters of Snap Lake. Increases in conductivity and TDS in Snap Lake have been demonstrated in previous AEMP reports (De Beers 2006, 2007b, 2008b, 2009, 2010b, 2011b, 2012b). To identify other water quality parameters that may be increasing in Snap Lake, Pearson correlation coefficients will be calculated between each parameter and conductivity using SYSTAT 13.00.05 (SYSTAT 2009) for AEMP data. Conductivity was selected as an indicator of exposure to the treated effluent because:

- conductivity is a routine parameter that can be measured easily in the field and laboratory;
- conductivity has increased throughout Snap Lake from 2004 to 2011, directly related to the input of treated effluent; and,
- conductivity is used to evaluate the degree of treated effluent exposure for other monitoring, in particular sediment quality and benthic invertebrates.

The Pearson correlation test will be used to identify a significant correlation between conductivity and all other parameters monitored in Snap Lake. A statistical probability (*P*-value) of 0.001 will be used to identify those parameters that are significantly correlated with conductivity to account for the large number of correlations and the large sample size. In cases where data outliers, which will be visually identified in the parameter dataset by plotting the parameter dataset against the conductivity dataset, appear to be influencing the parameter correlation with conductivity, the outliers will be removed and the Pearson correlation test re-run to determine whether they have an influence on the strength of the correlation. All parameters that significantly correlate with conductivity based on the inclusion or exclusion of the outliers will be reviewed for temporal trends in Snap Lake.

Temporal plots of concentrations of those parameters that are significantly positively correlated with conductivity will be completed for:

- SNAP13 and SNP02-20e (located near the diffuser);
- SNAP05;
- SNAP09;
- SNAP08;
- SNAP02 and SNAP02A (located in the northwest arm of Snap Lake); and,
- reference lakes (Northeast Lake and Lake 13).

Stations SNAP13 (diffuser) and SNAP02 (northwest arm) were established in 2004 and monitored until 2006. These stations were then discontinued, moved slightly and renamed SNP02-20e and SNAP02A, respectively. Data from both the historical and new stations will be included to provide a longer dataset for the analysis.

Temporal plots of four nutrient parameters (TP, nitrate, nitrite, and ammonia), at each of the above stations will also be reviewed, regardless of the strength of correlations with conductivity. Because of seasonal fluctuations in biological uptake and release of nutrients, nutrients could be increasing in Snap Lake without showing a strong correlation with conductivity. These nutrients were selected because results can be compared to a WQG, an EAR prediction, or both.

Each plot will be visually examined to identify increasing trends. The “normal range,” which is defined as the mean ± two standard deviations (SDs) from data collected from Snap Lake prior to treated effluent discharge (i.e., 2004), will be plotted for comparison. As well, water quality data for reference lakes will be visually reviewed for temporal trends and compared to Snap Lake. Mine-related changes in water quality are not expected in Northeast Lake or Lake 13. Therefore, any changes over time in Snap Lake that do not occur in the reference lakes are likely related to the Mine. Changes that occur in all three lakes would be attributed to non-Mine-related regional effects, such as climate change or hydrological variation (factors considered as part of the Site Characterization, Section 4.1).

4.2.5.4.3 Comparison of Temporal Trends to Model Predictions

Maximum concentrations in Snap Lake will be compared against maximum concentrations predicted in the EAR. For key parameters (i.e., TDS and nitrate), temporal plots of observed data will be superimposed on the EAR and updated prediction plots to determine whether values are increasing as expected. As part of the Water Licence renewal application process, the Snap Lake water quality model was updated in 2011 (Golder 2011a) to

update EAR predictions. Two scenarios, referred to as Upper Bound and Lower Bound, were modelled. Predictions for Snap Lake were provided near the diffuser and at the outlet. The exception was total phosphorus, for which conclusions are pending based on the resolution of analytical issues in the water quality analyses (Section 4.2.6.2). The updated predictions are applicable to the current Mine plan, and will need to be revisited if changes to the Mine plan occur.

4.2.5.4.4 Trend Analyses

For many water quality parameters (e.g., TDS and ions, nitrogen nutrients), temporal trends can be visually identified (Golder 2012) so rigorous statistical testing is no longer required to identify differences from the normal range. Where confirmation may be required, an appropriate statistical test will be used to confirm trends. A potential test would be the Seasonal Kendall Test, which removes seasonal cycles and tests for the presence of increasing and decreasing trends within the monitoring data. The test generates a z score that can be used to confirm the significance of the trend based on the *P*-value at a 95% confidence. The same stations selected in the visual review for temporal trends in the section above will be used in the Seasonal Kendall Test or relevant statistical test: SNAP13, SNP02-20e, SNAP05, SNAP09, SNAP08, SNAP02, and SNAP02A. SYSTAT 13.00.05, or an updated version, will be used to complete the statistical analyses (SYSTAT 2009).

4.2.5.4.5 Dissolved Oxygen

Vertical profiles of DO will be plotted over time to determine whether DO concentrations are decreasing over time at any given depth or within a lake area and, if so, whether the decreases are consistent with EAR and updated predictions.

4.2.5.5 Key Question 4: Are spatial and seasonal patterns in water quality in Snap Lake and downstream waterbodies consistent with predictions presented in the EAR and subsequent modelling predictions?

Spatial Patterns

Field measurements of conductivity from Snap Lake will be used to map the spatial patterns of the treated effluent plume in Snap Lake. Vertical profiles will be used to investigate the portion of water column influenced by treated effluent. As well, a series of figures showing the plume at snap-shots through time will be prepared to show both horizontal and vertical spatial patterns of water quality within Snap Lake. For these figures, conductivity between sampling stations will be estimated using an inverse distance weighted method of interpolation. The inverse distance weighted method will estimate conductivity values between sampling stations by averaging conductivity in the neighbourhood of each cell. The closer a sampling station is to the centre of the cell being estimated, the more influence, or weight it will have on the averaging process. The maps presenting near-surface and near-bottom conductivity values will be based on the single field conductivity measured nearest to the surface and bottom, respectively, at each station.

Seasonal Patterns

Seasonal patterns in key parameters within each of the major parameter groups will be identified through plots of average concentrations in different lake areas of Snap Lake and in the reference lakes. Data from each area in Snap Lake (main basin and northwest arm) and from Northeast Lake and Lake 13 will be separated by season (i.e., open-water and ice-cover). Results from the ice-covered season will include data collected between November (previous year) and June, and open-water results will include data collected between July and September.

Downstream Extent of Treated Effluent Plume

Water quality data for the AEMP downstream station, KING01, will be reviewed to identify potential changes in water quality at a station located 25 km downstream of Snap Lake. Temporal patterns in TDS and conductivity will be reviewed at KING01 to identify trends in salinity. If an increasing trend is detected at KING01, an evaluation of the potential for increases in Mine-related parameters to cause changes in water quality at KING01 would be recommended. The annual water quality results at KING01 will also be compared to AEMP benchmarks.

In addition to the KING01 site, a water quality program will also be conducted in three lakes (Lake 1, Lake 2, and Lac Capot Blanc) immediately downstream of Snap Lake to delineate the spatial extent of the treated effluent plume and assess current conditions. Data from this program will be plotted against distance downstream, and visually examined to identify any potential trends. The information gathered downstream of Snap Lake will be used in the future to develop a downstream monitoring program. This will be done in conjunction with a Downstream Lakes Special Study (Section 5.3) in 2013 to update the current information in these three downstream lakes.

4.2.5.6 Key Question 5: Is there evidence of acidification effects from the Mine on nearby waterbodies?

Water quality data for the three inland lakes, at stations IL3, IL4, and IL5, will be reviewed to identify any changes in pH and total alkalinity due to potential acid deposition resulting from Mine emissions. Water quality data from Stream 1 (Station S1) and Stream 27 (Station S27) will be reviewed to identify any changes in stream water quality related to mining activities, including potential acidification effects, and to document loadings to Snap Lake from this source. As part of the 2009 AEMP (De Beers 2010b), the potential for acidification of the three inland lakes was re-assessed based on updated air dispersion modelling and on advancements in the methods used to predict acidification since the EAR was prepared, as well as consideration of data collected during baseline and the AEMP. This assessment will be re-visited in 2013, using updated air modelling information and water quality data, to determine whether the results from the 2009 assessment (i.e., no risk of acidification to nearby waterbodies) remain valid, which presently appears to be the case. Results from the 2013 assessment will guide future monitoring requirements for the inland lakes and inflow streams.

4.2.5.7 Key Question 6: Is water from Snap Lake safe to drink?

Water quality parameters in Snap Lake were predicted to remain below drinking WQGs. As part of the annual AEMP report, water quality data collected from various locations in Snap Lake as part of the AEMP, as well as information collected from the water intake station (i.e., SNP02-15) will be compared against Health Canada (2012) drinking water guidelines. The parameter list includes microcystin-LR, as well as ions, nutrients, and metals with health-based drinking water guidelines.

4.2.6 QA/QC Procedures

The QA/QC procedures govern all aspects of the AEMP including field methods, laboratory analysis, data management and analysis, and reporting. Field QA/QC procedures pertain to the maintenance and operation of equipment and instrumentation, sampling methods, sample handling, and shipping. Laboratory QA/QC procedures incorporate protocols developed by analytical laboratories. Office QA/QC procedures include validation of field measurements and analytical results provided by analytical laboratories.

The QA/QC procedures currently implemented for the AEMP (De Beers 2012c) have been effective for assessing potential sample contamination, field precision, and accuracy associated with the environmental data collected. Results from the QA/QC assessments are used to make adjustments, when necessary, to the program to improve data quality.

4.2.6.1 Quality Assurance

4.2.6.1.1 Field Staff Training and Operations

Field staff training and field operation procedures provide known, acceptable, and defensible quality. To this end, the following measures will be implemented:

- Field staff will be trained to be proficient in standardized procedures, data recording, and equipment operations applicable to field sampling. Specific work instructions outlining each field task will be provided to the field crew.
- Detailed field notes will be recorded in waterproof field books and on pre-printed waterproof field data sheets in pencil. Data sheets and sample labels will be checked at the end of each field day for completeness and accuracy.
- Samples will be labelled, preserved, and shipped according to standard protocols provided by laboratories and De Beers Environmental Management System procedures (De Beers 2002b). Each sample will be given a name and unique sample control identification number. Mine-specific chain-of-custody forms are and will be used to track the shipment and analyses of samples.
- Field multi-meter, sampling and filtration equipment will be maintained regularly. The results of the calibration and any required maintenance will be recorded in the field data sheets or notebooks.
- Winkler titrations will be completed on samples collected from the field to verify that the DO probe of the multi-meter was functioning properly. Dissolved oxygen measurements obtained by the multi-meter and Winkler titration will be recorded in field data sheets or notebooks. In addition, a three-step Winkler titration is recommended if notable variability is observed between the first two Winkler titration results.

4.2.6.1.2 Laboratory Analysis

In accordance with the Water Licence (MVLWB 2013a) and the De Beers QA/QC Plan (De Beers 2008a), water samples will be submitted only to laboratories accredited by the Canadian Association for Laboratory Accreditation (CALA).

Project-specific chain-of-custody forms will be used to track the shipment and analyses of samples. The analytical laboratories have been instructed that they should not proceed with any analyses of samples that are not accompanied by both chain-of-custody and analysis request forms.

4.2.6.1.3 Office Operations

The office data management system provides an organized and consistent system of data control and analysis. This management system includes procedures for tracking collected samples, data entry, and data validation within a Microsoft Access database, referred to as the Snap Lake Environmental Database. These procedures involve:

- Laboratory data will be transferred electronically into the Snap Lake Environmental Database to avoid transcription errors associated with manual data. The laboratory analytical method for each parameter will be entered into the Snap Lake Environmental Database along with the analytical results.
- Qualifiers, or alphabetical codes, will be assigned by the laboratory to results that identify a potential issue with a result. In particular, the laboratory will be questioned if a parameter is frequently assigned a qualifier code. A list of qualifiers is available upon request.
- Required Snap Lake Mine (Mine) DLs are specified for all chemical analyses for the AEMP and SNP, and are included in the Snap Lake Environmental Database. The requested DLs and DLs provided by each laboratory for individual samples will be compared. If laboratory DLs are higher than requested DLs, the laboratory will be notified and requested to provide an explanation for the change in DLs. If possible, a parameter will be re-analyzed at the Mine DLs. If re-analysis is not possible, the results will be evaluated on a case-by-case basis to determine whether they are suitable for the assessment.
- Laboratory hold times, derived from American Public Health Association (APHA 2012), are the recommended maximum periods between sample collection and analysis. Hold times that are longer than the laboratory-recommended hold times will be reviewed for patterns, reasons for longer hold times, and the significance of not meeting the recommended hold times. If the recommended hold times are not met because of field or shipping procedures, these procedures will be reviewed and revised so that future field programs, to the extent possible, will meet recommended hold times for these parameters.
- The units reported by the laboratory will be compared against the expected units, as coded into the database, for each parameter and matrix type. Where laboratory units are inconsistent with expected units, the results will be confirmed with the laboratory and the units will be corrected in the database. If corrections are necessary, hard copies of the results will be re-issued by the laboratory.
- Approximately 5% of hard copies of the laboratory results will be compared to the data entered into the database. Any incorrect data will be re-checked and re-entered.
- Notes are recorded for the above six steps, which include results from each step and follow-up action items to resolve any significant issue. These notes will be stored electronically and printed, and stored with the hard copy of results. Once all QA/QC items will be resolved, the data are marked as valid and proofed in the database.

4.2.6.2 Quality Control

Quality control (QC) is a specific aspect of QA that refers to the internal techniques used to measure and assess data quality. The QC samples are used to detect and reduce systematic and random errors that may occur during field sampling and laboratory procedures. The QC samples will represent at least 10% of the total number of samples to be analyzed for each category of blank samples, and duplicate and split samples based on Environment Canada's recommendations (Environment Canada 1983, 2012).

The QC samples for each field program will consist of:

- Duplicate samples, prepared from a separate sample collected from the same location as the original sample. Duplicate samples will be prepared, labelled, and preserved individually and then submitted to the

appropriate analytical laboratories along with the original sample. These samples will be used to measure variability in water quality at the sampling site.

- Split samples, prepared from a single sample collected from a given location, which is split evenly into two sample containers. The split samples will be labelled and preserved individually, and then submitted to two separate laboratories, ALS and Maxxam, for identical analyses to evaluate the variability associated with sample heterogeneity and laboratory analysis.
- Equipment blanks, prepared in the water processing facility by filling bottles with laboratory-distilled de-ionized water (DDW) used to rinse the sampling equipment, including the plastic and Teflon Kemmerer samplers. Equipment blanks will be used to detect potential sample contamination due to the equipment.
- Field blanks, prepared in the field during each sampling event by filling sample bottles using DDW provided by the laboratory. These blanks will be exposed to the atmosphere for as long as it took to fill a normal sample bottle with a field water sample. Field blanks will be preserved at site, following the same method as the water samples. Field blanks are used to detect potential sample contamination during collection, handling, shipping, and analyses.
- Travel blanks, sample bottles pre-filled with DDW and sealed by the laboratory. These bottles remain sealed at all times during the sampling program, and accompany the sample bottles at all times. They are used to detect sample contamination during shipping, storage, and analyses.

All QC samples will be collected in the same manner as water samples, conforming to standard sampling methods. The QC samples will be labelled with unique sample control numbers so they cannot be identified as QC samples by the laboratory.

4.2.6.2.1 Assessment Criteria

Blank Validation

The results from equipment, field and travel blanks to be collected during the field program will be used to evaluate the future AEMP water quality data. The validation method using blanks is based on recommended methods prepared by the British Columbia Ministry of Environment (1998). A modified version of this method will be adopted for evaluating the future AEMP water quality data, using a process consistent with that presented in De Beers (2012b).

Duplicate and Split Samples

The relative percent difference (RPD) is the absolute difference between two values divided by the average of the two values. The results of the split and duplicate samples are considered acceptable when the RPD between the two results is 20% or less and the results are greater than five times above the DLs. The use of five times the DLs is based on accepted practices (USEPA 1994, 2007; BCMOE 2009 [with updates]) and recommendations from ALS staff, who state that a greater degree of uncertainty exists in results within five times the DLs (Crowther 2011, pers. comm.). For inter-laboratory split samples, RPD values will not be calculated when notable differences in the DLs are the source of the variation. When a parameter is detected at one laboratory, but the value is less than the DLs from the alternate laboratory, an “NA” will be presented in the results.

Within-site variability and field sampling precision of duplicate sample results will be rated as:

- low and high, respectively, if less than 10% of the parameters included in the duplicate sample analysis are notably different from one another;
- moderate, if 10% to 30% of the parameters included in the duplicate sample analysis are notably different from one another; or,
- high and low, respectively, if more than 30% of the parameters included in the duplicate sample analysis are notably different from one another.

Analytical precision of split sample results will be rated as follows:

- high, if less than 10% of the total number of parameters are notably different from one another;
- moderate, if 10% to 30% of the total number of parameters are notably different from one another; or,
- low, if more than 30% of the total number of parameter are notably different from one another.

Comparison of Total and Dissolved Concentrations

Corresponding dissolved and total concentrations will be compared for each parameter to determine whether the dissolved values are greater than the corresponding total values. The RPD between the dissolved and total metal concentrations will be calculated when the dissolved concentration is five times above the DL and the dissolved concentration is reported to be higher than the total concentration. If the RPD between the dissolved and total concentration is less than 30%, then the result will be accepted as valid. When the RPD is greater than 30%, the laboratory will be contacted to confirm the result. If the results are confirmed by the laboratory, the data will be further reviewed for other causes. If no other cause is identified, then the data will be considered valid for total, but the dissolved values will be qualified as having a dissolved to total RPD outside of the acceptable range.

Data Validation

Validation of data will be completed using a two-step process. The first step will be a visual review of the data on a parameter basis using scatter-plot charts to identify outliers from the overall dataset for that parameter. Data from the Snap Lake Environmental Database will be exported, appropriately grouped, and plotted. Unusually high or low data outliers will be selected for further investigation.

The second step of the process will involve data validation of the selected outlying data. The selected data will be invalidated on a case-by-case basis, considering the following test conditions:

- if the result of a duplicate or a split sample is not within the expected concentration in the lake;
- if unusually high or low results are inconsistent with the conductivity measurement in the same sample, in cases when a parameter is correlated with conductivity;
- if the concentration of a parameter is high in a lake station far from the diffuser and average lake concentrations measured are less than 10 times the unusual result; and,
- if the parameter has a high degree of contamination in the blank samples and average lake concentrations measured are less than 10 times the unusual result.

Invalidated data will be retained in the Snap Lake Environmental Database, but a flag of "X" will be appended to the data, indicating that the sample is considered contaminated or the results are designated as not correct due to an internal review of the data.

4.2.6.2.2 Continued Nutrient Investigation

Water samples collected between 2009 and 2011 during both the water quality and plankton programs of the AEMP were sent to different analytical laboratories (water quality program: ALS; phytoplankton program: Biogeochemical Analytical Laboratory, University of Alberta). A review of the data from the two simultaneous studies indicated that the results from the two laboratories were typically different, with generally higher concentrations reported in the samples collected by the plankton component. The difference in TP concentrations reported by the two AEMP components may be due to:

- differences in water sampling methods – full water column data were collected by the water quality component, in contrast to the euphotic zone data collected by the plankton component; and,
- issues with analytical accuracy by one or both of the analytical laboratories, which is common at the low TP concentrations present in Snap Lake.

A nutrient study was conducted in spring 2011 (Golder 2011b) to resolve this issue; however, inconclusive results from that study have prompted a continued re-evaluation of the nutrient results in 2012. Commercially available standard reference samples containing varying concentrations of nutrients were submitted blind to laboratories for analysis. Additional split samples from both the water quality and plankton programs were submitted to the various laboratories for analysis of the various phosphorus fractions. The results will be compared and, if possible, recommendations will be made regarding laboratory choice for future AEMP programs. Further clarification and follow-up sampling related to phosphorus will likely be necessary, and will be incorporated into future AEMP programs as part of ongoing QA/QC investigations. Recommendations for future work will depend on the results of the 2012 nutrient study, which will be provided in the 2013 annual AEMP report.

4.3 Sediment Quality

4.3.1 Objectives and Scope

The overall objective of the AEMP sediment quality monitoring program is to determine whether sediment quality in Snap Lake remains acceptable such that a healthy benthic invertebrate community is maintained. The specific objectives of the re-designed sediment quality monitoring component are:

- to characterize and interpret bottom sediment quality in Snap Lake and two reference lakes on an annual basis, and make comparisons to previous years;
- to verify predictions made in the EAR (De Beers 2002a) about Mine effects on lake bottom sediment quality; and,
- to recommend any necessary changes to the sediment quality component of the AEMP for future years.

The re-designed Snap Lake sediment quality monitoring program under the AEMP is intended to meet the conditions of Water Licence MV2011L2-0004 (Water Licence) Part G (MVLWB 2013a).

Analysis of the sediment quality data is intended to address the following study key questions:

- Are concentrations of sediment quality parameters above or below SQGs?
- Are there differences in sediment quality in Snap Lake relative to reference lakes and, if so, are they related to the Mine?
- Are concentrations of sediment quality parameters increasing over time?

4.3.2 Sampling Locations

The re-designed sediment quality component will consist of sample collection in Snap Lake (Figure 3.3-2) and two reference lakes, Northeast Lake (Figure 3.3-3) and Lake 13 (Figure 3.3-4). Sediments in Snap Lake have been sampled annually for the AEMP since 2004, and in Northeast Lake since 2008. Lake 13 is a new reference lake added to the AEMP, and was sampled for sediment quality for the first time in August 2012[10].

Within Snap Lake, the study area for the re-designed sediment quality component consists of three stations in the northwest arm and seven stations in the main basin (Table 3.3-1; Figure 3.3-2). The seven main basin stations consist of one diffuser station plus six stations in what were formerly the near-field, mid-field, and far-field areas of Snap Lake. These Snap Lake stations are identified as:

- Main Basin: Diffuser Station SNP02-20e, plus Stations SNAP03, SNAP05, SNAP06, SNAP08, SNAP09, and SNAP11A; and,
- Northwest Arm: Stations SNAP02A, SNAP20, and SNAP23.

10 Sediment chemistry data and analyses for Lake 13 are not yet available and therefore the suitability of Lake 13 as a reference lake has not been fully assessed. Full results of sampling conducted in 2012 will be presented in the 2012 AEMP annual report.

Stations in the two reference lakes, Northeast Lake (Figure 3.3-3) and Lake 13 (Figure 3.3-4) are identified as:

- Northeast Lake: Stations NEL01, NEL02, NEL03, NEL04, and NEL05; and,
- Lake 13: Stations LK13-01, LK13-02, LK13-03, LK13-04, and LK13-05.

It is anticipated that monitoring of sediment quality in one or more lakes downstream of Snap Lake will be incorporated into the AEMP in future, but at present this remains a Downstream Lakes Special Study (Section 5.3) while data for multiple monitoring components are collected to identify appropriate sampling locations.

4.3.3 Design Rationale

From 2004 to 2012, sediment quality monitoring within Snap Lake involved annual sampling at stations that represented five areas within the lake: northwest arm, diffuser, near-field, mid-field, and far-field. The number of stations monitored in Snap Lake has increased from 12 in 2004 to 18 since 2006. In addition, five stations have been sampled annually in Northeast Lake since 2008, and five stations were sampled in Lake 13 in 2012.

For this AEMP Design Plan, three modifications have been made to the sediment quality monitoring component:

- The number of stations monitored in the main basin of Snap Lake has been reduced from 15 to 7, reducing the total number of stations in Snap Lake from 18 to 10.
- Monitoring at the diffuser station (SNP02-20e) will continue annually, but monitoring at the other AEMP sediment stations will be reduced from annually to once every three years.
- Collection of composite samples from the top 5-cm layer of sediment will continue for all AEMP stations. Additional sampling of the top 2 cm of sediment will be included at the diffuser station (SNP02-20e).

4.3.3.1 Number of Stations to be Monitored

In the re-designed sediment quality component, the Snap Lake sampling stations that are being retained have been monitored annually since either 2004 or 2006. The reduction in stations in the main basin of Snap Lake represents a change in the study design such that the main basin will now be assessed as a whole and compared to reference and (in future) downstream conditions, rather than looking for spatial gradients within this relatively small lake. The gradient design was appropriate during the early years of the AEMP when the degree of exposure to treated effluent varied across Snap Lake; this is no longer the case.

Sediment quality was previously monitored at 14 stations located in the near-field, mid-field, and far-field areas of Snap Lake, and has now been reduced to 6 stations. To confirm that monitoring at this reduced number of stations would continue to be representative of sediment quality in the main basin, summary statistics (mean, SD, minimum, maximum, median, and coefficient of variation [CV]) were calculated based on both 6 and 14 stations, using the 2011 AEMP sediment chemistry data. The summary statistics for both station groupings are presented in Table 4.3-1. The comparison showed that reducing the number of main basin stations from 14 to 6 resulted in relatively little change to the ranges and median concentrations for most sediment quality parameters. The diffuser station (SNP02-20e) was excluded from this comparison because it is being retained in the re-designed monitoring program, and because this station was expected to have elevated sediment chemistry concentrations that would have increased the variability in both data sets.

4.3.3.2 Frequency of Monitoring

Although the Water Licence specifies that sediment quality be monitored under the AEMP, the only requirement with regard to station numbers and monitoring frequency is that sediment quality be monitored annually at the diffuser. From 2004 to 2012, sediment quality monitoring at the AEMP stations was conducted once annually; from 2004 to 2008 this was done in late winter under ice, and since 2009 this has been done in late summer during open water conditions.

In the re-designed sediment quality component, monitoring at the diffuser (Station SNP02-20e) will continue to be performed annually and will therefore serve as an "early warning" indicator of potential changes in sediment quality within Snap Lake. However, sediment quality monitoring at the other AEMP stations within Snap Lake and the reference lakes will now be conducted once every three years, with the next monitoring cycle occurring in 2015.

4.3.3.3 Sediment Sampling Depth

The top 5-cm layer of sediment is currently sampled for sediment quality monitoring. However, sedimentation rates in Arctic lakes are known to be low and concerns have been expressed as to whether the top 5 cm layer is too thick to be representative of recent Mine-related deposition.

Comparisons of sediment parameter concentrations in the top 5 cm versus the top 2 cm of sediment were performed on samples collected from six Snap Lake stations in 2011 and 2012[11]: SNAP 14 and SNAP 15 (near-field) and SNAP20 (northwest arm) were sampled in 2011, and SNP02-20e (diffuser), SNAP 03 (near-field), and SNAP 17 (mid-field) were sampled in 2012. For each parameter and sampling station, RPDs were calculated to provide a measure of the difference in concentrations between the two sampling depths (Table 4.3-2). Relative percent differences are a measure typically used to assess analytical precision through comparison of laboratory duplicate samples, with an RPD that is ≤20% representing good agreement between a sample and its corresponding laboratory duplicate. For this sampling depth comparison, the differences between parameter concentrations for the two sampling depths would need to be larger than the amount of variability that typically occurs between laboratory duplicate samples to warrant modifying the study design to change the sediment sampling depth.

At the diffuser station (SNP02-20e), 21 of the 40 nutrients or metals included in this comparison of sediment depths had RPDs that were >20% and the majority of RPDs were negative, which in this case meant that the sediment parameter concentration in the top 2-cm sample was higher than the concentration in the corresponding top-5-cm sample. One unexpected result was that the RPDs for available ammonium, available nitrate, available phosphate, and available potassium were large and positive, which meant that concentrations were lower in the top-2-cm sample; the analyses were repeated and the results were confirmed.

11 The 2011 comparison used an Ekman grab to sample both sediment depths. The 2012 comparison used an Ekman grab to sample the top-5-cm layer and a Tech-Ops corer to sample the top-2-cm layer.

Table 4.3-1 Comparison of Sediment Quality Parameter Concentrations for Snap Lake Main Basin (based on 6 and 14 stations)

Sampling Area	Units (dw)	6 Main Basin Stations (former NF, MF, and FF areas)							14 Main Basin Stations (former NF, MF, and FF areas)						
Parameter		n	Mean	SD	CV [%]	Median	Minimum	Maximum	n	Mean	SD	CV [%]	Median	Minimum	Maximum
Physical															
Moisture	%	6	94.7	0.6	0.6	94.8	93.8	95.4	14	94.4	1.4	1.5	94.7	89.9	95.5
Gravel (>2.0 mm)	% dw	6	<0.1	0	0.0	<0.1	<0.1	<0.1	14	<0.1	0	0.0	<0.1	<0.1	<0.1
Sand (>0.063 mm to <2.0 mm)	% dw	6	7.6	3.2	42.0	8.1	1.8	10.5	14	11.3	16.2	143.4	7.2	1.8	66
Silt (>0.004 mm to <0.063 mm)	% dw	6	52.9	10.8	20.4	52.9	41.1	69.1	14	49.7	12.0	24.1	48.0	23.5	69.1
Clay (<0.004 mm)	% dw	6	39.5	10.2	25.9	40.1	22.5	51.1	14	39.0	12.3	31.6	38.6	10.5	56.5
Fines (Silt + Clay)	% dw	6	92.4	3.2	3.4	91.9	89.5	98.1	14	88.7	16.2	18.3	92.8	34	98.1
Inorganic / Organic Carbon															
Calcium Carbonate Equivalents	% dw	6	1.32	0.30	22.9	1.29	0.9	1.69	14	1.29	0.27	21.2	1.28	0.9	1.69
Total Carbon	% dw	6	18.1	2.1	11.5	18.1	15.6	21.7	14	16.7	3.5	20.7	17.0	8.3	21.7
Inorganic Carbon	% dw	6	0.16	0.04	23.1	0.16	0.11	0.2	14	0.15	0.03	20.6	0.15	0.11	0.2
Total Organic Carbon	% dw	6	17.9	2.1	11.5	18.0	15.5	21.5	14	16.6	3.4	20.8	16.8	8.22	21.5
Nutrients															
Available Ammonium, as N	mg/kg dw	6	122	49	39.8	123	49.9	194	14	101	47	46.6	96	43.3	194
Available Nitrate, as N	mg/kg dw	6	3.2	0.4	12.9	<6	<6	<8	14	3.7	2.2	59.2	<6	<6	11.1
Total Kjeldahl Nitrogen	% dw	6	1.42	0.16	10.9	1.45	1.21	1.6	14	1.30	0.24	18.6	1.30	0.746	1.6
Total Nitrogen	% dw	6	1.41	0.16	11.5	1.43	1.18	1.59	14	1.27	0.26	20.6	1.28	0.65	1.59
Available Phosphate, as P	mg/kg dw	6	24.9	17.5	70.3	22.9	<4	46.5	14	24.1	13.0	54.0	21.8	<4	46.5
Available Potassium	mg/kg dw	6	153	70	45.8	127	102	293	14	143	50	35.2	124	102	293
Available Sulphate, as S	mg/kg dw	6	219	165	75.5	159	89.4	513	14	223	171	76.9	168	85.2	663
Metals															
Aluminum	mg/kg dw	6	16,617	3,039	18.3	17,750	10,900	19,200	14	16,886	2,945	17.4	18,200	10,900	19,600
Antimony	mg/kg dw	6	0.18	0.09	51.1	0.17	0.05	0.31	14	0.17	0.07	42.8	0.16	0.05	0.31
Arsenic	mg/kg dw	6	1.63	0.36	22.2	1.52	1.15	2.07	14	1.61	0.53	32.6	1.49	0.81	2.77
Barium	mg/kg dw	6	74	21	28.3	74	42.8	102	14	76	16	21.3	74	42.8	102
Beryllium	mg/kg dw	6	0.72	0.14	20.0	0.74	0.54	0.88	14	0.74	0.18	24.1	0.76	0.37	1.03
Bismuth	mg/kg dw	6	0.63	0.07	11.6	0.63	0.53	0.73	14	0.62	0.12	20.1	0.65	0.27	0.78
Boron	mg/kg dw	6	12.1	3.8	31.1	10.3	9.6	19.2	14	13.1	3.7	28.0	12.7	9.2	20.7
Cadmium	mg/kg dw	6	0.59	0.09	14.8	0.58	0.48	0.72	14	0.62	0.15	24.9	0.57	0.44	1.04
Calcium	mg/kg dw	6	4,712	907	19.3	4,575	3,880	6,440	14	4,724	660	14.0	4,575	3,880	6,440
Cesium	mg/kg dw	6	1.84	0.51	28.0	1.73	1.15	2.56	14	1.85	0.36	19.5	1.79	1.15	2.56
Chromium	mg/kg dw	6	32.0	6.1	19.0	32.0	23.4	39.7	14	32.6	4.7	14.3	32.0	23.4	39.7
Cobalt	mg/kg dw	6	16.9	8.1	48.2	13.2	10.8	31.2	14	14.6	5.8	39.7	13.0	8.3	31.2
Copper	mg/kg dw	6	108	9.4	8.7	108	92.4	119	14	105	16.9	16.1	109	51.4	119
Iron	mg/kg dw	6	42,100	26,674	63.4	31,300	25,300	95,000	14	36,671	18,903	51.5	34,350	17,600	95,000
Lead	mg/kg dw	6	6.08	1.95	32.1	5.82	4.21	9.77	14	5.83	1.50	25.7	5.32	4.21	9.77
Lithium	mg/kg dw	6	22.7	5.4	23.8	21.9	14.8	30.7	14	23.8	4.2	17.8	23.2	14.8	31.6
Magnesium	mg/kg dw	6	3,647	830	22.8	3,705	2,260	4,630	14	3,930	790	20.1	3,955	2,260	5,670
Manganese	mg/kg dw	6	333	220	66.2	258.5	158	772	14	326	170	52.2	258.5	158	772
Mercury	mg/kg dw	6	0.038	0.021	56.0	<0.05	<0.05	0.075	14	0.032	0.016	48.1	<0.05	<0.05	0.075
Molybdenum	mg/kg dw	6	11.0	1.8	16.7	11.3	8.13	13.4	14	10.4	2.7	25.7	11	3.12	13.8
Nickel	mg/kg dw	6	39.4	1.8	4.7	39.6	36.6	41.9	14	40.1	2.5	6.2	40.1	36.6	45.4
Phosphorus	mg/kg dw	6	937	86	9.2	955	830	1,050	14	880	174	19.8	925	390	1,050

Table 4.3-1 Comparison of Sediment Quality Parameter Concentrations for Snap Lake Main Basin (based on 6 and 14 stations) (continued)

Sampling Area	Units (dw)	6 Main Basin Stations (former NF, MF, and FF areas)							14 Main Basin Stations (former NF, MF, and FF areas)						
Parameter		n	Mean	SD	CV [%]	Median	Minimum	Maximum	n	Mean	SD	CV [%]	Median	Minimum	Maximum
Potassium	mg/kg dw	6	1,735	476	27.4	1,620	1,090	2,410	14	1,772	354	20.0	1,695	1,090	2,410
Rubidium	mg/kg dw	6	13.2	3.4	25.7	12.3	9	18	14	13.2	2.3	17.8	12.6	9	18
Selenium (by CCMS)	mg/kg dw	6	1.37	0.19	13.8	1.33	1.14	1.71	14	1.22	0.27	22.2	1.25	0.43	1.71
Selenium (by ICPMS)	mg/kg dw	6	1.09	0.16	14.6	1.085	0.84	1.34	14	0.98	0.27	27.8	1.02	0.25	1.34
Silver	mg/kg dw	6	0.20	0.05	26.1	0.2	<0.2	0.24	14	0.16	0.06	38.1	0.15	<0.2	0.24
Sodium	mg/kg dw	6	407	70	17.3	375	360	540	14	419	59	14.1	405	360	540
Strontium	mg/kg dw	6	57.6	20.2	35.1	53.95	37.8	96.8	14	57.4	16.5	28.8	53.95	37.8	96.8
Thallium	mg/kg dw	6	0.112	0.022	19.6	0.114	0.084	0.141	14	0.114	0.024	20.9	0.114	0.072	0.141
Tin	mg/kg dw	6	<2.0	0.0	0.0	<2.0	<2.0	<2.0	14	<2.0	0.0	0.0	<2.0	<2.0	<2.0
Titanium	mg/kg dw	6	214	42	19.5	210	168	282	14	233	94	40.5	207	168	541
Uranium	mg/kg dw	6	10.32	1.72	16.6	9.80	9.05	13.6	14	9.78	2.00	20.4	10.10	3.96	13.6
Vanadium	mg/kg dw	6	30.6	4.8	15.5	31.7	22.8	36.1	14	31.6	3.7	11.8	33.05	22.8	36.1
Zinc	mg/kg dw	6	128	24	18.6	130	98.4	167	14	133	18	13.2	134	98.4	167

Note: “metals” include metalloids such as arsenic and non-metals such as selenium.

<= less than detection limit; > = greater than detection limit; % dw = percent dry weight; mg/kg dw = milligrams per kilogram based on dry weight; mm = millimetre; n = number of samples; CV = coefficient of variation; FF = far-field; MF = mid-field; NF = near-field; SD = standard deviation; CCMS = collision cell inductively coupled plasma mass spectrometry; ICPMS = inductively coupled plasma mass spectrometry.

Table 4.3-2 Comparison of Sediment Quality Parameter Concentrations in 5-cm and 2-cm Sediment Depths

Sampling Station	Units (dw)	SNP02-20e (2012)			SNAP03 (2012)			SNAP 14 (2011)			SNAP15 (2011)			SNAP17 (2012)			SNAP20 (2011)		
Sediment Depth [cm]		Top 5 cm	Top 2 cm	RPD	Top 5 cm	Top 2 cm	RPD	Top 5 cm	Top 2 cm	RPD	Top 5 cm	Top 2 cm	RPD	Top 5 cm	Top 2 cm	RPD	Top 5 cm	Top 2 cm	RPD
Physical																			
Sand (>0.063 mm to <2.0 mm)	% dw	2.11	1.24	52%	0.18	0.18	0%	3.61	3.12	15%	2.89	3.26	-12%	6.96	6.46	7%	12.1	14.1	-15%
Silt (>0.004 mm to <0.063 mm)	% dw	88.1	89.5	-2%	88.9	91.2	-3%	47.9	47.4	1%	40.6	49.3	-19%	81.2	87.6	-8%	80.5	80.7	0%
Clay (<0.004 mm)	% dw	9.79	9.22	6%	10.9	8.62	23%	48.5	49.4	-2%	56.5	47.5	17%	11.9	5.92	67%	7.35	5.19	34%
Fines (Silt + Clay)	% dw	97.9	98.7	-1%	99.8	99.8	0%	96.4	96.8	0%	97.1	96.8	0%	93.1	93.5	0%	87.85	85.89	2%
Inorganic / Organic Carbon																			
Total Carbon	% dw	16.7	18.4	-10%	18.5	17.7	4%	16.7	17.7	-6%	16.2	15.9	2%	14.5	16.0	-10%	10.6	10.4	2%
Inorganic Carbon	% dw	0.12	<0.10	18%	<0.10	<0.10	0%	0.13	0.16	-21%	0.13	0.17	-27%	0.12	0.12	0%	0.2	0.2	0%
Total Organic Carbon	% dw	16.5	18.4	-11%	18.5	17.7	4%	16.6	17.5	-5%	16.1	15.7	3%	14.4	15.9	-10%	10.4	10.2	2%
Nutrients																			
Available Ammonium, as N	mg/kg dw	65	<25	89%	<19	<21	10%	88.1	85.2	3%	105	51.4	69%	23	<22	4%	68.6	49.6	32%
Total Kjeldahl Nitrogen	% dw	1.33	1.51	-13%	1.32	1.40	-6%	1.27	1.35	-6%	1.22	1.18	3%	1.11	1.28	-14%	0.871	0.893	-2%
Total Nitrogen	% dw	1.28	1.54	-18%	1.41	1.39	1%	1.23	1.35	-9%	1.2	1.18	2%	1.08	1.27	-16%	0.861	0.851	1%
Available Nitrate, as N	mg/kg dw	44.0	10.4	124%	6.9	18.1	-90%	<6.0	<6.0	0%	<6.0	<6.0	0%	<4.0	9.5	-81%	<6.0	<6.0	0%
Available Phosphate, as P	mg/kg dw	426	14.1	187%	41.1	6.0	149%	18.6	17	9%	14.6	12	20%	38.4	20.1	63%	<4.0	<4.0	0%
Available Potassium	mg/kg dw	1,320	269	132%	333	252	28%	120	171	-35%	145	138	5%	170	205	-19%	238	198	18%
Available Sulphate, as S	mg/kg dw	59.3	253	-124%	77.9	111	-35%	119	120	-1%	175	124	34%	134	160	-18%	208	197	5%
Metals																			
Aluminum	mg/kg dw	11,500	11,000	4%	12,600	11,500	9%	19,600	18,500	6%	18,400	17,700	4%	12,700	11,700	8%	12,300	12,200	1%
Antimony	mg/kg dw	0.12	0.38	-104%	0.23	0.27	-16%	0.13	0.15	-14%	0.2	0.19	5%	0.11	0.18	-48%	0.24	0.34	-34%
Arsenic	mg/kg dw	1.53	3.13	-69%	2.47	2.88	-15%	1.41	1.61	-13%	2.77	2.15	25%	1.82	2.43	-29%	6.91	6.97	-1%
Barium	mg/kg dw	68.9	76.8	-11%	54.7	49.3	10%	71.9	65.3	10%	83.1	77.4	7%	94.6	90.4	5%	520	737	-35%
Beryllium	mg/kg dw	0.69	0.50	32%	0.88	0.92	-4%	0.75	0.68	10%	0.95	0.8	17%	0.89	0.84	6%	0.38	0.39	-3%
Bismuth	mg/kg dw	0.68	0.77	-12%	0.77	0.72	7%	0.68	0.64	6%	0.78	0.73	7%	0.72	0.66	9%	0.47	0.45	4%
Boron	mg/kg dw	20.1	26.0	-26%	32.4	33.3	-3%	13	15.6	-18%	13.7	13.2	4%	22.0	24.1	-9%	4.6	4.3	7%
Cadmium	mg/kg dw	0.45	0.44	2%	0.55	0.48	14%	0.62	0.6	3%	0.8	0.75	6%	0.68	0.62	9%	0.59	0.57	3%
Calcium	mg/kg dw	3,930	6,490	-49%	5,550	5,950	-7%	4,450	4,880	-9%	5,210	5,400	-4%	4,620	5,390	-15%	2,630	2,930	-11%
Cesium	mg/kg dw	1.75	1.67	5%	1.73	1.65	5%	1.75	1.66	5%	1.92	1.88	2%	2.20	2.08	6%	1.26	1.21	4%
Chromium	mg/kg dw	30.8	38.7	-23%	29.1	28.3	3%	32.9	30.4	8%	30.7	30.5	1%	34.5	33.6	3%	25.9	25	4%
Cobalt	mg/kg dw	11.1	15.4	-32%	14.2	14.3	-1%	13.3	12.4	7%	17.6	15.2	15%	13.2	16.1	-20%	60	60.3	0%
Copper	mg/kg dw	106	94.8	11%	108	99.5	8%	109	102	7%	113	108	5%	99.9	90.0	10%	62.3	59.6	4%
Iron	mg/kg dw	17,600	26,300	-40%	34,800	36,500	-5%	33,900	31,500	7%	49,300	44,200	11%	19,200	23,500	-20%	220,000	199,000	10%
Lead	mg/kg dw	5.33	10.4	-64%	6.45	7.27	-12%	5.39	6.64	-21%	7.97	6.78	16%	5.60	6.34	-12%	8.37	8.51	-2%
Lithium	mg/kg dw	20.4	22.9	-12%	20.2	18.6	8%	23.8	23	3%	21.1	20.8	1%	24.7	24.1	2%	10.9	10.4	5%
Magnesium	mg/kg dw	2,920	5,790	-66%	2,920	2,940	-1%	4,080	3,970	3%	3,470	3,560	-3%	3,620	3510	3%	1,760	1,750	1%
Manganese	mg/kg dw	246	373	-41%	259	490	-62%	249	223	11%	552	721	-27%	273	652	-82%	27,800	41,800	-40%
Mercury	mg/kg dw	0.062	0.101	-48%	0.056	0.065	-15%	<0.050	<0.050	0%	0.051	<0.050	0%	<0.050	<0.050	0%	0.085	0.091	-7%
Molybdenum	mg/kg dw	9.18	13.5	-38%	14.8	15.8	-7%	11.9	10.9	9%	13.8	12.9	7%	9.78	11.4	-15%	16.5	16.2	2%
Nickel	mg/kg dw	33.1	53.9	-48%	43.9	45.3	-3%	37.3	36	4%	43.7	40.7	7%	44.1	47.8	-8%	43.6	41.5	5%
Phosphorus	mg/kg dw	1,510	1,620	-7%	1,280	1,250	2%	840	800	5%	1,050	1,000	5%	1,020	1,050	-3%	1,350	1,350	0%
Potassium	mg/kg dw	1,380	1,470	-6%	1,290	1,260	2%	1,740	1,650	5%	1,530	1,470	4%	2,190	2,190	0%	940	1,000	-6%
Rubidium	mg/kg dw	13.3	13.0	2%	12.3	11.6	6%	12.6	12.1	4%	12.5	12.1	3%	18.2	17.2	6%	7.2	7.3	-1%
Selenium (by ICPMS)	mg/kg dw	1.77	2.03	-14%	1.85	1.85	0%	0.87	0.79	10%	1.18	1.12	5%	1.48	1.65	-11%	1.07	1.06	1%
Silver	mg/kg dw	0.23	0.39	-52%	0.21	0.23	-9%	0.2	0.22	-10%	0.2	<0.20	0%	<0.20	<0.20	0%	<0.20	<0.20	0%
Sodium	mg/kg dw	440	810	-59%	560	620	-10%	460	490	-6%	470	430	9%	460	520	-12%	120	130	-8%
Strontium	mg/kg dw	44.9	110	-84%	82.0	88.3	-7%	51.8	64.3	-22%	72.5	71.3	2%	62.4	73.9	-17%	32.7	37.4	-13%
Thallium	mg/kg dw	0.135	0.127	6%	0.105	0.082	25%	0.138	0.121	13%	0.129	0.112	14%	0.178	0.169	5%	0.133	0.138	-4%
Titanium	mg/kg dw	245	248	-1%	192	165	15%	209	189	10%	180	175	3%	269	277	-3%	177	179	-1%
Uranium	mg/kg dw	8.27	8.80	-6%	9.89	9.48	4%	10.3	9.54	8%	9.89	9.61	3%	9.16	8.54	7%	3.76	3.59	5%
Vanadium	mg/kg dw	29.9	29.6	1%	30.1	28.2	7%	33.5	30.8	8%	33.4	31.7	5%	33.1	31.5	5%	25.9	25.1	3%
Zinc	mg/kg dw	110	102	8%	154	149	3%	147	136	8%	146	132	10%	159	140	13%	97	95.6	1%

Note: “metals” include metalloids such as arsenic and non-metals such as selenium.

RPD = Relative percent difference; <= less than detection limit; > = greater than detection limit; % = percent;% dw = percent dry weight; mg/kg dw = milligrams per kilogram based on dry weight; cm = centimetre; mm = milliimetre ICPMS = inductively coupled plasma mass spectrometry.

At the other 5 stations, at least 34 of the 40 nutrients or metals that were included for this sediment depth comparison had RPDs that were ≤20%, with the majority of those RPDs being <10%. The majority of RPDs were positive, meaning that the sediment parameter concentration in the top-2-cm sample was lower than the concentration in the corresponding top-5-cm sample.

Based on these results, the diffuser station was the only station where differences between the two sampling depths were large enough to be distinguishable from analytical variability and were indicative of a Mine-related effect. At the other stations, the differences in concentrations measured for the two sampling depths were small enough that they were not distinguishable from analytical variability associated with laboratory duplicate samples, and there was no clear pattern of concentrations being higher in shallower sediments, which would be expected if there was a Mine-related effect.

In the re-designed sediment quality component, sampling of the top-5-cm layer of sediment for chemistry analyses will continue for all AEMP stations. Sampling this sediment depth will continue to provide sediment chemistry data that will be relevant to the benthic invertebrate community component of the AEMP. However, annual monitoring at the diffuser station will involve sampling from both the top-2-cm and top-5-cm layers of sediment.

4.3.4 Field Methods

Sediment samples will be collected during late summer (i.e., early to mid-September) when ice-cover is absent on Snap Lake and the reference lakes. Treated effluent is typically discharging through the permanent diffuser at the time of sampling. The Snap Lake sampling stations will be accessed by boat; a helicopter will be used to transport the boat and field crew to each reference lake.

Station locations will be identified using a hand-held Global Positioning System (GPS) unit with Universal Transverse Mercator (UTM) coordinates, in conjunction with topographical maps showing station locations.

4.3.4.1 Supporting Environmental Variables

The following supporting environmental information will be recorded at the time of sediment sample collection:

- sampling date and time;
- weather conditions, such as air temperature, and wind velocity and direction;
- the GPS coordinates recorded as UTM for each station;
- water depth; and,
- vertical profiles of water temperature, DO, pH and conductivity, measured at 1-m intervals using a multi-meter.

4.3.4.2 Annual Sampling at Diffuser Station SNP02-20e

Sampling at Station SNP02-20e will be conducted annually. A 10-cm diameter Tech-Ops corer will be used to collect sediment from the top-2-cm and the top-5-cm layers of surface sediment. A minimum of three sediment cores will be collected for each sampling depth, but it is likely that a greater number of cores will be required to obtain the required sediment volumes for the chemistry analyses. A field duplicate sample will not be collected at this station.

For each sampling depth, the applicable segment of sediment will be extruded from the core tube and placed into a clean plastic container. This process will be repeated until the required sediment volume has been obtained. The sediments will be mixed until homogeneous in colour and texture to generate one composite sediment sample for each sampling depth. The homogenized sediment will be transferred to sample containers: two 250-mL pre-cleaned wide mouth glass jars for nutrients, carbon content, and total metals, and a Ziploc freezer bag for particle size, for each sampling depth. The samples will be packed in coolers with ice packs following collection, and kept cold until they are delivered to the analytical laboratory.

4.3.4.3 Routine AEMP Sampling

Sampling at the other AEMP stations in Snap Lake and the reference lakes will be conducted every three years. At each station, three sediment grabs will be collected using a 15 x 15-cm Ekman grab that samples an area of 0.023 square metres (m^2). The grab will be thoroughly rinsed with lake water before sampling. After a sediment grab sample has been collected, as much overlying water as possible will be drained off without disturbing the sediment surface. If the surface of the retrieved sediment sample is disturbed, either during the initial sample collection or during the draining of overlying water, the sample will be discarded and another grab sample collected.

At each station, the top 5 cm of sediment will be removed from each of the three grabs using a clean stainless steel spoon and placed into a clean plastic container. Once this portion of sediment has been removed from all three grabs, the sediments will be mixed until homogeneous in colour and texture to generate one composite sediment sample for each station. The homogenized sediment will be transferred to sample containers: two 250-mL pre-cleaned wide mouth glass jars for nutrients, carbon content, and total metals; and, a Ziploc freezer bag for particle size, for each station. The samples will be packed in coolers with ice packs following collection, and kept cold until they are delivered to the analytical laboratory.

Field duplicate samples will be collected at two randomly selected stations, using separately collected sets of grab samples to sample the top 5 cm of sediment.

4.3.5 Laboratory Methods

Composite sediment samples will be stored at 4 degrees Celsius (°C) and shipped on ice to ALS in Edmonton for analyses of particle size, nutrients, carbon content, and total metals[12]. The target parameter list, along with analytical methods/instrumentation, and target DLs, is provided in Table 4.3-3. Analyses for total metals are typically performed by the ALS Edmonton laboratory, and the other analyses are performed by the ALS Saskatoon laboratory.

12 The suite of elements reported in the ALS total metals analysis includes metalloids such as arsenic and non-metals such as selenium, which are collectively referred to as “metals” in this report.

Table 4.3-3 Target Parameter List for Laboratory Analyses of Sediment Quality Samples

Parameter	Units	Analytical Method / Instrumentation	Target Detection Limit
Moisture	%	gravimetric	0.1
Sand (2.0 mm to 0.063 mm)	% dw	PSA-3 (sieve – pipette)	0.1
Silt (0.063 to 0.004 mm)	% dw	PSA-3 (sieve – pipette)	0.1
Clay (<0.004 mm)	% dw	PSA-3 (sieve – pipette)	0.1
Total organic carbon	% dw	gravimetric	0.1
Available ammonium	mg/kg dw	colourimetric	2.0
Available nitrate	mg/kg dw	colourimetric	4.0
Available phosphate	mg/kg dw	colourimetric	2.0
Available potassium	mg/kg dw	flame photometer	20
Available sulphate	mg/kg dw	ICP-AES	2.0
Total Kjeldahl nitrogen	% dw	distillation-titration	0.02
Total nitrogen	% dw	combustion	0.02
Total aluminum	mg/kg dw	ICP-MS	50
Total antimony	mg/kg dw	ICP-MS	0.10
Total arsenic	mg/kg dw	ICP-MS	0.10
Total barium	mg/kg dw	ICP-MS	0.50
Total beryllium	mg/kg dw	ICP-MS	0.20
Total bismuth	mg/kg dw	ICP-MS	0.2
Total boron	mg/kg dw	ICP-MS	2.0
Total cadmium	mg/kg dw	ICP-MS	0.10
Total calcium	mg/kg dw	ICP-MS	100
Total cesium	mg/kg dw	ICP-MS	0.10
Total chromium	mg/kg dw	ICP-MS	0.2
Total cobalt	mg/kg dw	ICP-MS	0.10
Total copper	mg/kg dw	ICP-MS	0.50
Total iron	mg/kg dw	ICP-MS	200
Total lead	mg/kg dw	ICP-MS	0.50
Total lithium	mg/kg dw	ICP-MS	0.50
Total magnesium	mg/kg dw	ICP-MS	20
Total manganese	mg/kg dw	ICP-MS	1.0
Total mercury	mg/kg dw	CVAAS	0.050
Total molybdenum	mg/kg dw	ICP-MS	0.10
Total nickel	mg/kg dw	ICP-MS	0.50
Total phosphorus	mg/kg dw	ICP-MS	100
Total potassium	mg/kg dw	ICP-MS	20
Total rubidium	mg/kg dw	ICP-MS	1.0
Total selenium	mg/kg dw	ICP-MS	0.1
Total silver	mg/kg dw	ICP-MS	0.2
Total sodium	mg/kg dw	ICP-MS	100
Total strontium	mg/kg dw	ICP-MS	1.0
Total thallium	mg/kg dw	ICP-MS	0.050
Total tin	mg/kg dw	ICP-MS	2.0
Total titanium	mg/kg dw	ICP-MS	1.0
Total uranium	mg/kg dw	ICP-MS	0.050
Total vanadium	mg/kg dw	ICP-MS	0.20
Total zinc	mg/kg dw	ICP-MS	5.0

<= less than; % = percent; mg/kg dw = milligrams per kilogram dry weight;% dw = percent dry weight; mm = millimetre; ICP-AES = inductively coupled plasma atomic emission spectroscopy; ICP-MS = inductively coupled plasma mass spectrometry.

4.3.6 Data Analysis

In those years when sediment quality is only monitored at the diffuser station, the sediment chemistry results for that station will be compared to SQGs and temporal trends will be assessed through comparison to data collected in previous years. When the full set of AEMP stations is monitored every three years, data analyses will be performed as described below.

Sediment quality data analysis is designed to answer the key questions listed in Section 4.3.1. An overview of the analysis approach associated with these three questions is provided in Table 4.3-4. Specific details relevant to data analysis methods to address each key question are provided in Sections 4.3.6.2 to 4.3.6.4.

Table 4.3-4 Overview of Analysis Approach for Sediment Quality Key Questions

Key Question	Overview of Analysis Approach
1. Are concentrations of sediment quality parameters above or below sediment quality guidelines (SQGs)?	Concentrations of sediment quality parameters will be compared to appropriate SQGs. Instances where concentrations are above SQGs will be identified and qualitatively assessed for potential Mine-related causes.
2. Are there differences in sediment quality in Snap Lake relative to reference lakes and, if so, are they related to the Mine?	Statistical tests (e.g., analysis of variance) will be used to determine whether there are statistically significant differences in mean parameter concentrations between Snap Lake and the reference lakes.
3. Are concentrations of sediment quality parameters increasing over time?	Analysis of temporal patterns in concentrations of sediment quality parameters since 2004 baseline will be performed using statistical tests (e.g. Mann-Kendall or other appropriate test) to quantify the statistical significance of any potential temporal trends. Mean parameter concentrations will be compared to normal ranges.

4.3.6.1 Data Compilation and Summary

Sediment quality data for Snap Lake and the reference lakes will be summarized separately in terms of the whole-lake mean, median, minimum, maximum, and SD for each parameter. Annual mean concentrations for the northwest arm, diffuser, and main basin will be presented in time-series plots, along with means for each of the reference lakes.

For Snap Lake only, similar summary statistics will also be calculated for the northwest arm, diffuser, and main basin.

4.3.6.2 Key Question 1: Are concentrations of sediment quality parameters above or below sediment quality guidelines (SQGs)?

Sediment quality data will be compared to the interim sediment quality guidelines (ISQGs) and Probable Effect Levels (PELs) developed by the CCME (CCME 1999 with updates). These CCME guidelines are currently available for seven metals analyzed for the Snap Lake AEMP (Table 4.3-5). The ISQG is the concentration of a substance below which an adverse effect on aquatic life is unlikely, and the PEL is the concentration of a substance above which adverse effects are expected to occur frequently, but not always. In practice, the application of generic numerical guidelines has yielded a high percentage of false positives (Chapman and Mann 1999). The observation of a sediment concentration above the PEL value for a given parameter should not be interpreted as an indication that actual ecological harm has occurred or will occur, but rather that this is a possibility.

Table 4.3-5 Canadian Sediment Quality Guidelines for Protection of Freshwater Aquatic Life

Parameter	Guidelines [mg/kg dw]	
	Interim Sediment Quality Guideline	Probable Effect Level
Arsenic	5.9	17
Cadmium	0.6	3.5
Chromium	37.3	90
Copper	35.7	197
Lead	35	91.3
Mercury	0.17	0.49
Zinc	123	315

Source: Canadian Council of Ministers of the Environment (1999 with updates).

mg/kg dw = milligrams per kilogram dry weight.

4.3.6.3 Key Question 2: Are there differences in sediment quality in Snap Lake relative to reference lakes and, if so, are they related to the Mine?

Before statistical comparisons of lakes are conducted, the data will be checked to identify outliers and verify that the assumptions of parametric statistical tests are met (i.e., normally distributed data for each lake, homogeneous variances). If outliers are identified, statistical tests will be run with and without outliers to evaluate their influence on the results of the analysis. If required, the data will be transformed to meet parametric test assumptions and the success of the transformations will be verified. If parametric test assumptions cannot be met for a given data set, even after transformation, lake comparisons will be done using nonparametric tests.

The means of the three lakes will be compared to one another in an overall analysis of variance (ANOVA). Upon finding a significant result, two planned orthogonal contrasts will be run within the overall ANOVA to test the differences of means between Snap Lake and the two reference lakes, and between the two reference lakes (Sokal and Rohlf 1995). Although the comparison of primary interest is that of Snap Lake versus reference lakes, the reference lakes will also be compared to one another to evaluate whether the degree of natural variability between them is large enough to be statistically significant. For variables that do not meet parametric test assumptions, the Kruskal-Wallis test will be used to test for differences among the three lakes, followed by the same planned contrasts as done after ANOVA. Statistical tests will be considered significant at $P<0.1$, with the potential for an adjustment to account for lower power achieved by the nonparametric contrasts.

At the study design stage, the probability of a Type I error (α) is set to the same level (i.e., 0.1) as a Type II error (β), because the probability of missing important effects is deemed to be as important as the probability of finding an effect when none exists (Environment Canada 2012). This results in a power of 90% for the among-lake comparisons as designed. Based on power analysis results documented by Environment Canada (2012), a sample size of five stations per lake, which is the minimum within-lake sample size in this AEMP, is sufficient to detect a difference of 2 SD (i.e., the limit of the normal range) with Type I and II error probabilities of 0.1.

4.3.6.4 Key Question 3: Are concentrations of sediment quality parameters increasing over time?

The Snap Lake stations that have been retained for the AEMP have been monitored annually since 2004 or 2006. Statistical analyses for the presence of temporal trends will be performed using the non-parametric Mann-Kendall test (Gilbert 1987) to identify statistically significant temporal trends, increasing or decreasing, for each lake (or lake area in the case of Snap Lake).

To evaluate whether sediment quality in Snap Lake has changed relative to 2004 baseline conditions, sampling area means for 2005 to the present will be compared with the baseline concentration ranges referred to as the "normal range," which are expressed as the 2004 mean ± 2SD for most parameters. For nutrients that were added to the target parameter list in 2005 and 2006 (available ammonium, available nitrate, available phosphate, available potassium, and available sulphate), normal ranges were calculated using data collected during the first year of monitoring, but only from stations that had not yet been exposed to treated effluent discharge.

4.3.7 QA/QC Procedures

The QA/QC procedures govern all aspects of the AEMP (De Beers 2008a), including field methods, laboratory analyses, data management and reporting. The QA/QC procedures for the sediment quality component cover field sampling, laboratory analyses, and data management.

4.3.7.1 Field Quality Assurance/Quality Control Procedures

Specific work instructions outlining each field task will be provided to field personnel. Detailed field notes will be recorded in pencil in waterproof field books and on pre-printed waterproof field data sheets. Data sheets and sample labels will be checked at the end of each field day to confirm completeness and accuracy. Samples are and will be labelled and shipped according to standard protocols provided by the laboratory and De Beers. Each sediment sample will be identified by its station location and a unique sample control number.

Project-specific chain-of-custody forms will be used to track the shipment and analyses of samples. ALS has been instructed that they should not proceed with any analyses of samples that are not accompanied by both chain-of-custody and analysis request forms.

4.3.7.2 Laboratory Quality Assurance/Quality Control Procedures

Laboratories that conduct sediment quality analyses have internal QA/QC procedures. In accordance with the Water Licence (MVLWB 2013a) and the De Beers QA/QC Plan (De Beers 2008a), sediment samples will be submitted to an accredited analytical laboratory where rigorous QA/QC procedures are in place. Details of these laboratory QA/QC procedures are available upon request.

Internal laboratory QC samples that will be included with analysis of the sediment quality samples consist of method blanks, laboratory duplicates, and certified or other reference materials, to allow for assessment of analytical precision and accuracy. Results from these QC samples will be reviewed to determine whether data quality objectives (DQOs) were met, and if not, whether data quality is affected.

4.3.7.3 Office Quality Assurance/Quality Control Procedures

Office QA/QC requirements involve procedures to validate data and results of data analyses, which are described below.

Data Validation

A data management system is in place to provide an organized, consistent system of data control and data analyses. This management system follows De Beers' Environmental Management System procedures for sample collection, data entry, and analysis within a Microsoft Access database that is referred to as the Snap Lake Environmental Database.

Data received from the analytical laboratory will be transferred electronically into the Snap Lake Environmental Database to avoid transcription errors associated with manual data entry. The laboratory analytical method for each parameter is entered into the database along with the analytical results.

After data are entered into the database, a multi-step procedure will be followed to validate the sample results. The purpose of data validation is to identify results that may not be valid, and to validate data collection, handling, and analysis procedures, so that any identified problems can be corrected. This consists of checking DLs, concentration units, data qualifiers, and sampling holding times, checking for data completeness, and reviewing results of field and laboratory QC analyses.

Data Analysis

Data for the AEMP will be analyzed within the Snap Lake Environmental Database and in separate software such as Microsoft Excel spreadsheets and Systat or SigmaPlot statistical software. Data will be transferred electronically from the database to software packages used for data analyses, to facilitate consistency between users and software, and to avoid transcription errors. Data analyses will be checked for accuracy and realistic results. Where appropriate, data will be plotted to visually confirm statistically significant results for spatial and temporal comparisons to baseline data. Data or statistical results observed to be inconsistent with expected concentrations or results will be investigated further.

4.4 Plankton

4.4.1 Objectives and Scope

The principal objective of the plankton monitoring component of the Aquatic Effects Monitoring Plan (AEMP) for the Mine is to meet the following specific Water Licence (Part G, Schedule 6, Item 1) conditions:

a) *Monitoring for the purpose of measuring Project-related effects on the following components of the Receiving Environment:*

   viii. *the communities of zooplankton and phytoplankton due to changes in water quality;*

b) *Monitoring the following as indicators of nutrient enrichment in Snap Lake:*

   ii. *chlorophyll a and algal biomass and species composition of the phytoplankton community.*

c) *Monitoring to verify or assess the Environmental Assessment predictions relating to the trophic and dissolved oxygen status of Snap Lake including monitoring of:*

   iv. *Concentration of chlorophyll a in Snap Lake in early summer after the loss of ice cover and mid-summer; and*

   v. *Algal biomass and species composition for phytoplankton in Snap Lake in mid-summer. The monitoring should include measures of cyanobacteria biomass and species composition and cyanotoxins in the event that algal community compositions shift to favour cyanobacteria.*

The following key questions are designed to focus different lines of evidence toward meeting the plankton program objectives on an annual basis:

- What are the current concentrations of chlorophyll *a* and *c*, and what do these concentrations indicate about the trophic status of Snap Lake, Northeast Lake, and Lake 13?
- What is the current status, in terms of abundance, biomass and composition, of the phytoplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?
- What is the current status, in terms of abundance, biomass and composition, of the zooplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?
- How do observed changes compare to applicable predictions in the EAR?

4.4.2 Sampling Locations

Sampling will occur at nine stations in Snap Lake (five stations in the main basin and four stations in the northwest arm), five stations in Northeast Lake, and five stations in Lake 13 (Table 3.3-1; Figures 3.3-2, 3.3-3 and 3.3-4). The Snap Lake stations are:

- Main Basin: SNAP 02-20e, SNAP03, SNAP06, SNAP08, and SNAP11A; and,
- Northwest Arm: SNAP02A, SNAP20B, SNAP23, and SNAP29.

Stations in the two reference lakes are:

- Northeast Lake: NEL01, NEL02, NEL03, NEL04, and NEL05; and,
- Lake 13: LK13-01, LK13-02, LK13-03, LK13-04, and LK13-05.

The sampling stations for the plankton component will be consistent with stations monitored under the water quality component.

4.4.3 Design Rationale

The 2013 Design Plan includes a number of refinements to the original AEMP study design. A number of plankton stations will be relocated to integrate the plankton and water quality programs. In addition, the number of stations will decrease by one station in the northwest arm; the number of stations in the main basin will remain the same as in 2012. The overall number of stations within each area of Snap Lake was determined by a visual assessment of the data to determine adequate spatial coverage. Mixing of the treated effluent in Snap Lake has been greater than originally anticipated, resulting in similar exposure to treated effluent throughout the main basin. Therefore, a reduction of stations is appropriate for each area of Snap Lake and will enable better integration with the water quality components.

Five stations will be added in Lake 13 to assess temporal variation in the plankton community caused by regional factors, such as climate. The new stations in this lake will match water quality sampling stations.

In addition, with better station integration, the supporting limnological data (i.e., limnology profiles that measure specific conductivity, DO, water temperature and pH) and nutrient data[13] collected by the water quality component can be used by the plankton component, thereby reducing overall program redundancy.

Sampling frequency for the plankton component will remain consistent with previous years, specifically annual sampling during the open-water period in July, August, and September. A reduction in sampling frequency would reduce the quality of the data and make interpretation of results, particularly changes due to natural variability, more difficult.

Monitoring of microcystin-LR concentrations will be completed as part of the water quality component. In the event of elevated microcystin-LR concentrations, the plankton component will assess potential cause(s) by correlating to phytoplankton community composition and biomass.

4.4.4 Field Methods

Phytoplankton, chlorophyll *a* and *c*, and zooplankton samples will be collected annually at a frequency of once per month during the open-water season (i.e., July, August, and September) in Snap Lake, Northeast Lake, and Lake 13 during the 2013 to 2015 open water season, to meet the requirements of the Water Licence. In addition, sampling related to the Picoplankton Special Study (Section 5.2) will be continued as part of the plankton program. Plankton sampling will be completed in conjunction with the water quality program in Snap Lake, Northeast Lake, and Lake 13.

13 Results from the 2012 Nutrient Special Study may demonstrate that the mid-depth water quality nutrient samples do not provide the necessary information required by the plankton component. Therefore, the plankton component may need to reincorporate depth-integrate nutrient sample collection into the plankton monitoring program.

At each sampling station, Secchi depth, maximum depth, and limnology profiles will be measured prior to the collection of the plankton samples. The maximum water depth is required to determine the sampling depth for zooplankton.

Phytoplankton

One phytoplankton sample will be collected at each station for a total of nine phytoplankton samples per sampling event from Snap Lake and a total of five phytoplankton samples per sampling event from each of Northeast Lake and Lake 13. Phytoplankton samples will be collected within the top 6 m of the water column to remain consistent with previous years (i.e., 2004 to 2012). Sampling depth will be reduced if the water depth is less than 6 m (e.g., at SNAP08 the water depth is typically 5 m); however, water depth at most stations is expected to be greater than 6 m.

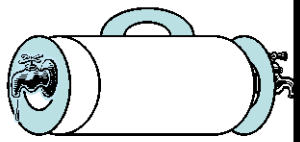
A Kemmerer sampler will be used to collect water at 2-m intervals within the 6-m sampling depth. If the water depth is 6 m, water will be collected at the surface (0 m), 2 m, 4 m, and 6 m. If the water depth is less than 6 m, water will be collected at surface (0 m), 2 m, and 4 m. Equal volumes of the water will be combined into a large bucket to create a composite sample.

The Kemmerer sampler will be lowered slowly to the desired water depths and the messenger dropped to close the sampler. The sampler will be brought to the surface and the water from the desired depth will be transferred from the Kemmerer into the bucket. Pre-labelled, prepared phytoplankton collection bottles will then be filled with the composite water from the bucket. The phytoplankton bottles will be prepared by placing 2.5 millilitres (mL) of acidified Lugol's solution in the 250-mL amber Nalgene® bottles prior to sample collection (Figure 4.4-1). Samples will be stored in the dark, either refrigerated or at ambient temperatures.

Chlorophyll

The remaining water in the bucket from the composite Kemmerer grab samples will be used for the chlorophyll *a* and *c* samples. A 2-L amber Nalgene® bottle will be filled with composite water and returned to the laboratory for filtration. The collected water sample will be filtered onto 47-mm Glass Fibre type C Filters (GF/C) using a glass filter tower and vacuum pump. The chlorophyll filtration will be done under low light conditions in the laboratory. A sufficient volume of water must be filtered to discolour the filter, approximately 500 mL per filter. For each sample, duplicate chlorophyll filters will be prepared (Figure 4.4-1). Both chlorophyll *a* and *c* can be analyzed from the same filter.

Once the filtering is complete, the filter will be taken off the tower, folded in half and put into a pre-labelled Petri dish. The volume filtered will be recorded on the datasheet as well as the sample label. Samples will then be wrapped in aluminum foil to prevent light penetration, and frozen.



Water collected from 0, 2, 4, and 6 m (when possible) and combined to create a composite water sample; samples distributed as follows:

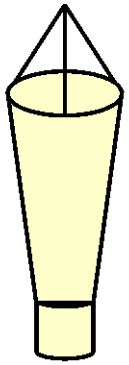
Chlorophyll *a* and *c*
Collect 2 L of the composite water in an amber plastic bottle and return to laboratory to filter for two chlorophyll *a* and *c* samples.

Place individual filters into petri dishes, wrap in foil and freeze.

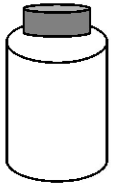
Phytoplankton Taxonomy
Collect one 250 mL sample from the composite water in amber plastic bottles

Special Study: Picoplankton and FlagellateTaxonomy [b]
Collect two 250 mL samples from the composite water in amber plastic bottles, one for picoplankton and one for flagellate taxonomy.

Phytoplankton and flagellate samples preserved with acidic Lugol's solution; picoplankton sample preserved with 10% buffered formalin.



Collect a single vertical zooplankton tow from 1 m off the lake bottom into 250 mL clear plastic bottle.



Place one-half of an Alka-Seltzer® tablet into the sample; allow tablet to dissolve and then preserve with 10% buffered formalin.

Notes:
a Sampling related to the Picoplankton Special Study will continue as part of the plankton component.

PROJECT
De Beers CANADA
SNAP LAKE MINE

TITLE
OVERVIEW OF THE PLANKTON SAMPLE COLLECTION METHODS

Golder Associates

PROJECT No.	12-1337-0002		FILE No.	12133700021100C019
DESIGN	TD	23/10/2012	SCALE AS SHOWN	REV. 0
CADD	JEF	23/10/2012	**FIGURE: 4.4-1**	
CHECK	TD	30/10/2012		
REVIEW	PC	30/10/2012		

Zooplankton

A single zooplankton sample will be collected at each station for a total of nine samples per sampling event from Snap Lake and five samples per sampling event from each of Northeast Lake and Lake 13. Zooplankton samples will be collected using the vertical tow method, with the bottom of the net being lowered approximately 1 m above the bottom substrate (i.e., 1 m should be subtracted from the maximum depth); this depth will be recorded as the depth for the zooplankton vertical tow. A 30-cm diameter, 153-micrometre (µm) Nitex mesh plankton net with a removable plankton bucket along with a Rigo flow meter will be used to collect zooplankton samples. The flow meter will be zeroed by turning the propeller blades prior to the net being deployed to the required depth.

The plankton net will be pulled to the surface at an approximate rate of 0.5 metres per second (m/s). Once the plankton net is out of the water, it will be rinsed down by splashing lake water on the outside of the net to transfer any zooplankton clinging to the plankton net walls into the plankton bucket. The plankton bucket will be removed and the sample transferred into a 250-mL clear Nalgene® sample bottle (Figure 4.4-1). The plankton bucket will be washed to remove all organisms, using a 500-mL wash bottle with deionized water. The final sample will be concentrated so that it fills no more than half of the sample bottle (i.e., 125 mL or less in the 250-mL collection bottles). The flow meter reading will be recorded on the field datasheet.

Once the zooplankton sample has been collected, one half of an Alka-Seltzer tablet will be added to the container and allowed to dissolve (1 to 2 minutes). This is to prevent the zooplankton from being shocked and contorted by the preservative and to facilitate taxonomic identification and length determination. The zooplankton samples will then be preserved by filling the bottle (up to 125 mL) with 4% buffered formalin solution and the lid secured.

4.4.5 Laboratory Methods

Water samples will be collected and submitted to Biogeochemical Analytical Service Laboratory (BASL) in Edmonton, AB, for analysis of chlorophyll *a* and *c*. Phytoplankton and zooplankton samples will be submitted to Bio-Limno Research and Consulting Ltd. in Halifax, NS, for taxonomic composition (to the lowest practical taxonomic level), abundance, and biomass following methods provided below.

Phytoplankton: Aliquots of the preserved phytoplankton samples will be allowed to settle overnight in sedimentation chambers following the procedure of Lund et al. (1958). Algal units will be counted from randomly selected transects on a Zeiss Axiovert 40 CFL inverted microscope. Counting units will be individual cells, filaments, or colonies depending on the organization of the algae. A minimum of 400 units will be counted for each sample. The majority of the samples will be analyzed at 500 times (X) magnification, with initial scanning for large and rare organisms (e.g., *Ceratium* sp.) completed at 250X magnification. Taxonomic identifications will be based primarily on: Geitler (1932); Skuja (1949); Huber-Pestalozzi (1961, 1972, 1982, 1983); Findlay and Kling (1976); Anton and Duthie (1981); Prescott (1982); Whitford and Schumacher (1984); Starmach (1985); Tikkanen (1986); Krammer and Lange-Bertalot (1986, 1988, 1991a,b); Komárek and Anagnostidis (1998; 2005); and, Wehr and Sheath (2003).

Wet weight biomass will be calculated from recorded abundance and specific biovolume estimates based on geometric solids (Rott 1981), assuming unit specific gravity. The biovolume, in units of cubic millimetres per cubic metre (mm^3/m^3) wet weight of each species, will be estimated from the average dimensions of 10 to 15 individuals. The biovolumes of colonial taxa will be based on the number of individuals within each colony. All calculations for cell concentration and biomass will be performed with Hamilton's (1990) computer program.

Zooplankton: Three 1- to 5-mL sub-samples will be removed from each sample for identification and enumeration of zooplankton taxa. Exact volumes of each sub-sample will be dependent on the amount of particulate material present in the sample. Macro-zooplankton consisting of cladocerans, cyclopoids, and calanoids, will be identified and enumerated using a dissecting microscope at magnifications between 12 and 50X. An inverted microscope at magnification 200 to 400X will be used to identify and enumerate rotifers and copepod nauplii. Sub-samples for rotifers and nauplii will be allowed to settle for 24 hours before counting. Taxonomic identifications will be based primarily on: Brooks (1957); Edmondson (1966); Chengalath et al. (1971); Grothe and Grothe (1977); Pennak (1978); Stemberger (1979); Clifford (1991); and, Thorp and Covich (1991).

Zooplankton lengths will be determined directly on the microscope fitted with a micrometre inside the ocular lens. In general, lengths will be measured on a minimum of 40 to 50 individuals of each species or genus encountered within a representative subset of samples. Length measurements will be recorded for rare taxa or those that occur in low numbers as they are encountered. Wet weight biomass will be calculated for each sample, based on published length-weight regressions cited in Botterell et al. (1976), Downing and Rigler (1984), and Stemberger and Gilbert (1987). For each sample, mean individual weights for each species will be calculated by averaging estimated weights. Total biomass for each species or developmental stage will be calculated as the product of its abundance and estimated mean individual weight.

4.4.6 Data Analysis

4.4.6.1 Approach

The plankton component analyses will be designed to answer the key questions listed in Section 4.4.1. An overview of the analysis approach associated with these four questions is provided in Table 4.4-1. Specific details relevant to data analysis methods to address each key question are provided in Sections 4.4.6.2 to 4.4.6.5.

Table 4.4-1 Overview of Analysis Approach for Plankton Key Questions

Key Question	Overview of Analysis Approach
1. What are the current concentrations of chlorophyll *a* and c, and what do these concentrations indicate about the trophic status of Snap Lake, Northeast Lake, and Lake 13?	Temporal trends in chlorophyll *a* and *c* concentrations will be examined and current concentrations will be compared to trophic classifications outlined in the EAR.
2. What is the current status, in terms of abundance, biomass and composition, of the phytoplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?	Annual qualitative comparisons will be completed, comparing the current Snap Lake phytoplankton community to the reference lakes and to baseline (i.e., 2004). Supporting information from other components (water quality, air and hydrology) will be used to assess any habitat-related variation. Nonparametric correlations, such as Spearman rank order correlations will be used, where appropriate. Changes in the proportion of edible and inedible phytoplankton will be visually examined using spatial and temporal trend analyses. Quantitative comparisons will be completed following three years of data acquisition using the new design (commencing in 2013) and will include comparisons to baseline data as well as further temporal and spatial trend analyses in the form of comprehensive multi- and univariate statistical analyses such as non-metric multidimensional scaling, as appropriate.

Table 4.4-1 Overview of Analysis Approach for Plankton Key Questions (continued)

Key Question	Overview of Analysis Approach
3. What is the current status, in terms of abundance, biomass and composition, of the zooplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?	Annual qualitative comparisons will be completed, comparing the current Snap Lake phytoplankton community to the reference lakes and to baseline (i.e., 2004). Supporting information from other components (water quality, air and hydrology) will be used to assess any habitat-related variation. Nonparametric correlations, such as Spearman rank order correlations will be used, where appropriate. Quantitative comparisons will be completed following three years of data acquisition using the new design (commencing in 2013) and will include comparisons to baseline data as well as further temporal and spatial trend analyses in the form of comprehensive multi- and univariate statistical analyses such as non-metric multidimensional scaling, as appropriate.
4. How do observed changes compare to applicable predictions in the EAR?	A qualitative assessment of annual trends in Snap Lake will be completed and compared to the EAR predictions.

EAR = Environmental Assessment Report; AEMP = Aquatic Effects Monitoring Program

4.4.6.2 Key Question 1: What are the current concentrations of chlorophyll a and c, and what do these concentrations indicate about the trophic status of Snap Lake, Northeast Lake, and Lake 13?

Annually, spatial and temporal trends in chlorophyll *a* and *c* concentrations will be examined and current concentrations in Snap Lake, Northeast Lake, and Lake 13 will be compared to trophic classifications outlined in the EAR.

4.4.6.3 Key Question 2: What is the current status, in terms of abundance, biomass and composition, of the phytoplankton community in Snap Lake, Northeast Lake, and Lake 13, and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?

Qualitative reviews of the phytoplankton data, in the form of spatial and temporal trend analyses will be completed as part of the annual AEMP reports. Trend analyses comparing the current Snap Lake phytoplankton community to the reference lakes and to baseline (i.e., 2004) will be completed. This information in combination with the WOE assessment (Section 7.0) will be used to determine whether abundance, biomass, or community composition in Snap Lake show signs of Mine-related nutrient enrichment or toxicological impairment.

Annually, phytoplankton abundance and biomass data will be divided into groups based on taxonomic results. Phytoplankton groups will be cyanobacteria, chlorophytes, chrysophytes, cryptophytes, dinoflagellates, diatoms, and others (when necessary).

The relative proportion accounted for by each group, based on both abundance and biomass, will be calculated separately for each station and for each sampling event to evaluate temporal and spatial variability in community structure.

Information collected as part of the water quality component, such as maximum water depth, Secchi depth, limnology profiles (i.e., specific conductivity, DO, water temperature, and pH), nutrient concentrations[14], and

14 Results from the 2012 special nutrient study may demonstrate that the mid-depth water quality nutrient samples do not provide the necessary information required by the plankton component. Therefore, the plankton component may need to reincorporate depth-integrate nutrient sample collection into the plankton monitoring program.

microcystin-LR concentrations, will be incorporated into the plankton component, as required. In addition, supporting environmental information such as cloud cover, solar radiation, air temperature, water levels, and annual temperature logger data, presented in a separate environmental variables section, will be integrated into the plankton community assessment, if applicable. Nutrient data including phosphorus, nitrogen, and silica concentrations from the water quality component will be compared to phytoplankton community data to assess potential Mine-related eutrophication. Toxicity data from the water quality component will be assessed and compared to plankton community data to assess the potential for Mine-related toxicological impairment. Supporting information (i.e., Site Characterization, Section 4.1) will be used to assess any habitat-related variation and to assist in determining any Mine-related changes. Nonparametric correlations, such as Spearman rank order correlations, will be used to assess potential habitat-related variation, where appropriate.

In addition, an annual edibility assessment will be carried out on the phytoplankton data. Changes in the proportion of edible and inedible phytoplankton (based on size and potential toxicity) will be visually examined using spatial and temporal trend analyses. These changes will then be related to changes in zooplankton abundance and biomass to gain a better understanding of any trophic effects on zooplankton.

Quantitative comparisons (i.e., statistical analyses) will be completed following three years of data acquisition using the refined design, commencing in 2013. These quantitative comparisons will be presented in the 2016 Annual AEMP Report and will include comparisons to baseline (i.e., 2004) data as well as further temporal and spatial trend analyses in the form of comprehensive multi- and univariate statistical analyses, as appropriate.

Non-metric multidimensional scaling (Kruskal 1964; Cox and Cox 2001) will be run on the phytoplankton biomass data set to summarize the community and evaluate potential differences in community structure between Snap Lake, Northeast Lake, and Lake 13. Non-metric multidimensional scaling is a nonparametric ordination method that allows for the reduction of a data set consisting of a large number of taxa to typically two or three new dimensions referred to as ordination axes (Clarke 1993). The analysis is based on a station-by-station distance matrix and provides a visual representation of ecological distances among stations.

A station-by-station Bray-Curtis distance matrix will be generated from the biomass data and used as the input for the ordination. The number of dimensions selected for the ordination will be determined by using a configuration that has a reasonably low stress level (less than 0.2). Non-metric multidimensional scaling will be run using SYSTAT 13.00.05 (SYSTAT 2009). The ordination results will be presented as two-dimensional scatter-plots of the sampling stations in ordination space.

4.4.6.4 Key Question 3: What is the current status, in terms of abundance, biomass and composition, of the zooplankton community in Snap Lake, Northeast Lake, and Lake 13, and do these results suggest signs of Mine-related nutrient enrichment or toxicological impairment?

Qualitative reviews of the zooplankton data, in the form of spatial and temporal trend analyses will be completed as part of the annual AEMP reports. Trend analyses comparing the current Snap Lake zooplankton community to the reference lakes and to baseline (i.e., 2004) will be completed. This information in combination with the WOE assessment (Section 7.0) will be used to determine whether abundance, biomass, or community composition in Snap Lake show signs of Mine-related nutrient enrichment or toxicological impairment.

Annually, zooplankton abundance and biomass data will be divided into groups based on taxonomic results. Zooplankton groups will be cladocerans, calanoid copepods, cyclopoid copepods, rotifers, and others (when necessary).

The relative proportion accounted for by each group, based on both abundance and biomass, will be calculated separately for each station and for each sampling event to evaluate temporal and spatial variability in community structure.

Information collected as part of the water quality component, specifically maximum water depth, Secchi depth, limnology profiles (i.e., specific conductivity, DO, water temperature, and pH), nutrient concentrations[15], and microcystin-LR concentrations, will be incorporated into the plankton component, as required. In addition, supporting environmental information such as cloud cover, solar radiation, air temperature, water levels, and annual temperature logger data, presented in a separate environmental variables section will be integrated into the plankton community assessment, if applicable. Nutrient data including phosphorus, nitrogen, and silica concentrations from the water quality component will be compared to zooplankton community data to assess potential Mine-related eutrophication. Toxicity data from the water quality component will be assessed and compared to plankton community data to assess the potential for Mine-related toxicological impairment. Supporting information (i.e., Site Characterization, Section 4.1) will be used to assess any habitat-related variation and assist in determining any Mine-related changes. Nonparametric correlations, such as Spearman rank order correlations will be used to assess potential habitat-related variation, where appropriate.

Quantitative comparisons (i.e., statistical analyses) will be completed following three years of data acquisition commencing in 2013. These quantitative comparisons will be presented in the 2016 Annual AEMP Report and will include comparisons to baseline (i.e., 2004) data as well as further temporal and spatial trend analyses in the form of comprehensive multi- and univariate statistical analyses, as appropriate.

Non-metric multidimensional scaling (Kruskal 1964; Cox and Cox 2001) will be run on the phytoplankton biomass data set to summarize the community and evaluate potential differences in community structure between Snap Lake, Northeast Lake, and Reference Lake 13. Non-metric multidimensional scaling is a nonparametric ordination method that allows for the reduction of a data set consisting of a large number of taxa to typically two or three new dimensions referred to as ordination axes (Clarke 1993). The analysis is based on a station-by-station distance matrix and provides a visual representation of ecological distances among stations.

A station-by-station Bray-Curtis distance matrix will be generated from the biomass data and used as the input for the ordination. The number of dimensions selected for the ordination will be determined by using a configuration that has a reasonably low stress level (less than 0.2). Non-metric multidimensional scaling will be run using SYSTAT 13.00.05 (SYSTAT 2009). The ordination results will be presented as two-dimensional scatter-plots of the sampling stations in ordination space.

15 Results from the 2012 special nutrient study may demonstrate that the mid-depth water quality nutrient samples do not provide the necessary information required by the plankton component. Therefore, the plankton component may need to reincorporate depth-integrate nutrient sample collection into the plankton monitoring program.

4.4.6.5 Key Question 4: How do observed changes compare to applicable predictions in the EAR?

A qualitative assessment of annual trends in Snap Lake will be completed and compared to the EAR predictions.

4.4.7 QA/QC Procedures

The QA/QC procedures will be applied during all aspects of the plankton component to verify that the data collected are of acceptable quality. Data entered electronically will be reviewed for data entry errors and appropriate corrections will be made.

Ten percent of both the phytoplankton and zooplankton samples will be re-counted by a third party taxonomist, to verify counting efficiency. Samples will be reanalyzed if 10% or more of the samples were counted incorrectly.

The inherent variability associated with the plankton samples prevents the establishment of a QC threshold value. For the purposes of the plankton QC, the proportion of each major group will be calculated and the occurrence of dominant species will be used to assess consistency between the field samples and duplicate samples analyzed. In addition, the Bray-Curtis index and RPD will be used to assess the overall similarity between the field and duplicate samples. Due to high variability in species occurrence, these comparisons will be made at the major group level for both abundance and biomass, not the species level. The Bray-Curtis index only allows for comparison between entire samples, while the RPD compares differences in abundance and biomass of each major group between each pair of duplicate samples.

The data will be reviewed for unusually high or low values (i.e., greater or less than 10 times typical lake values), which would suggest erroneous results. Unusually high or low results will be validated on a case-by-case basis. All invalidated data will be retained in the appendix tables, but a flag of “XC” will be appended to the data, indicating that the sample was considered unreliable or the results were designated as not correct due to an internal review of the data.

4.5 Benthic Invertebrates

4.5.1 Objectives and Scope

The benthic invertebrate community survey is designed to address Water Licence MV2011L2-0004 (Water Licence) (MVLWB 2013a) Schedule 6, Part G (1a, vii), which requires an evaluation of the effects on the benthic invertebrate community due to changes in water or sediment quality in Snap Lake, and Schedule 6, Part G, which requires monitoring the deep water benthic invertebrate community to verify or assess the Environmental Assessment predictions relating to the trophic and DO status of Snap Lake.

The objectives of the Snap Lake benthic invertebrate community survey are to address the following two key questions:

- Is the benthic invertebrate community affected by changes in water and sediment quality in Snap Lake?
- If the benthic invertebrate community is affected, is the change greater than that stated in the EAR?

4.5.2 Sampling Locations

Benthic invertebrate community sampling will be conducted in Snap Lake (Figure 3.3-2) and two reference lakes (Northeast Lake, Figure 3.3-3 and Lake 13, Figure 3.3-4). Sampling stations in Snap Lake will be as follows:

- Main Basin: SNAP03, SNAP05, SNAP06, SNAP07, SNAP09, SNAP11A, and SNAP15; and,
- Northwest Arm (historical reference area): SNAP02A, SNAP20, and SNAP23.

Stations in the two reference lakes will be as follows:

- Northeast Lake: Stations NEL01, NEL02, NEL03, NEL04, and NEL05; and,
- Lake 13: Stations LK13-01, LK13-02, LK13-03, LK13-04, and LK13-05.

4.5.3 Design Rationale

The benthic invertebrate community survey will be conducted every three years, as outlined in the AEMP Re-evaluation Report (De Beers 2012a). If necessary, increased frequency of benthic invertebrate sampling could be triggered by results of annual water quality and sediment quality monitoring, the level of effects detected during the AEMP benthic study, or substantive changes to Mine operations.

All sampling stations will be located at water depths ranging from 10 to 15 m, as in monitoring programs from 2006 to 2012, to eliminate depth as a potential confounding factor when analyzing benthic invertebrate data for potential mine-related effects.

Northwest arm stations will continue to be sampled as part of the AEMP because they are less exposed to treated effluent compared to the main basin of Snap Lake and will be used to monitor the spread of treated effluent in the Northwest Arm. In the northwest arm, benthic invertebrate stations will be the same as those sampled by the water quality component with the exception of SNAP20, which will be sampled in place of water quality station SNAP20B, because SNAP20B is deeper than the maximum depth of 15 m selected for benthic invertebrate sampling.

Near-field, mid-field, and far-field areas from previous AEMP monitoring programs will be combined into a single exposure area (main basin) for the updated AEMP, because these three areas are similarly exposed to treated Mine effluent as indicated by similar conductivity profiles during both late-winter and fall. The number of stations sampled in the main basin area has been reduced to seven from the ten originally sampled. In the main basin, benthic invertebrate samples will be collected at the same stations sampled by the water quality component with the following exceptions:

- SNAP15 will be monitored in place of water quality station SNP02-20e because SNP02-20e is deeper than the maximum depth of 15 m required for benthic invertebrate sampling.
- SNAP07 will be added to the monitoring program to monitor the benthic invertebrate community near the outlet of Snap Lake. This station will be monitored in place of the water quality station SNAP08 because SNAP08 is shallower than the minimum depth required for benthic invertebrate sampling.

Two reference lakes will be sampled for comparisons with the Snap Lake main basin. Benthic invertebrate sampling will be conducted at five stations in both Northeast Lake and Lake 13.

The sampling effort required within a sampling area can be estimated based on power analysis and depends on the parameters required by power analysis (i.e., α, β, critical effects size, estimate of among-station variation). Setting the critical effects size to ±2 SD of the reference mean is recommended for aquatic EEM to evaluate the effects of pulp mills and metal mines (Environment Canada 2010, 2012) and represents a reasonable approach for evaluating mine-related effects. Using this approach the power analysis becomes generic, with results being summarized in the Metal Mining EEM (Environment Canada 2012). Results of the generic power analysis suggest a minimum of five stations in each sampling area to detect a change at a β of 0.1 (i.e., power of 0.9).

4.5.4 Field Methods

Benthic invertebrate sampling will be conducted in the fall open-water season at the stations described above, which are located at water depths ranging from 10 to 15 m. Samples will be collected using a standard Ekman grab (15 cm x 15 cm x 15 cm) from a boat anchored at the sampling station. Six individual Ekman grab samples will be collected at each station. Each sample will be sieved through a 500-µm mesh Nitex® screen. Material retained in the mesh will be placed into separate sample containers for discreet samples (one station per sampling area) and into a single container for composite samples, thus creating a single composite sample consisting of six individual Ekman grabs. Samples will be preserved in 10% neutral buffered formalin.

Discreet samples will be collected at the following stations (all other stations will be composite samples):

- SNAP05 (Main Basin);
- SNAP20 (Northwest arm);

- NEL01 (Northeast Lake); and,
- LK13-03 (Lake 13).

Benthic invertebrate samples will be shipped to J. Zloty, Ph.D. in Summerland, BC, for identification and enumeration of benthic invertebrates and determination of biomass for major taxonomic groups.

Sediment samples will also be collected at each benthic invertebrate sampling station for analysis of sediment chemistry (metals, nutrients, and carbon content) and particle size distribution. Sediment sampling details can be found in the sediment quality section (Section 4.3).

4.5.5 Laboratory Methods

Samples will be processed according to standard protocols based on recommendations in Environment Canada (2002) and Gibbons et al. (1993). Benthic invertebrate samples will first be washed through a 500-µm sieve to remove the preservative and fine sediments remaining after field sieving. Organic material will be separated from inorganic material using elutriation and the inorganic material will be checked for any remaining shelled or cased invertebrates, which will be removed and added to the organic material. The organic material will be split into coarse and fine fractions using a set of nested sieves of 1-millimetre (mm) and 500-µm mesh size. Because samples are expected to be generally small, typically containing fewer than 100 organisms, laboratory subsampling is not expected to be required.

Invertebrates will be identified to the lowest practical taxonomic level, typically genus, using recognized taxonomic keys. Organisms that cannot be identified to the desired level, such as immature or damaged specimens, will be reported as a separate category at the lowest taxonomic level possible, typically family. Organisms that require detailed microscopic examination for identification, such as midges (Chironomidae) and aquatic worms (Oligochaeta), will be mounted on microscope slides using an appropriate mounting medium. Most common taxa should be distinguishable based on gross morphology and require only a few slide mounts for verification. All rare or less common taxa will be slide-mounted for identification.

Invertebrates removed from the samples, sorted organic material, and archived samples will be stored for six years to allow possible comparisons, if necessary, with samples collected during subsequent monitoring.

4.5.6 Supporting Environmental Variables

The following supporting data will be collected at each benthic invertebrate sampling station as part of the annual benthic invertebrate monitoring program:

- exact station location as UTMs, including UTM zone using NAD 83;
- water depth;
- weather conditions;
- habitat description;
- field water quality (DO, water temperature, conductivity, pH) as vertical profiles prior to disturbing the sediments;

- bottom sediment-related information (texture, colour, odour, particle size);
- benthic sample-related information (sampler used, sieve mesh size, sampler fullness, preservative); and,
- any additional pertinent information.

4.5.7 Data Analysis

4.5.7.1 Approach

The benthic invertebrate component data analysis is designed to answer the key questions listed in Section 4.5.1. An overview of the analysis approach for these two key questions is provided in Table 4.5-1. Specific details relevant to data analysis methods to address each key question are provided in Sections 4.5.7.2 and 4.5.7.3.

Table 4.5-1 Overview of Analysis Approach for Benthic Invertebrate Community Key Questions

1. Is the benthic invertebrate community affected by changes in water and sediment quality in Snap Lake?	Benthic invertebrate community summary variables will be evaluated to determine whether changes in the benthic invertebrate community have occurred, using both statistical (quantitative) and visual (qualitative) methods. Univariate statistical methods will include among lake comparisons of the Snap Lake main basin with Northeast Lake and Lake 13. Multi-variate statistical analysis will also be used to evaluate potential differences in benthic community structure between Snap Lake and the reference lakes. Also, evaluation of trends over time will be conducted to determine whether changes in the benthic invertebrate community of Snap Lake are occurring. If changes in the benthic invertebrate community have occurred, water and sediment quality data will be evaluated to determine whether changes in the benthic invertebrate community can be attributed to corresponding changes in water and sediment quality.
2. If the benthic invertebrate community is affected, is the change greater than predicted in the EAR?	If changes in the benthic invertebrate community are observed, an evaluation of the statistical and visual results will be used to determine whether the change in the benthic community is within EAR predictions. This evaluation will be based on the magnitude of change observed and consider whether results from multiple evaluation methods indicate a change.

EAR = Environmental Assessment Report.

4.5.7.2 Key Question 1: Is the benthic invertebrate community affected by changes in water and sediment quality in Snap Lake?

Benthic invertebrate summary variables used in the data analysis will be:

- total invertebrate density (organisms per m^2);
- taxonomic richness as total richness (taxa per station);
- Simpson's diversity index (diversity);
- evenness;
- densities of dominant taxa defined as those taxa accounting for more than 5% of the total invertebrates across all stations;
- community composition as percentages of major taxonomic groups;
- Bray-Curtis Index; and,
- biomass (milligrams [mg] wet weight).

Summary statistics including the arithmetic mean, median, minimum, maximum, SD, and SE will be calculated for the above variables, excluding community composition by major taxonomic group.

Data analysis will consist of visual and statistical evaluations of differences among sampling areas and a qualitative evaluation of temporal trends. Before statistical testing, data will be checked for normality using the Shapiro-Wilk test and for homogeneity of variances using Bartlett's test. Summary variables that are non-normal or have significant heterogeneous variances among sampling areas will be transformed to approximate normal distributions and to equalize variances as appropriate. For variables where transformations do not eliminate deviations from normality or equalized variances, nonparametric statistical tests will be used.

Relationships between habitat variables and biological variables will be evaluated by calculating Spearman rank correlation coefficients and examining scatter plots. Significant correlations that are in a direction considered appropriate will be considered for addition into statistical comparisons as a covariate. Correlations will be considered significant at $P<0.05$.

4.5.7.2.1 Among Area Comparisons

Before statistical comparisons of lakes are conducted, the data will be checked to identify outliers and verify that the assumptions of parametric statistical tests are met (i.e., normally distributed data for each lake, homogeneous variances). If outliers are identified, statistical tests will be run with and without outliers to evaluate their influence on the results of the analysis. If required, the data will be transformed to meet parametric test assumptions and the success of the transformations will be verified. If parametric test assumptions cannot be met for a given data set, even after transformation, lake comparisons will be done using nonparametric tests.

The means of the three lakes will be compared to one another in an overall ANOVA. Upon finding a significant result, two planned orthogonal contrasts will be run within the overall ANOVA to test the differences of means between Snap Lake and the two reference lakes, and between the two reference lakes (Sokal and Rohlf 1995). Although the comparison of primary interest is that of Snap Lake versus reference lakes, the reference lakes will also be compared to one another to evaluate whether the degree of natural variability between them is large enough to be statistically significant. For variables that do not meet parametric test assumptions, the Kruskal-Wallis test will be used to test for differences among the three lakes, followed by the same planned contrasts as done after ANOVA. Statistical tests will be considered significant at $P<0.1$, with the potential for an adjustment to account for lower power achieved by the nonparametric contrasts.

At the study design stage, the probability of a Type I error (α) is set to the same level (i.e., 0.1) as a Type II error (β), because the probability of missing important effects is deemed to be as important as the probability of finding an effect when none exists (Environment Canada 2012). This results in a power of 90% for the among-lake comparisons as designed. Based on power analysis results documented by Environment Canada (2012), a sample size of five stations per lake, which is the minimum within-lake sample size in this AEMP, is sufficient to detect a difference of 2 SDs (i.e., the limit of the normal range) with Type I and II error probabilities of 0.1.

4.5.7.2.2 Multivariate Analysis

Non-metric multidimensional scaling (Kruskal 1964; Cox and Cox 2001) will be run on the benthic invertebrate data set to summarize community structure and evaluate potential differences in community structure between Snap Lake and the two reference lakes. Non-metric multidimensional scaling is a nonparametric ordination method that allows for the reduction of a data set consisting of a large number of taxa to typically two or three new dimensions referred to as ordination axes (Clarke 1993). The analysis is based on a station-by-station distance matrix and provides a visual representation of ecological distances among stations.

A station-by-station Bray-Curtis distance matrix will be generated from the density data and used as the input for the ordination. The number of dimensions selected for the ordination will be determined by using a configuration that has a reasonably low stress level (less than 0.2). Non-metric multidimensional scaling will be run using SYSTAT 13.00.05 (SYSTAT 2009).

Ordination results will be presented as scatter-plots of the sampling stations in ordination space. Since non-metric multidimensional scaling does not provide an indication of the taxa associated with each dimension, Spearman rank correlation coefficients will be generated between scores on each dimension and abundances of the taxa in the reduced biological data set used for the ordination. Results of the ordination will be presented as two-dimensional scatter-plots.

4.5.7.2.3 Temporal Trends

Snap Lake main basin means for summary variables will be calculated and plotted with normal ranges from Northeast Lake and Lake 13 overlaid to determine whether any of the variables for a given year were outside the normal range, indicating a difference from the reference areas. Trends over time in the main basin of Snap Lake will also be evaluated using these graphical data plots.

Area means for community composition by major taxa were will be calculated and plotted as stacked bar graphs to determine whether changes in benthic community composition have occurred over time in Snap Lake. Presence/absence data will be compared among years using data at the lowest taxonomic resolution for the main basin of Snap Lake, to evaluate changes in community composition at a finer taxonomic level than major group.

4.5.7.3 Key Question 2: If the benthic invertebrate community is affected, is the change greater than predicted in the EAR?

If changes in the benthic invertebrate community are observed, an evaluation of the statistical and visual results will be used to determine whether the change in the benthic community is within EAR predictions. This evaluation will be based on the magnitude of change observed and consider whether results from multiple evaluation methods indicate a change.

4.5.8 QA/QC Procedures

4.5.8.1 Benthic Invertebrate Taxonomy

Invertebrate sample sorting efficiency will be verified by an individual other than the original sorter by performing spot-checks on sediment remaining after sorting (the debris). Ten percent of the samples will be re-sorted. The data quality objective is a minimum removal of 90% of the total number of organisms in a sample. If more than 10% of the total number of organisms removed from the sample is found in the debris, then all samples will be re-sorted, by an individual other than the original sorter. In addition, if an entire taxonomic group is inadvertently omitted by the sorter, then all samples will be re-sorted by an individual other than the original sorter.

4.5.8.2 Data Entry

In accordance with Golder's standard QA/QC protocol, 10% of all habitat data entered electronically will be reviewed for data entry errors. If errors are found in this sub-sample, all habitat data entered electronically will be reviewed and corrections made as appropriate. Supporting data entered from field data sheets will be quality checked independently by a second person. Calculations performed during the data summary and analysis stage will be spot-checked for potential errors, and appropriate logic checks will be performed to verify the accuracy of calculations.

4.6 Fish Health

4.6.1 Objectives and Scope

The objective of the fish health survey is to determine whether treated Mine effluent has a significant effect on the growth, reproduction, survival, and/or condition of fish in Snap Lake. Specific Water Licence conditions applying to the fish health component of the AEMP for Mine in the Water Licence MV2011L2-0004 [Part G, Schedule 6, Item 1a (iii) and 1(d) of MVLWB (2013a)] are:

> *a) Monitoring for the purpose of measuring Project-related effects on the following components of the Receiving Environment:*
>
> *iii. fish health;*
>
> *d) Procedures to minimize the impacts of the AEMP on fish populations and fish habitat.*

Two components to the Fish Health component are proposed:

- a lethal survey of Lake Chub (*Couesius plumbeus*) to examine growth, reproduction, and condition; and,
- a non-lethal survey of Lake Chub to examine growth, survival, and condition.

These surveys will compare the health of Lake Chub in Snap Lake relative to populations in two reference lakes, to address the following key questions:

- Is fish health affected by changes in water and sediment quality in Snap Lake?
- Are changes observed in fish health greater than those predicted in the EAR?

4.6.2 Sampling Locations

The sampling locations for the fish monitoring includes Snap Lake (the exposure area), Northeast Lake (a reference lake), and Lake 13 (a reference lake) (Figure 3.3-1). Northeast Lake and Lake 13 are included as reference lakes because, as previously noted, they were found to be reasonably similar to Snap Lake in the 2005 reference lake survey (De Beers 2005a,b).

4.6.3 Design Rationale

The rationale for the design and analysis of fish health studies is based on guidance from the federal EEM programs (Environment Canada 2010, 2012). Although these regulations do not apply to diamond mines, they are the only formal, federal monitoring protocols available for mining. EEM has been broadly accepted in Canada as a valuable monitoring tool, and the fish health end-points suggested by Environment Canada are those that are most likely to be affected by exposure to treated effluent.

4.6.3.1 Design Changes for 2015

Inclusion of Small-bodied Fish Only

During the baseline, 2004, and 2009 AEMP programs, target fish species were Lake Trout (*Salvelinus namaycush*) and Round Whitefish (*Prosopium cylindraceum*). A small-bodied fish species, Lake Chub, was

added to the program in 2009; both large-bodied and small-bodied fish were collected in 2009. The lethal large-bodied fish program was not included in the overall AEMP in 2012 due to concerns regarding mortality of Lake Trout and Round Whitefish populations in Snap Lake. The 2012 Snap Lake AEMP moved to a small-bodied fish health study, with Lake Chub as the study species. A Lake Trout population estimate program was initiated in Snap Lake in 2012 and will be completed in 2013 (Section 5.4). The outcome of this special study will provide an estimate of population size, which will determine the potential impact of repeated AEMP fish survey sampling on the population. This information will direct any future decisions regarding the inclusion or exclusion of a large-bodied fish health program.

Efforts were made to include a second small-bodied fish in the study. Fishing for Slimy Sculpin occurred in 2011 and 2012 to determine whether a sufficient sample size of Slimy Sculpin could be captured. Both the winter survey (March) and the summer survey (July) yielded insufficient fish for inclusion as a study species. Details of these surveys will be provided in the 2012 AEMP annual report.

Inclusion of New Types of Data

A number of additional endpoints and analytical approaches are being added to the 2015 lethal Lake Chub program.

- Liver lipids are being added as an additional endpoint for Lake Chub to examine whether conditions in Snap Lake result in elevated lipid concentrations and, therefore, increased liver size and energy available to fish for growth and reproduction. The liver lipid endpoint is being added due to increasing concentrations of nutrients and TDS and possible indicators of nutrient enrichment in Snap Lake.
- Size at maturity will be examined among water bodies by plotting gonadosomatic index (GSI) against a measure of body size (length or weight) to examine size at maturity and spawning strategy (i.e., presence/absence of alternate year spawners) between the exposure and reference areas.
- The proportion of fish captured that are in spawning condition will be calculated to examine whether reproductive status is comparable among fishing methods and among areas. Fish that will spawn will be defined as fish that are found to be pre-spawning, ripe or spent (see Table 4.6-1).
- The percent of total fish caught by different gear types in each lake is being added as an additional endpoint to determine whether sampling method is correlated with fish health endpoints, and to comply with the updated Metal Mining Effluent Regulations EEM guidance (Environment Canada 2012). Should any fish health endpoint vary predictably or consistently with fishing method, fish health data will be analyzed separately by fishing method. In the absence of predictable or consistent variations in fish health endpoints that correlate with fishing method, fish data will be pooled between fishing methods and conclusions on exposure area fish relative to reference area fish will be made independently of fishing method.
- The sex ratio of adult fish from Snap Lake and the reference lakes will be examined to determine whether a different number of males and females are caught by different gear in different lakes and, if not, whether the potential for sex ratio differences exists in the population among the lakes or whether potential activities of males and females differ at the time of capture (e.g., spawning versus feeding).

4.6.4 Field Methods

4.6.4.1 Sampling Locations

Fish will be collected from the main basin of Snap Lake, and two reference lakes, Northeast Lake and Lake 13. Fish will be collected from the same sampling locations and similar habitat types in Snap Lake as previous AEMP studies to maintain consistency between years of the program and baseline data. The main basin of Snap Lake will be the primary focus of fishing efforts, but other areas of the lake may be sampled if necessary, as dictated by fish captures and densities.

4.6.4.2 Timing of Sampling

In 2009 and in 2012, sampling was conducted immediately following ice-out as this is the peak pre-spawning development period for Lake Chub. Sampling will continue to occur in early to mid-July for the fish health program in 2015, and will continue on a 3-year cycle.

4.6.4.3 Study Species

The Snap Lake fish health AEMP design in 2015 will include a lethal and non-lethal small-bodied fish health program. Both surveys will target adult and juvenile Lake Chub as the sentinel species. If changes are observed in Lake Chub that may be due to treated effluent, a lethal large-bodied fish health program with Lake Trout may be re-initiated to determine whether there are also changes occurring in the large-bodied species in Snap Lake.

4.6.4.4 Target Sample Sizes

The target numbers of Lake Chub to be collected for the lethal and non-lethal fish health survey are:

- **Lethal survey:** 40 adult male, 40 adult female (>50 mm length) and 40 juvenile (≤50 mm length) Lake Chub; and,
- **Non-lethal survey:** ≥100 adult and juvenile Lake Chub (maximum of 400).

The above sample sizes represent an increase relative to previous years (i.e., n = 40 versus n = 30 in 2009 and 2012). This increase in sample size represents a compromise between maintaining acceptable levels of mortality to the fish population, and attempting to achieve improved statistical power to detect differences between fish health endpoints in fish collected in the exposure area and reference lakes as compared to previous results (e.g., De Beers 2010b). The grouping of data by sex, reproductive status, and parasite presence/absence, combined with an increase in sample size from 30 to 40 male, female and juvenile fish, will provide for better power for statistical analyses in 2015. The data screening and statistical procedures to be used during the statistical analyses are described in Section 4.6.5.3.

4.6.4.5 Collection Methods

The field methods being considered include techniques suitable for lake shore habitats and those most successful in previous years of the Snap Lake AEMP program. The gear types being proposed are the following: minnow traps, fyke nets, hoop nets, and boat electrofishing. For each day of fishing on each lake, the following information will be recorded:

- time (in hours) for each fishing effort for each gear type;

- gear specific parameters (e.g., settings for electrofisher);
- water depth of each gear-type set;
- GPS coordinates of each fishing effort;
- substrate type (e.g., mud, sand, gravel, cobble) at each fishing location;
- water quality field measurements (e.g., DO, water temperature, pH, conductivity, and turbidity), one time daily in each lake;
- weather (air temperature and wind velocity and direction, taken from the on-site weather station);
- number of each fishing effort (an effort identification number);
- number and species of fish captured; and,
- photographs of representative habitat types and fish species captured.

Fish collected and retained for the lethal survey will be transported back to the on-site laboratory for processing in aerated containers. Fish collected for the non-lethal survey will be held in a recovery bin before processing, and will be immediately live-released following processing. All non-target fish species captured will be enumerated and measured for length and weight and released live.

A representative photograph of each species captured will be taken. Wet gloves will be used during fish handling to reduce stress on the fish mucosal layer. If a specimen cannot be readily identified in the field a specimen will be collected and brought to the office for identification. The total number of fish captured and released will be recorded so as to track fish numbers relative to Fisheries and Oceans Canada permit limits.

4.6.4.6 Parameters

4.6.4.6.1 Lethal Survey

External Examinations

All target fish captured during the study will be examined externally. Any features of the fish that do not appear normal (i.e., wounds, tumours, parasites, fin fraying, gill parasites, or lesions) will be reported in detail, and if necessary, submitted for further analysis (i.e., histopathology). When possible, information on maturity, sex, and overall health will be recorded; this information will be verified during the internal examination. External examinations will be completed following the recommendations outlined in Chapter 3 of the Metal Mining Effluent Regulations Technical Guidance Document (Environment Canada 2012). Photographs will be taken of any fish with abnormal external features.

Internal Examinations and Organ Collections

Target adult and juvenile Lake Chub will be sacrificed by a sharp blow to the back of the head and cervical dislocation (i.e., cutting the spinal cord immediately behind head) followed immediately by an internal examination.

The biological variables collected from lethally sampled Lake Chub will be:

- photograph (external);
- species name;
- fork length (±1 mm);
- total length (±1 mm);
- total body weight (±0.001 g);
- physical abnormalities (e.g., tumours, lesions, parasites);
- internal pathology (e.g., liver and kidney colour, fat content);
- parasite weight (if present; ±0.001 g);
- sex;
- stomach contents (% fullness);
- liver weight (±0.001 g);
- whole gonad weight (±0.001 g);
- individual gonad lobe weight (±0.001 g);
- photograph of whole gonad and under 10% magnification on microscope;
- state of reproductive development (i.e., maturity; categories as outlined in Table 4.6-1);
- carcass weight (±0.001 g); and,
- age (year).

Tissue samples will be collected for specialized analyses immediately following or during the internal health assessment:

- gonad histology (each fish);
- fecundity/egg weight (adult females only);
- liver lipids (i.e., glycogen and triglyceride analysis) and protein (each fish);
- stomach contents (all fish with >50% stomach fullness);
- carcass tissue metals analysis (adults only); and,
- otoliths for aging (each fish).

Table 4.6-1 Gonad Maturity Categories to be use in the Lake Chub lethal fish health survey for Snap Lake, 2015.

Life Stage	Maturity Stage	Definition
1	Unknown (UN)	External examination only, or unable to determine following internal examination.
2	Immature (IM)	Fish has never spawned and will not spawn in the coming season; testes/ovaries transparent, very small and close under the vertebral column, determination of sex may be difficult.
3	Maturing (MA)	Fish has not spawned before, but will spawn in the coming season; gonads developed primarily in the anterior body cavity.
4	Seasonal Development (SD)	Sexually mature, has spawned before, gonads developing for coming season.
5	Pre-spawning (PR)	Sexually mature, gonads filling ventral cavity, testes white, eggs round - some translucent.
6	Ripe (RP)	Roe/milt extruded with very slight pressure on belly.
7	Spent (SP)	Spawning completed, reabsorption of residual ovarian tissue not yet completed.
8	Reabsorbing (RB)	Sexually mature, was developed for the current season but did not spawn; interrupted spawning effort; eggs become atritic (small, hard, white).
9	Resting (RS)	Sexually mature, has spawned before; gonads not developing for the coming season; alternate year spawner.

Internal condition will be observed and recorded immediately following the opening of the body cavity (i.e., tissue colour and condition). Liver weight will be recorded and the liver tissue will be immediately processed for liver glycogen and lipids analyses by placing the whole liver in labelled sample tubes and storing the tubes on dry ice (i.e., snap freezing). During excision of the liver, the gall bladder will be observed and percent fullness recorded. Stomach fullness will be noted along with a general description of gut contents and parasite load. All stomachs with at least 50% fullness or more will be excised and stored in a vial with 10% buffered formalin for stomach content analyses.

Gonads will be weighed together (i.e., total gonad weight), and then, for females only, the lobes will be weighed individually and their weights recorded as “lobe 1” and “lobe 2”. Photographs will be taken of representative normal gonads, as well as any abnormalities. If possible, a photograph (through the microscope on 10x magnification) will be taken of each gonad. For males, the total gonad will be placed in a labelled vial and preserved in 10% buffered formalin for histology. For females, one lobe will be processed for histology, while the second lobe will be processed for fecundity by preserving in either Gilson’s solution or 10% buffered formalin. Lobe numbers for each respective analysis will be recorded accordingly on data sheets and sample labels. Fecundity will be calculated by counting all developing eggs contained within the ovary using a dissecting microscope (and recording the total number of eggs in the ovary lobe), and measuring the diameter of 30 eggs with a micrometer under a dissecting scope (and recording each egg diameter). Representative photographs of the ovary lobe and eggs will be taken through the microscope for each sample during fecundity analyses.

Sagittal otoliths (pairs) will be collected from all lethally sampled Lake Chub for aging purposes. If both otoliths are not recovered, a few scales and the left pectoral fin rays will be taken as secondary aging structures. Ageing structures will be wrapped in wax paper and then put into envelopes for small-bodied fish and labelled with the fish biomarker number (see below for numbering system). Any incidental mortalities of non-target species will also have aging structures collected; this information will contribute to the overall Snap Lake fish community dataset. Ageing structures will be wrapped in wax paper and then put into envelopes for small-bodied fish and labelled with the fish capture number.

Carcass weight (i.e., body without liver, gonads, stomach, intestines and aging structure) will be measured and recorded for each fish and the carcasses will be submitted for tissue chemistry analyses (see Section 4.8).

The variables to be collected from non-target fish are:

- species;
- physical abnormalities (e.g., tumours, surficial lesions, obvious parasites);
- fork length (±1 mm, if applicable);
- total length (±1 mm); and,
- total body weight (±0.001 g).

4.6.4.6.2 Non-Lethal Survey

As described for the lethal survey, all target fish captured during the study will be examined externally. Any features of the fish that do not appear normal (i.e., wounds, tumours, parasites, fin fraying, gill parasites, or lesions) will be photographed and reported in detail. When possible, information on maturity, sex, and overall health will be recorded. External examinations will be completed following the recommendations outlined in Chapter 3 of the Metal Mining Guidance Document (Environment Canada 2012).

For each fish specimen to be live-released, measurements will be taken as follows:

- species;
- fork length (±1 mm);
- total length (±1 mm);
- total body weight (if possible) (±0.001 g);
- sex (if evident);
- life stage (if evident, otherwise will be recorded as unknown); and,
- external health assessment.

This information will be recorded on the catch record field data sheet. Measurements will be taken in the field and the fish will be released near the capture location.

4.6.5 Data Analysis

Data will be analyzed to address the key questions (Table 4.6-2). Details on each type of analysis follow.

Table 4.6-2 Overview of Analysis Approach for Fish Health Key Questions

Key Question	Overview of Analysis Approach
1. Is fish health affected by changes in water and sediment quality in Snap Lake?	Fish abundance as estimated by CPUE will be calculated in all water bodies. A lethal and non-lethal small-bodied fish health survey using Lake Chub will measure fish health endpoints related to survival (e.g., age), growth (e.g., size at age), reproduction (e.g., relative gonad size, relative fecundity), and condition (e.g., condition, relative liver size) and will compare these endpoints from Snap Lake with the reference lakes, taking into consideration sex, state of maturity and parasite presence/absence. Additional analyses from Lake Chub including stomach contents and liver lipid and protein concentrations will be analyzed and compared between Snap Lake and the reference lakes.
2. Are changes observed in fish health greater than those predicted in the EAR?	Fish health endpoints related to survival (e.g., age), growth (e.g., size at age), reproduction (e.g., relative gonad size, relative fecundity), and condition (e.g., condition, relative liver size) measured as part of the small-bodied fish health survey using Lake Chub will be compared to applicable EAR predictions.

CPUE = catch-per-unit-effort; EAR = Environmental Assessment Report.

4.6.5.1 Catch Data Summary

Catch-per-unit-effort (CPUE) provides an estimate of abundance by standardizing catch data according to fishing effort. CPUE will be calculated for all fish captured during the health survey, and will be summarized by both area and sampling method to document the amount of effort expended to collect the required number of fish. Total numbers of fish collected and processed as part of the lethal and non-lethal Lake Chub fish health surveys will be summarized by water body and presented in summary tables.

4.6.5.2 Descriptive Statistics

Common fish indices that describe relationships between body metrics will be calculated as follows:

Condition factor (K) $$K = \left(\frac{carcass\ weight}{fork\ length^3}\right) \times\ 100;$$ Equation 5

Gonadosomatic Index (GSI) $$GSI = \frac{gonad\ weight}{carcass\ weight} \times 100;$$ and, Equation 6

Liversomatic Index (LSI) $$LSI = \frac{liver\ weight}{carcass\ weight} \times 100;$$ Equation 7

where all weight measurements are in grams (g) and length is in millimetres (mm). Carcass weight is the measured body weight following removal of the liver, gonad, and viscera as well as any parasites and will be used in the calculations of GSI and LSI because of possible differences in organ weight among sampling areas. In some instances, carcass weight may be replaced with adjusted body weight in the above equations for supporting analyses. Adjusted body weight is the total body weight minus parasite weight (if parasites are present).

Descriptive statistics (i.e., sample size, mean, SD, SE, minimum, and maximum) will be calculated for mature fish and summarized for all quantitative fish health endpoints and indices. The incidences of abnormalities and parasites will be quantified for each area.

4.6.5.3 Analyses for Lethal Survey

The objective of the fish health survey is to determine whether Snap Lake treated effluent has a significant effect on the growth, reproduction, survival, and/or condition of fish in Snap Lake relative to fish populations in the reference lakes. Analyses will involve the following endpoints:

- survival (e.g., age);
- energy use (e.g., size-at-age; relative gonad size; fecundity); and,
- energy storage (e.g., condition; relative liver size).

Survival is a measure of the difference in the mean age of all fish (separated by species and sex) between the exposure and reference areas. A healthy population should exhibit variability in age.

Energy Use is a measure of the ability of the fish population to utilize resources in their environment to grow and reproduce. It is also an indicator as to whether a population is growing and reproducing normally and successfully.

Energy Storage is a measure of the energy reserves of the fish population. Condition and relative liver size provide valuable information on food quality and availability to the fish population. A healthy fish will demonstrate a greater body weight to length ratio and have a liver weight that is proportional to its body size. Stressors from the environment, whether they are natural or anthropogenic, can affect the condition of a fish population and alter the relative liver size (e.g., enlarged liver as a result of contaminant depuration processes or increased lipid processing as a result of eutrophication).

Fish health endpoints related to the above responses will be statistically compared between the exposure and reference lakes to identify whether an effect has occurred on the fish population in Snap Lake as per EEM guidelines (Environment Canada 2012). In EEM, an “effect” is defined as a statistically significant difference in effect indicators measured between an area exposed to treated effluent and a reference area, or a statistically significant difference in these effect indicators within an exposure area along a gradient of treated effluent concentrations (Environment Canada 2012). Table 4.6-3 outlines fish health response effect indicators, endpoints, dependent variables and covariates (as appropriate), and statistical procedures that are applicable to the fish health component of the AEMP. Fish data will be divided by sex, state of maturity (i.e., male and female fish will be analyzed separately, and immature fish will not be included), and presence or absence of parasites. This is necessary due to different energetic requirements associated with reproduction, which result in differences in growth patterns and subsequent differences in growth rate, body weight, gonad size, and liver size (Environment Canada 2012). Parasitism will also be considered due to the influence some parasites, especially tapeworms (e.g., *Schistocephalus*) can have on nutrient uptake and, therefore, energy availability for reproduction and growth.

Once data are sub-divided based on sex and state-of-maturity and, if applicable, parasitism status, but prior to further statistical analyses, data will be tested for normality and homogeneity of variances and screened for potential outliers. All data will be log10 transformed prior to screening the data for outliers and completing the statistical analyses. This will be done because the majority of biological data do not satisfy the statistical requirements of normality and homogeneity of variance unless log transformed. The transformed data will be screened for potential outliers by visual examination of box and whisker plots and linear regression plots.

Studentized residuals (SR) from the linear regression analyses will be used as an additional screening tool. Observations that are more than three SDs (i.e., SR>|3|) from the mean will be checked and validity confirmed; data points will only be removed if warranted. Any outliers that will be removed will be identified, the reasons for removal (e.g., transcription error, analytical error) will be described, and the screening will be re-run (i.e., box plots, linear regression). If there is no obvious reason for the presence of the outlier, the ANOVA and analysis of covariance (ANCOVA) will be completed both with and without the outlier. All statistical analyses, including screening, will be conducted using the software SYSTAT 13.00.05 (SYSTAT 2009).

Table 4.6-3 Statistical Procedures Used in the Lethal Lake Chub Survey for Identifying Differences between Reference and Exposure Areas for Endpoints

Effect Indicator	Endpoint	Dependent Variable (Y)	Covariate (X)	Statistical Procedure
Survival	Age	n/a	n/a	ANOVA
Growth (Energy Use)	Size at age	Adjusted body weight	Age	ANCOVA
		Length	Age	ANCOVA
	Length-frequency distribution	n/a	n/a	K-S test
	Body weight	n/a	n/a	ANOVA
	Length	n/a	n/a	ANOVA
Reproduction (Energy Use)	Relative gonad size	Gonad weight	Carcass weight	ANCOVA
		Gonad weight	Length	ANCOVA
	Relative fecundity	# eggs/ female	Adjusted body weight	ANCOVA
		# eggs/female	Length	ANCOVA
		# eggs/female	Age	ANCOVA
Condition (Energy Storage)	Condition	Adjusted body weight	Length	ANCOVA
		Carcass weight	Length	ANCOVA
	Relative egg size	Mean egg weight	Adjusted body weight	ANCOVA
		Mean egg weight	Carcass weight	ANCOVA
		Mean egg weight	Age	ANCOVA
	Relative liver size	Liver weight	Length	ANCOVA
		Liver weight	Carcass weight	ANCOVA

n/a = not applicable; ANOVA = Analysis of Variance; K-S test = 2-sample Kolmogorov-Smirnov test; ANCOVA = Analysis of Covariance; Adjusted body weight = total body weight minus parasite weight (if parasites present); Carcass weight = measured carcass weight after removal of liver, gonads, stomach, intestines, and aging structures.

Additional supporting analyses being added to the Snap Lake fish health program in 2015 will be:

- liver lipids (i.e., glycogen and triglyceride) and protein concentrations;
- size at maturity;
- the proportion of target species in spawning condition by different gear types in each lake at the time of sampling;
- the percent of total fish caught by different gear types in each lake; and,
- the sex ratio of the population sampled by different gear types from each lake.

The ANOVA will be used to test whether there is a statistical difference between Snap Lake and reference lakes fish in age, total body weight, carcass weight, and length for each sex (Table 4.6-3). For each analysis, the level of significance (*P)* for the test statistic will be reported. If a statistical difference is detected, direction and magnitude of effect will be calculated. Direction provides an indication of whether the exposure area means are larger or smaller than the reference means. Magnitude is the percent difference between two areas, and will be calculated by comparing the means between Snap Lake and the reference lakes according to Equation 8:

$$Magnitude = \left(\frac{exposure\ mean - reference\ mean}{reference\ mean}\right) x\ 100 \qquad \text{Equation 8}$$

A general linear model (GLM) followed by ANCOVA will be used to assess endpoints, including size-at-age, condition (adjusted body weight against length), liver size, egg size, gonad size, and fecundity. GLM will be used to test for homogeneity of slopes between the dependent variable and covariate for fish in each lake (i.e., test for significant covariate interaction). In cases where a significant interaction between areas and covariate is found, but the difference in the R^2 value between the full regression model and the reduced regression model is less than 0.02, ANCOVA will proceed as per Barrett et al. (2009) as cited in the EEM guidance (Environment Canada 2012). If the difference in the R^2 value is greater than 0.02, ANCOVA will not be conducted and an ANOVA will be performed on the dependent variable. Magnitude will be calculated by comparing the least squares mean (LSM) between the exposure and reference areas according to Equation 9:

$$Magnitude = \left(\frac{exposure\ LSM - reference\ LSM}{reference\ LSM}\right) x\ 100 \qquad \text{Equation 9}$$

In cases where the GLM produces no significant interaction between areas and the covariate (i.e., homogeneity of slopes is not violated), but there is no significant regression with the covariate, ANOVA analysis will be completed on the dependent variable following the procedure outlined above. In cases where the GLM produces no significant interaction between areas and the covariate, and there is a significant regression relationship with the covariate, ANCOVA will be performed. If the results of the ANCOVA indicate significant differences between the exposure and reference areas, hypothesis testing will be performed to determine which areas are different from each other (i.e., pair-wise comparisons will be performed by hypothesis testing).

At the study design stage, the probability of a Type 1 error (α) is set to the same level (i.e., 0.1) as a Type II error (β) because the probability of missing an important effects is deemed to be as important as the probability of finding an effect when none exists (Environment Canada 2012). This results in a power of 90% for the among-lake comparisons as design. Power analysis will be performed on all statistical tests performed (i.e., ANOVA and ANCOVA analyses) to determine whether there was sufficient power to detect differences in the population. In any case where there is deemed to be low power, the required number of samples to achieve sufficient power (i.e., 90%) will be calculated.

4.6.5.4 Analyses for Non-Lethal Survey

While it is possible to estimate state-of-maturity (i.e., young-of-the-year (YOY), juvenile, or adult) for Lake Chub based on fork length, approximate size distributions, and GSI-length plots, it is not possible to determine sex from an external examination. Therefore, data cannot be subdivided by sex and state-of-maturity for the non-lethal survey. The fish health effect indicators, effect endpoints, dependent variables, covariates, and statistical procedures to be used for identifying statistical differences between Lake Chub from the exposure area and reference areas are presented in Table 4.6-4.

Table 4.6-4 Statistical Procedures Used in the Non-Lethal Lake Chub Survey for Identifying Differences between Reference and Exposure Areas

Effect Indicator	Endpoint	Dependent Variable (Y)	Covariate (X)	Statistical Procedure
Survival	Length frequency distribution [E]	n/a	n/a	K-S test
Growth (Energy Use)	Length [S]	n/a	n/a	ANOVA
	Weight [S]	n/a	n/a	ANOVA
Condition (Energy Storage)	Condition [E]	Total body weight	Length	ANCOVA

n/a = not applicable; K-S test = 2-sample Kolmogorov-Smirnov test; ANOVA = Analysis of Variance; ANCOVA = Analysis of Covariance; E = Effect Endpoint; S = Supporting Endpoint.

4.6.6 QA/QC Procedures

The QA/QC procedures are designed such that all field sampling, laboratory analyses, data entry, data analyses, and report preparation produce technically sound and scientifically defensible results. As part of routine QA/QC for field operations, equipment will be calibrated and samples will be collected by experienced personnel and will be labelled, preserved, and shipped according to standard protocols. Specific work instructions outlining each field task in detail will be provided to the field personnel by the task manager and reviewed prior to the start of the field program. Detailed field notes will be recorded in waterproof field books and on pre-printed waterproof field data sheets in either pencil or indelible ink. Data sheets and all sample labels will be checked at the end of each field day for completeness and accuracy. Chain-of-custody forms will be used to track the shipment of all samples. Ten percent of the histology data will be randomly selected and re-analyzed by an independent histopathologist. As a QA/QC procedure for fish age estimates, 10% of the prepared sections will be re-aged by an independent fish ageing specialist. If there is a discrepancy greater than 10% between the specialist's results and the initial results, all samples will be re-analyzed. For every ten fecundity samples, one sample will be re-counted by a second person. If the re-count of the sample is within 10% of the initial count, the initial count will be regarded as acceptable and no re-count of the remaining samples will be required. If the re-count is not within 10% of the initial count, the initial count will be regarded as unacceptable and the remaining nine samples will be re-counted. The QA/QC procedure will be repeated until re-counts are within 10% of the previous count.

The QA/QC for data entry involves checking a minimum of 10% of the data for completeness, data entry errors, transcription errors, and invalid data. This checking will be done by an independent person from the person who entered the data. If an error is found, all data will undergo a zero tolerance (i.e., every datum checked) QA check. All statistical results will be independently reviewed by a senior statistician. Tables containing both summary data and statistical results will be reviewed and values verified by a second person.

4.7 Fish Community

4.7.1 Objectives and Scope

A fish community monitoring program will be conducted as part of the AEMP. Specific Water Licence conditions applying to the fish community component of the AEMP for the Mine in the Water Licence MV2011L2-0004 [Part G, Schedule 6, Item 1a (iv) and 1d of MVLWB (2013)] are:

> *a) Monitoring for the purpose of measuring Project-related effects on the following components of the Receiving Environment:*
>
> *iv. fish population, and year-class strength and community composition using standard methods;*
>
> *d) Procedures to minimize the impacts of the AEMP on fish populations and fish habitat.*

The principal objective of the fish community component is to answer the following key question:

- Will the fish community be affected by the changes in water quality in Snap Lake and will any change be greater than predicted in the EAR?

Effects to the fish community will be assessed based on abundance as well as on year class strength, and community composition.

4.7.2 Design Rationale

The AEMP Design Plan considers the following:

- the requirements of the Water Licence;
- the desire expressed by Aboriginal organizations to include Lake Trout in the Snap Lake AEMP;
- Fisheries and Oceans Canada concerns about monitoring not only Lake Trout but the entire Snap Lake fish community, including measures of community composition, and year class strength; and,
- the need to use a standardized and well-established, widely accepted method.

The BsM protocol (Sandstrom et al. 2009) will be used to assess the fish communities in Snap Lake, Northeast Lake, and Lake 13. The BsM uses a widely-accepted sampling method developed by the Ontario Ministry of Natural Resources, and is endorsed by Fisheries and Oceans Canada as the desired assessment method. This method can be used to derive population parameters (i.e., biomass, abundance, community composition, and size at age).

Unlike other sampling methods such as Summer Profundal Index Netting that target specific fish species (e.g., Lake Trout), the BsM method employs large- and small-mesh gillnets to provide measures of relative abundance for the entire fish community. Such relative abundance measures can be used to track changes over time within Snap Lake, as well as to make comparisons between Snap Lake and the two reference lakes or to lakes in other parts of Canada where the BsM protocol has been used. While considerable effort has been expended to calibrate Summer Profundal Index Netting estimates of relative fish abundance with actual fish abundance (mostly for southern Canadian lakes), there are few data available to link BsM abundance with actual

fish abundance. Accordingly, the Ontario Ministry of Natural Resources is moving ahead with a database to tabulate actual fish abundance measurements (e.g., mark-recapture studies) and to facilitate analyses.

The BsM method was first used at Snap Lake and Northeast Lake in 2009, after the Mine began operations. As a result, evaluating the effects of the Mine on fish abundance based on the BsM method will be limited to evaluating effects compared to 2009.

In the 2009 sampling program, the BsM method was found to be suitable for assessing the abundance of large-bodied fish. However, it was not successful in the collection of small-bodied fish or the small-bodied stages (juveniles) of large-bodied fish, a situation that appears unique to Snap Lake and Northeast Lake. Various alternative methods are proposed to quantitatively assess the abundance of small-sized fish such as Ninespine Stickleback (*Pungitius pungitius*), Lake Chub (*Couesius plumbeus*), Slimy Sculpin (*Cottus cognatus*), and juvenile stages of Lake Trout and Round Whitefish. Because of concerns about the level of fish mortality associated with the BsM, and the need for live fish to meet the sampling needs of the AEMP fish health program, as well as other logistical considerations, several deviations were made from BsM method as described by Sandstrom et al. (2009) for the 2009 sampling program. One of these was to fish half the nets for 18 hours and the other half for 2 hours; however, the 2-hour sets yielded relatively few fish and were not comparable to the 18-hour sets even after adjustment for the time difference. As a result, the CPUE for 2009 was based on a smaller level of effort than specified for the BsM method.

In 2013, sampling will follow the BsM method as described by Sandstrom et al. (2009); therefore, results will be comparable to other lakes where the BsM method has been applied in northern and southern Canada. Beginning in 2012, a mark-recapture study was initiated to provide a reference value for the absolute number of Lake Trout in Snap Lake that can be applied to the BsM program (see Section 5.4). The BsM is proposed for 2013, 2015, and every three years thereafter; the program in 2015 is proposed such that the fish community program conforms to the same schedule as the fish health, benthic invertebrate, and sediment programs. The BsM method will be applied to the 2013 and 2015 sampling programs, and the results will be reviewed at the end of each of those years to assess whether the methods are meeting the goals of the AEMP Design Plan.

4.7.3 Field methods

The BsM protocol has been identified as a North American standard, and has been extensively evaluated (Lester et al. 1991; Bonar and Hubert 2002; Sandstrom et al. 2009). The BsM protocol specifies a combination of large- and small-mesh gillnets spanning a range of mesh sizes in each gang to target a broad range of fish sizes and species (Bonar and Hubert 2002). Large- and small-mesh nets will not be set in the same area; this will avoid large fish being attracted to small fish caught in the small-mesh nets, which could bias catches of large fish. Net gangs of large- or small-mesh nets will be set on bottom at a range of depths but perpendicular to depth contours, according to the specifications in Sandstrom et al. (2009), which are dependent on lake area and maximum depth.

Nets will be set for a minimum of 18 hours; to standardize catches, all catches will be converted to number per 24-hour period. Ideally, for the BsM to be most reflective of the fish community, composition, and abundance, netting would include both crepuscular periods (i.e., dawn and dusk), but because of the long hours of daylight at Snap Lake's latitude and also because of logistical considerations, nets will be set and retrieved entirely during daylight hours. Similar to 2009, sampling will be conducted after ice-out when the lake is nearly isothermal and fish are most active and most likely to be randomly distributed.

4.7.3.1 Sampling Locations and Effort

The field program will consist of approximately 21 consecutive days of fishing effort, with 7 days each at Snap Lake, Northeast Lake, and Lake 13. In general, fish capture and processing will follow the Ontario Ministry of Natural Resources BsM protocol (Sandstrom et al. 2009). Sampling will occur within one exposure area (Snap Lake) and two reference lakes (Northeast Lake and Lake 13). According to the BsM protocol (Sandstrom et al. 2009), sampling effort (i.e., length, size, and number of gillnets) is determined by a lake's surface area and maximum water depth. The surface areas and maximum water depths of the fish population monitoring sites are as follows:

- Snap Lake: surface area 1,425 ha, maximum depth 45 m;
- Northeast Lake: surface area 1,767 ha, maximum depth 28 m; and,
- Lake 13: surface area 1,050 ha, maximum depth 22 m.

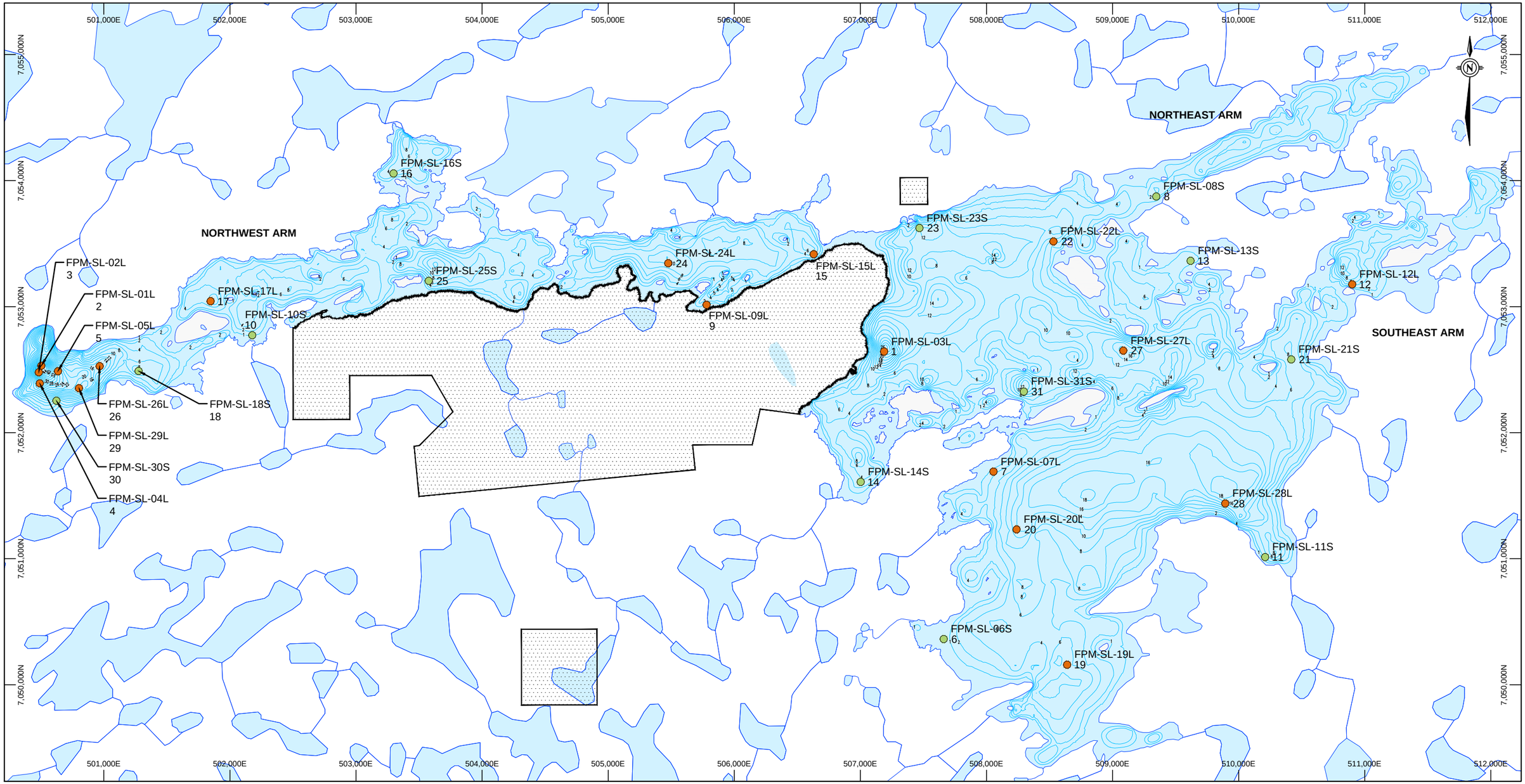
Sampling effort will be allocated as equally as possible in all regions of each lake and will be spatially stratified by water depth (Figures 4.7-1, 4.7-2, and 4.7-3; Appendix C; Tables C-1, C-2, and C-3) using gear as described in Section 4.7.3.2.

Based on the surface area and maximum water depth of Snap Lake, Northeast Lake, and Lake 13, a minimum of 87 net deployments (48 large-mesh and 39 small-mesh) will be required to obtain a representative sample for all 3 lakes (Sandstrom et al. 2009). The number of net deployments for the three lakes, with an 18 hour set duration, is shown in Table 4.7-1.

Table 4.7-1 Number of 18-Hour Net Deployments for Snap and Northeast Lakes and Lake 13

Design		Number of Net Deployments					
Strata ID	Depth [m]	Snap Lake		Northeast Lake		Lake 13	
		Large Mesh	Small Mesh	Large Mesh	Small Mesh	Large Mesh	Small Mesh
1	1 to 3	2	4	2	4	2	4
2	3 to 6	4	4	4	4	4	4
3	6 to 12	4	3	4	3	4	3
4	12 to 20	3	2	3	2	3	2
5	20 to 35	3	-	3	-	3	-
Total		**16**	**13**	**16**	**13**	**16**	**13**

m = metre; - = not applicable.



LEGEND

- FISH COMMUNITY MONITORING STATION - LARGE MESH GILLNET
- FISH COMMUNITY MONITORING STATION - SMALL MESH GILLNET
- DEPTH CONTOUR (m)
- WATERCOURSE
- WATERBODY
- SNAP LAKE MINE FOOTPRINT

REFERENCES

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 OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

SNAP LAKE PLANTSITE DRAWING OBTAINED FROM CLIENT. DATE: JUNE 12, 2012. "SNAPLAKE-08_STATMAP_2012". DRAWN BY Nampcy Solutions Ltd.

NOTES

MAP MOVED TO PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD83, COORDINATE SYSTEM : UTM ZONE 12.

PROJECT

De Beers Canada
SNAP LAKE MINE

TITLE

FISH COMMUNITY GILL NET MONITORING SITES IN SNAP LAKE, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C011
DESIGN	RS	2/10/1012	SCALE	AS SHOWN REV. 0
CADD	JEF	10/10/2012		
CHECK	TD	30/10/2012		
REVIEW	PC	30/10/2012		

FIGURE: 4.7-1

L:\2012\1337\12-1337-0002\1100\Report_C\ Drawing file: Fig4.7-1_12133700021100C011 FishMon2013-2016.dwg Nov 01, 2012 - 2:04pm

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7,064,000N 7,063,000N 7,062,000N 7,061,000N 7,060,000N 7,059,000N 7,058,000N 7,057,000N

FPM-NEL-04S 4
FPM-NEL-15S 15
FPM-NEL-23L 23
FPM-NEL-05S 5
FPM-NEL-32S 32
FPM-NEL-12L 12
FPM-NEL-13L 13
FPM-NEL-31L 31
FPM-NEL-14S 14
FPM-NEL-25S 25
FPM-NEL-18S 18
FPM-NEL-34S 34
FPM-NEL-35L 35
FPM-NEL-02L 2
FPM-NEL-36L 36
FPM-NEL-06S 6
FPM-NEL-28L 28
FPM-NEL-21L 21
FPM-NEL-30L 30
FPM-NEL-03L 3
FPM-NEL-26S 26
FPM-NEL-38L 38
FPM-NEL-29L 29
FPM-NEL-37L 37
FPM-NEL-33S 33
FPM-NEL-11L 11
FPM-NEL-09L 9
FPM-NEL-24S 24
FPM-NEL-22L 22
FPM-NEL-27S 27
FPM-NEL-08S 8
16
FPM-NEL-16S
FPM-NEL-20L 20
FPM-NEL-19L 19
FPM-NEL-01L 1
FPM-NEL-10L 10
FPM-NEL-07S 7
FPM-NEL-17S 17

LEGEND

- FISH COMMUNITY MONITORING STATION - LARGE MESH GILLNET
- FISH COMMUNITY MONITORING STATION - SMALL MESH GILLNET
- DEPTH CONTOUR (m)
- WATERCOURSE
- WATERBODY

REFERENCES

DIGITIZED FROM NTS TOPOGRAPHIC MAP 75 M/10 Ë 1985 HER MAJESTY THE QUEEN IN RIGHT OF CANADA. DEPARTMENT OF ENERGY, MINES AND RESOURCES. PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD27, COORDINATE SYSTEM : UTM ZONE 12.

REFERENCE LAKE OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

NOTES

MAP MOVED TO PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD83, COORDINATE SYSTEM : UTM ZONE 12.

500 0 500
SCALE METRES

PROJECT
De Beers Canada
Snap Lake Mine

TITLE
FISH COMMUNITY GILL NET MONITORING SITES IN NORTHEAST LAKE , 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C012
DESIGN	TD	2/10/1012	SCALE	AS SHOWN REV. 0
CADD	JEF	11/10/2012		
CHECK	TD	30/10/2012		
REVIEW	PC	30/10/2012		

FIGURE: 4.7-2

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LEGEND

- FISH COMMUNITY MONITORING STATION - LARGE MESH GILLNET
- FISH COMMUNITY MONITORING STATION - SMALL MESH GILLNET
- DEPTH CONTOUR (m)
- MINE FOOTPRINT
- WATERCOURSE
- WATERBODY

REFERENCE

BASE VECTOR DIGITAL CANVEC 1:50K DATA OBTAINED FROM GEOGRATIS ONLINE.
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ALL RIGHTS RESERVED.
DATUM: NAD83 PROJECTION: UTM ZONE 12

PROJECT
De Beers Canada
SNAP LAKE MINE

TITLE
FISH COMMUNITY GILL NET MONITORING SITES IN LAKE 13, 2013 TO 2016 AEMP

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	121337000211000013	
DESIGN	RS	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	10/10/2012			
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

FIGURE: 4.7-3

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Each deployment of fishing gear will be assigned a sampling effort code according to the convention shown in Table 4.7-2. Effort Number will be assigned sequentially as per Table 4.7-3 and fish identification number as per Table 4.7-4.

Table 4.7-2 Code Convention for Sampling Effort

Lake	Year	Site	Effort Number
Snap Lake	13	FPM-SL-xx	001
NEL	13	FPM-NEL-xx	100
Lake 13	13	FPM-L13-xx	200

Table 4.7-3 Range of Unique Fishing Effort Number Numbers for Each Gear Type and Lake

Gear type	Unit of Effort	Snap Lake	Northeast Lake	Lake 13
Gillnet	1 set and lift	001 to 099	100 to 199	201 to 299

Note: will not duplicate 2009 sample identification numbers

Table 4.7-4 Range of Unique Fish Identification Number for Each Gear Type, Lake, and Program

Gear Type	Snap Lake	Northeast Lake	Lake 13
Gillnet	00001 to 00999	08000 to 08999	0Y000 to 0YYYY

Note: will not duplicate 2009 sample identification numbers

One Sampling Effort Datasheet will be completed per sampling event. The following information will be recorded for each sampling event (effort):

- effort number;
- site number;
- UTM coordinates;
- set date and time;
- lift date and time;
- gear type;
- gear dimensions/settings;
- depth of site;
- water quality field measurements (water temperature [ºC], DO [mg/L], conductivity [µS/cm], pH);
- Secchi depth;
- weather conditions (air temperature and wind speed and direction, taken from the on-site weather station);
- general habitat description including substrate type; and,
- number of target species and non-target species captured.

4.7.3.2 Net Design and Setting

Large-mesh gangs will be 24.8 m long (8 mesh sizes x 3.1 m panels) by 1.8-m high and have mesh sizes as described below and in Appendix C, Table C-4. All panels in the gang will be sewn together with 2 m of mesh to 1 m of lead line. Double-knotted construction will be used for all mesh sizes. Mesh panels will be non-sequentially arranged in a single series. The recommended configuration is a double gang, strapped (joined) at the ends of the spanners. Panels on either side of the join should not be the same mesh size. Specifications for the large-mesh gillnets are provided in Appendix C, Table C-4.

Small-mesh gangs will be 12.5 m long (5 mesh sizes x 2.5-m panels) by 1.8 m high and have mesh sizes as described below and in Appendix C, Table C-4. The panels in the gang will be sewn together with 5 m of mesh to 2.5 m of lead line. Double-knotted construction will be used for all mesh sizes, except for the 13- to 25-mm panels, which will be single-knotted because these diameters are too fine for double knotting. Panels will be non-sequentially arranged in a single series. The recommended configuration is a double gang strapped (joined) at the ends of the spanners. Panels on either side of the join should not be the same mesh size. Specifications for the small-mesh gillnets are provided in Appendix C, Table C-4.

The following is summary of the basic details of the large- and small-mesh net design and setting:

Sampling season:	early summer right after ice-out
Set duration:	large mesh: minimum 16 hours; maximum 22 hours; target 18 hours
	small mesh: minimum 12 hours; maximum 22 hours; target 18 hours
	all catches expressed as catch per 24 hours
Gear length:	large mesh: 49.6 m (8 panels x 3.1-m panels x 2 gangs)
	small mesh: 25.0 m (5 panels x 2.5-m panels x 2 gangs)
Gear height:	large mesh: 1.8 m
	small mesh: 1.8 m
Mesh series:	large mesh: 38, 51, 64, 76, 89, 102, 114, 127 (stretch mm)
	small mesh: 13, 19, 25, 32, 38 (stretch mm)
Mesh order:	non-sequential single series
Set orientation:	perpendicular or oblique to contours
Depth stratification:	1 to 3 m, 3 to 6 m, 6 to 12 m, 12 to 20 m, 20 to 35 m, 35 to 50 m
Spatial stratification:	effort equally distributed over entire lake

An unique identification number will identify each individual fish. Fish identification numbers will be assigned sequentially for each gear type and lake, as described in Appendix C, Table C-4.

4.7.3.3 Gear Configuration and Deployment

Gear will be configured and deployed according to the following guidelines:

- All netting occurs after ice-out over an approximate three-week period.
- If the water column is stratified, nets within a particular stratum are not allowed to straddle the thermocline.
- All gear is set on the bottom and oriented perpendicular or near-perpendicular to depth contours.
- Individual nets span only one depth stratum.
- The minimum set depth is 2 m.
- During setting, islands, shoals, and reefs are avoided.
- Small-mesh gangs should not be fished in association with large-mesh gangs (i.e., within 50 m).
- In the event of wind, nets are set and lifted up-wind as much as possible.

The following information will be collected for each sampling effort:

- UTM coordinates and water depth at either end of each net;
- the set and lift time of each net;
- major substrate type (e.g., mud, sand, gravel, cobble);
- water quality field measurement profiles (DO, temperature, conductivity, pH, and water clarity);
- time (hour) for each fishing effort for each gear type;
- gear specific parameters (mesh size that each fish was captured in); and,
- weather (air temperature and wind velocity and direction, taken from the on-site weather station).

4.7.4 Fish Processing

All live fish will be removed immediately from nets as they are lifted and kept live in a separate container of fresh water or in a live box attached to the side of the boat. Once all nets have been collected, live fish will be identified by species, measured for total length (±1 mm), fork length (±1 mm), and fresh body weight (±0.1 g wet weight [ww]). The first two leading fin rays of the left pelvic fin ray will be removed to use as ageing structures. All external anomalies (described below) will be noted and, where identification of the anomaly is uncertain, a photograph will be taken. Where possible, the sex and stage of sexual maturity will be determined from external features. If there is uncertainty about species, a voucher sample will be sacrificed by a blow to the head, placed in a labelled bag, and kept on ice until it can be frozen. Once all live fish have been processed, they will be released at their original capture location.

For all mortalities, the following measurements and samples will be taken:

- total length (±1 mm);
- fork length (±1 mm);
- total body weight (±1 g);

- stomach contents;
- age (sagittal otolith and pelvic fin rays);
- sex;
- gonad weight (±0.001 g);
- liver weight (±0.001 g);
- fecundity and egg weight estimate for mature females;
- state of reproductive development;
- life stage; and,
- external and internal examinations (see Sections 4.7.5.1 and 4.7.5.2).

4.7.4.1 External Examinations

Total length (±1 mm), fork length (±1 mm), and total body weight (±1 g) will be recorded for all captured fish. External observations will be made on features of the fish (eyes, gills, pseudobranchs, thymus, skin, body form, fish, and opercules) that do not appear normal (i.e., wounds, tumours, parasites, fin fraying, gill parasites, or lesions).

4.7.4.2 Internal Examinations

Reproductive tissues will be carefully excised for obvious signs of asymmetry or unusual patterns of gonadal development. Total gonad weight and liver weight will be recorded. An ovary sample consisting of approximately 5 g will be removed from left and right ovaries and weighed to as close to 0.1 g as possible for fecundity analysis and egg weight measurement. The samples will be placed in vials and placed in 10% buffered formalin.

Photographs will be taken of any abnormal gonads and of representative normal gonads. Whole gonads will also be preserved in 10% buffered formalin when abnormal conditions are observed or when gonad staging determinations are in question. Other organ systems will be examined for their general appearance and the presence of abnormalities. If abnormalities, such as tumours, necrosis, or heavy parasite loads are observed, their appearance will be noted and photographs will be taken. The gastrointestinal tract will be dissected. Stomach fullness will be noted along with a general description of gut contents and parasite load.

A skinless 5-g dorsal muscle plug from each of the species collected will be removed to support the Stable Isotope Food Web Analysis Special Study (Section 5.5). Remaining tissue will be used in the fish tissue chemistry analysis (Section 4.8).

4.7.5 Data Analysis

4.7.5.1 Approach

Data will be analyzed to address the key question (Table 4.7-5). Details on each type of analysis follow.

Table 4.7-5 Overview of Analysis Approach for Fish Community Key Question

Key Question	Overview of Analysis Approach
1. Will the fish community be affected by the changes in water quality in Snap Lake and will any change be greater than predicted in the EAR?	▪ whole-lake-area weighted catch-per-unit-effort; ▪ age structure; ▪ size (length and weight); ▪ mortality; ▪ maturity; ▪ age at maturity; ▪ ; ▪ growth rate; ▪ fecundity; and, ▪ community composition.

4.7.5.2 Abundance

The resulting catch per unit effort from the BsM for each depth stratum will be scaled to the area of the lake within that depth stratum based on examination of the hypsometric curve for that lake. A whole-lake-area weighted CPUE will be calculated as the mean of the depth-strata-area weighted CPUEs. To establish a CPUE for Lake Trout, only fish caught in large-mesh nets will be used. Once sufficient years of sampling have been completed to establish among-year temporal variation, it may be possible to determine how effective the sampling method is at detecting change, and to relate this change to the low action level for the Response Framework (Section 7).

The BsM method only provides a measure of relative fish abundance, and there is a need to relate this to the actual abundance and weight of fish in the lake, especially if there is a large increase or decrease in CPUE. To provide a reference value of Lake Trout abundance in Snap Lake in 2013, a mark-recapture study for Lake Trout will be conducted in Snap Lake in 2012 and 2013 as a Lake Trout Population Estimate Special Study (details in Section 5.4). The number of marked fish, along with the proportion recaptured up until the final sampling date in July 2013, will be used to estimate the number of Lake Trout and their weight in the lake. The number of Lake Trout in the lake will be related to the CPUE of Lake Trout from the BsM method to equate CPUE.

Another use of the calibration of Snap Lake BsM is that for future collections, the total number of Lake Trout collected will be expressed in terms of proportion relative to the entire population, and adjustments will be made to sampling effort to verify that sampling is sustainable.

4.7.6 Fish and Community Attributes

In addition to providing a relative measure of abundance, the fish captured in the BsM netting will also be used to provide measures of fish population parameters:

- age structure;
- size (length and weight);
- mortality;
- maturity;
- age at maturity;
- growth rate;
- fecundity; and,
- community composition.

Age structure: All large-bodied fish (e.g. Lake Trout, Round Whitefish, Northern Pike, Burbot, Longnose Sucker) collected in the BsM sampling will be aged using pelvic fin rays and otoliths. Both structures will be processed using thin-sectioning technique. The comparability of these methods will be examined using regression analysis, but since otolith age is considered to be a more accurate and more precise measure of aging (Campana 2001) otolith age will, where possible, be used to examine age-dependent criteria such as growth and fecundity, and the relationship between pelvic fin and otolith age will be used to calculate an adjusted fin ray age. Comparisons of mean age within and between sexes, and, within and among lakes, will be conducted as an indication of age class structure. The lake-area weighted CPUE will be converted to numbers of fish per hectare from the calibration. These numbers will be apportioned to each age class and the resulting data will be fitted with a decay curve. Alternatively, the fish density will be transformed to linearize the relationship. From the resulting relationships, the age at zero density will be calculated.

To compare Lake Trout age composition among lakes, ages for each lake will be binned into five-year periods. The distribution of ages for each lake will be determined by count or percentage, and the distributions will be compared among lakes using Chi-square or K-S tests, respectively.

Size of fish: Fish will be measured for total length (±1 mm) and total weight (±1 g). Fish weighing greater than 500 g will be measured using a 5-kg Pesola spring scale. Fish weighing less than 500 g will be measured to the nearest 0.1 g using an Acculab V-600 electronic balance. Comparisons of mean fish size within and between sexes, within and among lakes, will be made using univariate methods, as appropriate. Data will be examined for normality and homogeneity of variance using the K-S test and Levene's test, and if necessary will be subjected to a number of different data transformations and then re-assessed for normality.

***Mortality*:** Mortality rate (Z) within and among lakes for Lake Trout and Round Whitefish will be estimated from the catch curve based on the number of fish in each age-class caught during BsM sampling. Specifically Z is estimated as the difference from 1 of the antilog of the slope of the negative linear relationship between log-normal CPUE and otolith age for fish older than the median age. Where the most abundant age group differs

among lakes, the same age groups will be included in the catch curve for each lake to standardize between or among lakes.

Maturity: All gonads will be examined for stage of maturity and assigned to one of three groups: juvenile and immature, male and mature, or female and mature. To confirm measures of maturity, the individual weight of both gonads will be determined and ranked by GSI (percentage of total body weight) from highest to lowest within a sex and for juveniles. A logistic curve will be fitted to these data, and mature fish will be reclassified as immature if GSI is less than 20% of the asymptotic GSI.

Age at maturity: Using data from the maturity determination, all fish will be assigned to age bins consisting of four to five age groups from youngest to oldest with at least five fish per age bin. This will be done for juveniles and males, and juveniles and females. The percentage of mature fish within a bin will be calculated and the data for percentage mature will be arcsine-transformed and fitted to the midpoint age of the age bin using a logistic curve. From this relationship, the bin midpoint age group will be estimated for 50%, 75%, and 100% mature. As a measure of resting fish (those fish that are of an age that they should have spawned but probably have not due to limited food intake), all fish older than the midpoint age of the age bin corresponding to 100% maturity will be deemed resting. This will be done separately for males and females.

Growth rate: To evaluate growth rate over the range of fish length collected, the relationship between log length and age will be examined and comparisons will be made between and among groups using analysis of covariance (ANCOVA). To compare fish growth parameters (L_∞, asymptotic length; theoretical length to which the fish would grow if permitted to grow infinitely old), K (von Bertalanffy growth coefficient; the instantaneous rate at which length approaches L_∞) to the parameters of other fish stocks, a von Bertalanffy growth equation will be used. Growth parameters for individual fish will be estimated from the von Bertalanffy length-age model ($L_t = L_\infty(1-e^{-K(t-t0)})$ based on back-calculated length at age (Quinn and Deriso 1999). In the event that slopes are heterogeneous in the ANCOVA, data will be examined for obvious outliers and the methods outlined in Barrett et al. (2009) for dealing with heterogeneity of slopes will be applied.

Growth rate: To evaluate growth rate, the relationship between log length and age will be examined and comparisons will be made between and among groups using ANCOVA. To compare fish growth parameters to the parameters of other fish stocks, a von Bertalanffy growth equation will be used. In the event that slopes are heterogeneous in the ANCOVA, data will be examined for obvious outliers and the methods outlined in Barrett et al. (2009) for dealing with heterogeneity of slopes will be applied.

Fecundity: As a measure of fecundity (i.e., eggs per female), the combined number of eggs from both gonads for the current year's spawning will be determined. Fecundity will be measured by estimating the number of eggs in a subsample preserved in 10% buffered formalin, which preserves egg size and shape. Comparisons of fecundity between or among groups will be made by examining the relationship between fecundity and length (Koops et al. 2004) by ANCOVA.

Community composition: The community composition within and among lakes will be examined to evaluate measures of evenness and numbers within the fish community using Shannon's index of diversity (H'):

$$H' = -\sum_{i=1}^{R} p_i \log p_i$$

Equation 10

where p_i is the proportion of individuals belonging to the *i*th species.

4.7.7 QA/QC Procedures

The QA/QC procedures are designed such that field sampling, laboratory analyses, data entry, data analyses, and report preparation produce technically sound and scientifically defensible results. As part of routine QA/QC for field operations, equipment will be calibrated and samples will be collected by experienced personnel and will be labelled, preserved, and shipped according to standard protocols. Specific work instructions that outline each field task in detail will be provided to field personnel by the task manager. Detailed field notes will be recorded in waterproof field books and on pre-printed waterproof field data sheets in either pencil or indelible ink. Data sheets and sample labels will be checked at the end of each field day for completeness and accuracy. Chain-of-custody forms will be used to track the shipment of all samples.

All gillnet sampling related to BsM will be uniquely numbered with UTM coordinates, set and lift time and date, gear type, and water depth. At the time of sampling, the water quality will be recorded along with the wind direction and intensity, and wave height.

In the field, data forms will be reviewed for accuracy daily by crew leads. Data will be entered into a Microsoft Access database. Upon completion of data entry, each table in the database will be reviewed for accuracy using a series of error checking queries as a secondary level of QC. Finally, 10% of the sampling effort and fish biological data will be manually verified against the hard copy data forms as a third level of QC.

For every ten fecundity samples, one sample will be re-counted by a second, independent individual. If the re-count of the sample is within 10% of the initial count, the initial count will be regarded as acceptable and no re-count of the remaining samples will be required. If the re-count is not within 10% of the initial count, the initial count will be regarded as unacceptable and the remaining nine samples will be re-counted. The QA/QC procedure will be repeated until re-counts are within 10% of the previous count.

A review of data entry will involve checking a minimum of 10% of the data for completeness, data entry errors, transcription errors, and invalid data. This checking will be done by a second, independent individual. If an error is found, all data will undergo a zero tolerance QA check (i.e., every datum checked). All statistical results will be independently reviewed by a senior statistician. Tables containing both summary data and statistical results will be reviewed and values verified by a second, independent individual.

4.8 Fish Tissue Chemistry

4.8.1 Objectives and Scope

The Water Licence requires that the AEMP include monitoring of contaminant levels in fish flesh due to the changes in water quality in Snap Lake and Northeast Lake (Schedule 6, G (a) (v)). As discussed previously, Lake 13 will be included as an additional reference lake.

An objective of assessing fish tissue metal concentrations under the AEMP is to determine whether treated effluent discharged from the Mine has altered fish in such a way as to limit their use by humans. Fish usability can be affected by altered flavour or odour (tainting), or contaminant (e.g., metal) concentrations above consumption guidelines. In addition, body burdens of various contaminants can confirm exposure and may help explain any effects observed during the fish health survey.

Analyses of fish tissues for metal concentrations will be conducted on Lake Chub collected as part of the fish health program and on Lake Trout and Round Whitefish collected during the fish community program. The Lake Chub results will be used as an early warning indicator of potential effects on tissue quality of Lake Trout and as part of the interpretation of the fish health study. The fish tissue survey is designed to address the following key questions:

- Are tissue metal concentrations in fish from Snap Lake increasing relative to baseline?
- Are tissue metal concentrations in fish from Snap Lake increasing relative to reference lakes?

An increase in tissue metal concentrations in Lake Trout or Round Whitefish relative to baseline will be used as an early warning indicator of effects on fish usability.

4.8.2 Sampling Locations

Fish will be collected from the main body of Snap Lake, Northeast Lake, and Lake 13.

4.8.3 Design Rationale

Two sentinel fish species, Lake Trout and Round Whitefish, will be monitored to retain consistency with the baseline data collection and to document tissue concentrations in species of fish that are likely to be eaten by community members. A small-bodied fish, Lake Chub, will also be added to determine whether metal concentrations are different in small and large-bodied fish, to provide an early indicator of potential changes in large-bodied fish, and to support potential effects observed during the fish health survey.

The frequency of determination of metal levels in fish tissue will be increased from the 2005 AEMP Design Plan. The previous Water Licence and 2005 AEMP Design Plan required the collection of fish tissue every five years. In the AEMP Re-evaluation Report (De Beers 2012a), it was determined that studying fish every five years was potentially insufficient to detect meaningful trends over the life of the mine; therefore, a recommendation to analyze fish tissues every three years was made; fish health and fish community studies were also recommended to move to a frequency of every three years.

Sampling will take place every three years starting in 2013 for large-bodied fish and 2012 for small-bodied fish. This sampling frequency strikes a balance between the need for monitoring and the mortality caused by

monitoring. A non-lethal tissue plug method may be considered for large-bodied fish, pending sufficient tissue sample and appropriate DLs achievable from the tissue plug sampling method, to reduce total mortalities if additional sampling is required. Fish collection for fish tissue will be harmonized with the fish health and community programs to reduce the number of mortalities due the AEMP sampling.

4.8.4 Field Methods

Fish collected as part of the 2012 and 2013 Fish Health and Fish Community programs will be used in the Fish Tissue component of the 2013 AEMP. The small-bodied fish, Lake Chub, will be captured during the Fish Health program and two large-bodied species, Lake Trout and Round Whitefish, will be captured during the Fish Community program. Fish captured and sacrificed during these assessment surveys will be used in the 2013 tissue analysis to reduce fish mortality. Carcass (Lake Chub) and muscle, liver, and kidney (Lake Trout and Round Whitefish) will be analyzed.

A sub-sample of adult Lake Chub carcasses will be submitted from each lake for tissue chemistry; eight male and eight female carcasses (minimum 5 g weight each) will be retained for these analyses. If fish of sufficient size are not available from each lake to meet this minimum sample weight, then composite samples made up of similar sized (i.e., medium and large) and same sex (i.e., male only and female only) fish will be used. Composites will be composed of no more than four fish. The remaining carcasses will be archived.

For large-bodied fish, the liver and kidney tissues will be removed, weighed and placed in a separate Ziplock® bag and labelled appropriately, including fish identification number, tissue type, and analyses required. Immediately after the organs have been removed, fillets will be removed from ten fish of each species (five of each sex) from each lake and analyzed for metal concentrations. Flesh from an additional two fish from each sex will be removed and archived. Fillets will be removed from each fish using a clean filleting knife. The skin will be removed from the fillets and efforts will be made to eliminate contamination by covering the work area with clean plastic wrap that will be changed after each dissection, and rinsing all utensils in 5% nitric acid between fish. Each fillet will be weighed and the measurements will be recorded. Each fillet will be placed in a separate Ziplock® bag and labelled appropriately, including fish identification number and analyses requested.

Tissues from the three species of fish will be sent to an appropriate laboratory for analyses of the metals and major ions listed in Table 4.8-1.

4.8.5 Data Analysis

4.8.5.1 Approach

The fish tissue component analyses is designed to answer the key questions listed in Section 4.8.1. An overview of the analysis approach associated with these two questions is provided in Table 4.8-2. Specific details relevant to data analysis methods to address each key question are provided in Section 4.8.5.2.

4.8.5.2 Analysis

Prior to summarizing and performing statistical analyses on the fish tissue chemistry data, values below the limit of detection, or non-detects, will be reviewed. Where data are below the laboratory detection limit, values will be set to one-half the detection limit to calculate summary statistics (i.e., the mean, SD, SE, maximum, and minimum values). If results for one parameter are all below the detection limit, no mean will be calculated, and the result will be reported as "not-detected".

Table 4.8-1 Variables to be Analyzed in Tissue Samples for the Snap Lake AEMP

Variable	Detection Level (µg/g ww)	Variable	Detection Level (µg/g ww)
% Moisture	0.1	Molybdenum (Mo)	0.004
Aluminum (Al)	0.4	Nickel (Ni)	0.01
Antimony (Sb)	0.002	Phosphorus (P)	5 to 15
Arsenic (As)	0.004	Potassium (K)	20 to 60
Barium (Ba)	0.01	Rhenium (Re)	0.002
Beryllium (Be)	0.002	Rubidium (Rb)	0.01
Bismuth (Bi)	0.002	Selenium (Se)	0.02
Boron (B)	0.2	Silver (Ag)	0.001
Cadmium (Cd)	0.002	Sodium (Na)	20 to 60
Calcium (Ca)	0.5 to 1.5	Strontium (Sr)	0.01
Cesium (Cs)	0.001	Tellurium (Te)	0.004
Chromium (Cr)	0.01	Thallium (Tl)	0.0004
Cobalt (Co)	0.004	Thorium (Th)	0.002
Copper (Cu)	0.01	Tin (Sn)	0.004
Gallium (Ga)	0.004	Titanium (Ti)	0.01
Iron (Fe)	0.2	Uranium (U)	0.0004
Lead (Pb)	0.004	Vanadium (V)	0.004
Lithium (Li)	0.02	Yttrium (Y)	0.002
Magnesium (Mg)	1 to 3	Zinc (Zn)	0.1
Manganese (Mn)	0.004	Zirconium (Zr)	0.04
Mercury (Hg)	0.001		

µg/g ww = micrograms per gram wet weight.

Table 4.8-2 Overview of Analysis Approach for Fish Tissue Key Questions

Key Question	Overview of Analysis Approach
1. Are tissue metal concentrations in fish from Snap Lake increasing relative to baseline?	Tissue chemistry concentrations from Lake Chub (i.e., carcass), and the large-bodied fish Lake Trout and Round Whitefish (i.e., liver, kidney, and flesh) will be compared to the normal range of baseline tissue concentrations, where possible.
2. Are tissue metal concentrations in fish from Snap Lake increasing relative to reference lakes?	Tissue chemistry analyses will be performed on Lake Chub carcass as well as large-bodied fish tissues (i.e., liver, kidney and muscle tissue from Lake Trout and Round Whitefish) from Snap Lake and will be compared to the tissue concentrations in the reference lakes, as well as the normal range (i.e., reference lake tissue concentration ± 2 standard deviations).

4.8.5.2.1 Key Question 1: Are tissue metal concentrations in fish from Snap Lake increasing relative to baseline?

Where tissue concentrations (flesh, liver and kidney) in Lake Trout and Round Whitefish are above the limit of detection in more than 50% of the samples, tissue metal concentrations from Snap Lake will be compared to the normal range to determine whether there has been an increase in tissue metal concentrations relative to baseline concentrations. The normal range will be calculated as the mean of the pooled Snap Lake baseline concentrations ± 2 SD, and the mean and SD of tissue metal concentrations from Snap Lake will be compared to the normal range of the baseline data, as per the statistical tests presented in Table 4.8-3. However, if the measured concentration of a metal in 2015 fish tissue samples is below the limit of detection from baseline

analyses (i.e., analytical DLs have improved and metals are detectable in 2013 at levels that were not measurable during the baseline studies), then statistical tests will not be performed and no conclusions will be made regarding temporal trends for that metal in fish tissue relative to baseline.

4.8.5.2.2 Key Question 2: Are tissue metal concentrations in fish from Snap Lake increasing relative to reference lakes?

Where tissue concentrations are above the limit of detection in more than 50% of the samples, tissue metal concentrations in Snap Lake and the reference lakes will be compared to determine whether there are statistically significant differences between Snap Lake and the reference lakes as per the statistical tests presented in Table 4.8-3. The normal range will be calculated as the mean of the pooled reference areas ± 2 SD, and the mean and SD of tissue metal concentrations from Snap Lake will be compared to the normal range from the reference lakes.

Table 4.8-3 Statistical Procedures Used in the Analysis of Fish Tissue for Identifying Differences between Reference and Exposure Areas for Endpoints

Metal	Dependent Variable (Y)	Covariate (X)	Statistical Procedure
Mercury (Hg), Selenium (Se)[(a)]	Tissue mercury or selenium concentration	Length, weight or age[(b)]	ANCOVA
Aluminum (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Bismuth (Bi), Boron (B), Cadmium (Cd), Calcium (Ca), Cesium (Cs), Chromium (Cr), Cobalt (Co), Copper (Cu), Gallium (Ga), Iron (Fe), Lead (Pb), Lithium (Li), Magnesium (Mg), Manganese (Mn); Molybdenum (Mo), Nickel (Ni), Phosphorus (P), Potassium (K), Rhenium (Re), Rubidium (Rb), Silver (Ag), Sodium (Na), Strontium (Sr), Tellurium (Te), Thallium (Tl), Thorium (Th), Tin (Sn), Titanium (Ti), Uranium (U), Vanadium (V), Yttrium (Y), Zinc (Zn), Zirconium (Zr)	n/a	n/a	ANOVA

(a) mercury and selenium can biomagnify (i.e., accumulate to a greater degree in higher trophic level organisms), therefore these metals are standardized to fish size for statistical testing.

(b) The best covariate will be used in the statistical analysis, as determined by regressing tissue mercury or selenium concentration against each potential covariate (i.e., length, weight or age). The covariate with the strongest regression relationship (i.e., smallest *P*-value) will be used as the covariate for the ANCOVA analysis.

4.8.6 QA/QC Procedures

Duplicate tissue samples from large-bodied fish will be collected in selected sampling areas and submitted as available with sufficient sample sizes. Inter-laboratory comparisons will be done with large-bodied fish with a subset of samples going to two laboratories to compare results.

As per the industry standard, a series of sample blanks, spikes, and duplicates, as detailed above, will be run in parallel with the tissue chemistry samples. All results of these internal QA processes will be reported with the laboratory data and any deviations from acceptable limits will be reported. If acceptable limits are exceeded, samples will be re-assessed and, if necessary, re-analyzed.

Laboratory data will be screened similar to the water quality data (Section 4.2.6.2). A review of the data entry will involve checking a minimum of 10% of the data for completeness, data entry errors, transcription errors, and invalid data. This checking will be done by a second, independent individual. If an error is found, all data will undergo a zero tolerance (i.e., every datum checked) QA check. All statistical results will be independently reviewed by a second, competent statistician. Tables containing both summary data and statistical results will be reviewed and values verified by a second, independent individual.

4.9 Fish Tasting

Since 2004, fish tasting has been conducted annually by De Beers in conjunction with the AEMP. The fish tasting program is an informal annual gathering of members of Aboriginal organizations and De Beers staff at the Mine site to taste fish harvested from Snap Lake. The fish tasting event was developed in 2004 in response to Aboriginal group concerns that the Mine may adversely affect the texture and taste of fish in Snap Lake. The fish tasting program is also conducted to meet requirements under the Environmental Agreement and Water Licence. During the fish tasting, community members determine whether the flavour and texture of cooked fish are acceptable to community members.

4.9.1 Objectives and Scope

The principal objective of the fish tasting is to obtain feedback from community members relating to Snap Lake Lake Trout and Round Whitefish taste, texture, general condition, and health. A secondary objective is to meet the requirements set out in Part G of the Water Licence:

> *1a) a process for measuring the Project-related effects on:*
>
> *vi. the taste of fish, to be completed with the communities, due to changes in water quality at Snap Lake.*

The key question of the fish tasting program is:

- Are the taste and texture of fish captured in Snap Lake acceptable to community members?

4.9.2 Sampling Locations

The fish for the fish tasting program will be captured in the main basin of Snap Lake. The sampling locations will be chosen by the Aboriginal fishermen based on traditional knowledge of fish habitat preferences along with past fish health program sampling success. If possible, fish will be caught from the same vicinity each year.

4.9.3 Design Rationale

The first fish tasting at Snap Lake was held in May 2004. De Beers conducts the Fish Tasting Program annually during the open water season. The study methods are based on advice provided by Fisheries and Oceans Canada during discussions at the May 24, 2005, Fisheries Authorization Coordination meeting and comments from Snap Lake Environmental Monitoring Agency and Aboriginal organizations participating in the fish tastings.

4.9.4 Field Methods

Catching the Fish (Fishing)

Community members will be invited to angle and set nets on Snap Lake for a period not exceeding two days during September. The location will be recorded using a GPS. As recommended by Fisheries and Oceans Canada, a 2-panel, 3-inch mesh monofilament gill net will be used. To stay within the annual catch limits established by DFO, the volume of fish caught will not exceed 40 kg.

The amount of time spent fishing with each type of fishing gear will be recorded to calculate fishing effort. The species of fish caught, and the date and time of capture will also be recorded.

Preparing the Fish (Filleting)

Fish will be cleaned by an Aboriginal community member, or by De Beers staff as requested by the community members present. Fish length and weight will be recorded and internal and external health assessments will be completed at the discretion of the community members present.

The fish will be filleted at the Snap Lake outdoor gazebo, the environmental laboratory, or the kitchen. The whole fish will be reviewed and assessed for general health. Participants will evaluate the health, texture, and taste of the fish according to the Fish Preparation and Observation Protocol (Appendix D). The assessment will involve taking a photograph, checking the internal organs, and recording general observations when the fish are being prepared for cooking.

Fish health observations will be recorded using the procedures outlined in the Fish Tasting Protocol:

1) Fish appears to be above average in health (“very good”).
2) Fish appears to be of average health (“good”).
3) Fish is below average health (“not good”).

If parasites are observed, or if there appear to be health issues or abnormalities, the parasite or abnormality will be preserved in 10% neutral buffered formalin for further identification and representative photographs will be taken. The non-consumable components of the fish (guts, bones, fins, scales, etc.) will be disposed appropriately.

Cooking the fish (Cooking)

Consistency in fish cooking methods will be maintained by following traditional cooking methods. The fish will be cooked according to traditional cooking methods:

1) Preparation of the fish will be only by boiling. Each individual fish will be boiled separately in water that has not been used for the preparation of any prior fish.
2) No cooking medium (oil, butter, margarine) and no spices, seasoning, salt, or pepper will be applied to the fish.

The fish will be cooked at a location determined by De Beers based on the weather conditions and other potential health and safety considerations (Snap Lake outdoor gazebo, environmental laboratory, or the kitchen). If the fish tasting occurs outdoors, the fish may be cooked over an open fire and De Beers will provide wood for the fire.

Evaluating the fish (Evaluating)

Comments from the participants regarding the taste and texture of the cooked fish will be recorded on a data sheet that will be provided. Additionally, comments from the participants will be verbally recorded using a video camera. To qualify the fish palatability, participants will follow the evaluation protocol, which will be explained prior to tasting to promote consistency among participants. If required, De Beers will provide translation services.

The texture of the cooked fish will be evaluated based on the following:

1) Texture is firm; fish is above average quality (“very good”).
2) Texture is of average firmness, fish is average quality (“good”).
3) Texture is below average firmness; fish is below average quality (“not good”).

The taste of the fish will be evaluated based on the following:

1) Fish taste appears to be above average (“very good”).
2) Fish taste appears to be average (“good”).
3) Fish taste is below average (“not good”).

4.9.5 Data Analyses

The fish length and weight will be recorded. Should internal and external fish health assessments occur, these will also be recorded. The results collected from the evaluation protocol will be recorded. Additional comments regarding the general health, taste, and texture of the fish will also be recorded.

The results of the fish tasting program will be included in the Annual AEMP Report for submission to the MVLWB, and reported in the De Beers EAR. Results will be focused around answering the question of whether or not the fish taste and texture was acceptable to community members (Table 4.9-1).

Table 4.9-1 Overview of Analysis Approach for Fish Tasting Key Question

Key Question	Overview of Analysis Approach
1. Are the taste and texture of fish captured in Snap Lake acceptable to community members?	A summary of the number of participants who found the taste acceptable will be made along with their comments and evaluation.

4.9.6 QA/QC Procedures

The QA/QC control measures that will be taken during the fish tasting program are:

- completing QA/QC checks on catch numbers and efforts on datasheets;
- inspecting nets so that nets with holes are not used;
- limiting the number of individuals who handle the fish;
- washing the filleting workspace and tools appropriately; and,
- using clean water to boil the fish.

4.10 Traditional Knowledge

4.10.1 Objectives and Scope

The Water Licence (MV2011L2-0004 [Part G, Schedule 6, Item 2 (d) of MVLWB (2013a)] requires that the AEMP include:

> *A summary of how Traditional Knowledge has been collected and incorporated into the AEMP, as well as a summary of how Traditional Knowledge will be incorporated into further studies relating to the AEMP.*

The primary objectives of the Traditional Knowledge (TK) component of AEMP for the Snap Lake Mine are to:

- meet Water Licence requirements;
- include TK with scientific knowledge in the design and implementation of the AEMP; and,
- recommend changes to the AEMP for future years.

The revised scope of the TK component is not yet finalized. The fish tasting program is a TK component and has been incorporated since 2004. De Beers would like to expand the TK component and have additional community involvement in the AEMP Design Plan and the field programs. A preliminary meeting with communities was held on September 19, 2012. Community visits were scheduled for November 2012, and follow-up meetings to refine the scope of the TK component are planned for 2013. Analyses and interpretation of the TK component will focus on answering key questions; these key questions will be developed in consultation with community members in 2013.

4.10.2 Sampling Locations

The sampling locations are not finalized but will likely include Snap Lake, and its downstream waterbodies to MacKay Lake and to Great Slave Lake.

4.10.3 Background on Traditional Knowledge at the Snap Lake Mine

The design of the Snap Lake Mine incorporated TK during the conceptual and operational phases, and during the early years of the AEMP. This was recently summarized by De Beers as part of the Gahcho Kué Environmental Assessment (EIR 0607-001, Undertaking #5; De Beers 2012d).

In 2001, De Beers sponsored a workshop to assess the Snap Lake Project using TK (Lutsel K'e Dene Elders 2001). Elders from Lutsel K'e participated and contributed toward:

- completing a site reconnaissance and survey;
- providing TK about potential Mine-related effects; and,
- recommending mitigation types, and scope of monitoring.

The results of this study informed De Beers of a number of potential effects and concerns related to water quality, dust production, chemical contamination, and disturbance of wildlife that were identified by Lutsel K'e Elders prior to the development of the Snap Lake Mine. Concerns identified by Elders of the Yellowknives Dene

during an earlier TK study of EKATI (Weledeh Yellowknives Dene 1997) were also considered for Snap Lake Mine. The results of these studies were acknowledged in the EAR (De Beers 2002a). More specific details on the recommendations from Elders are found in Lutsel K'e Dene Elders (2001) and De Beers (2012c).

TK has continued to inform the design of wildlife monitoring for the Snap Lake Mine. For example, wolverine habitat preferences (boulder and shoreline) were identified through discussions with Bobby Algona, an Aboriginal hunter who contributed important TK information regarding wolverine behaviour on the tundra (BHPB 2004). The wolverine snow track surveys at Snap Lake were specifically designed to sample these habitats in consideration of this knowledge. As well, Pete Enzoe of Lutsel K'e has been involved in wildlife and aquatic programs at Snap Lake since 2003. Pete Enzoe has contributed to wildlife monitoring by helping to identify where to survey for wildlife and by identifying wildlife signs (e.g., hair, tracks, and scat) (De Beers 2011d). He has also assisted with water quality sampling programs.

In 2004, community members from a number of communities toured the Snap Lake Mine and participated in a workshop to provide advice on the scope and direction of habitat compensation activities. From 2004 to 2012, community members from a variety of communities have participated in the annual Fish Tasting Program at Snap Lake. Participants are asked to determine whether the taste and texture of fish are acceptable (Section 4.9).

Incorporation of TK into the AEMP has, to date, consisted of an annual Fish Tasting event for Aboriginal Elders and other community members. De Beers has taken steps to update and expand their Aboriginal Engagement program, to build long-lasting relationships of mutual trust and respect with Aboriginal communities, and to enrich the AEMP process with TK input. The most recent step began with a workshop held with representatives of De Beers and Golder Associates Ltd. (Golder), and representatives of Deninu Kué First Nation, Lutsel K'e Dene First Nation, NWT Métis Nation, North Slave Métis Alliance, Tlicho Government, and Yellowknives Dene First Nation on September 19, 2012 in Yellowknife, NWT. The purpose of the workshop was two-fold:

- provide an overview of the results of the AEMP to date; and,
- seek guidance from the communities on the ways in which they would like to see TK included in the AEMP for Snap Lake.

The results of this workshop are described in the following section.

4.10.4 Results of the Traditional Knowledge AEMP workshop

During the workshop, the community representatives had the opportunity to caucus as a group, after which they presented recommendations on how they would like De Beers to incorporate TK into the AEMP for Snap Lake. The community representatives, as a whole, indicated that De Beers should visit each of their respective communities and hold a meeting to determine the types of TK and the process for incorporating TK into future AEMP updates. Other recommendations made by the community representatives were:

- Work with the Aboriginal communities to design data collection methods that are culturally-appropriate;
- Work together with Aboriginal communities to achieve a common definition of TK;
- Establish a shared vision and mutually-understood measures of success for the Aboriginal Engagement program;

- Recognize that each community is unique and will have specific preferences for engagement;
- Remember that TK is collective in nature, and that it belongs to the community;
- Close the feedback loop and report back to Aboriginal communities throughout the process so that they can see how their TK input was incorporated into the AEMP; and,
- Provide plain-language summaries of information to workshop participants in advance of events and learn Aboriginal language terms for environmental features to facilitate communication.

Some of the participants at the September 19 workshop offered to write letters to the Mackenzie Valley Land and Water Board, to provide direction for the future. If available at the time of this submission, they will be included as attachments. If unavailable, they will be included as amendments at a later date.

4.10.5 Future Traditional Knowledge in the AEMP

As stated above, the Fish Tasting Program is a TK component and De Beers has taken steps to update and expand the TK component, and to have additional community involvement in the AEMP Design Plan and the field programs. Based upon the results of the workshop held with community representatives on September 19, De Beers will develop specific programs through discussion with the communities in 2013. The scope of TK inclusion will include the advice of TK holders about field sampling and study design as well as participation in field studies.

5.0 2013 SPECIAL STUDIES

5.1 Littoral Zone Special Study

5.1.1 Objectives and Scope

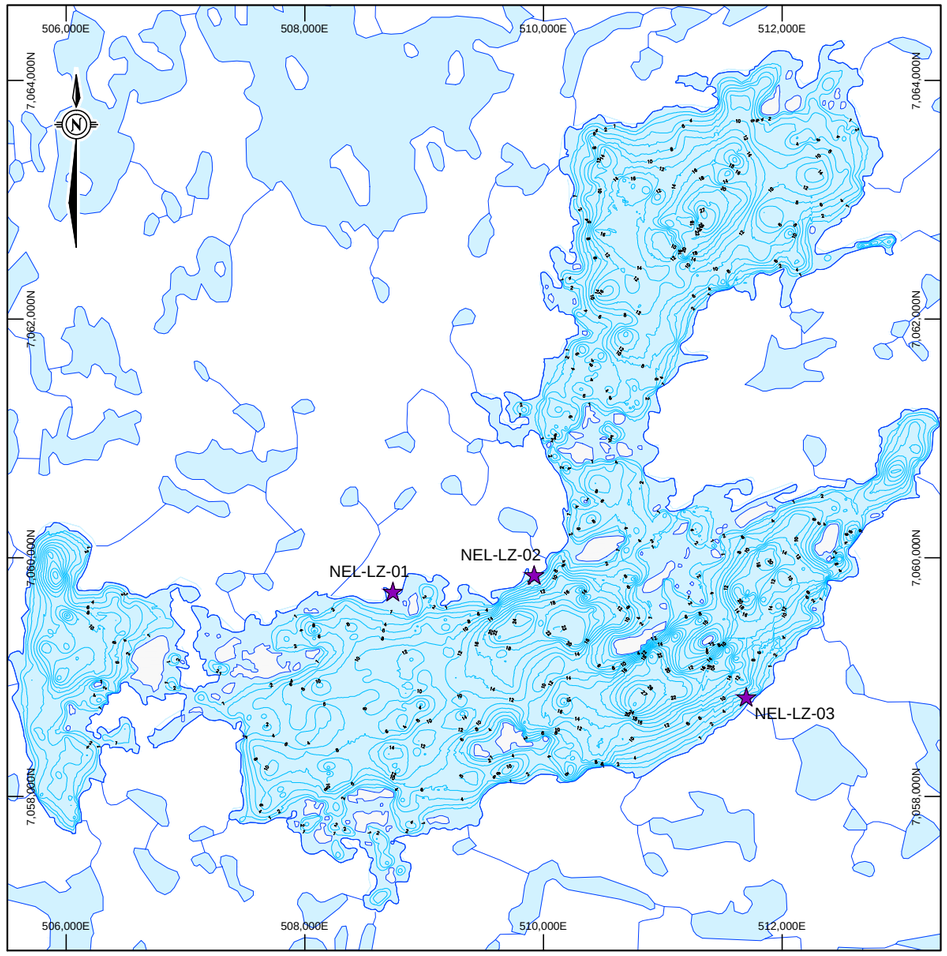
The primary objective of the Littoral Zone Special Study is to determine the importance of the littoral zones to overall productivity in Snap Lake and Northeast Lake. Specifically, this special study is designed to determine whether littoral productivity, as indicated by epilithic algal biomass and community composition, and by littoral invertebrate density and community composition, is an important component of the lakes' food webs and whether, by comparing the two lakes, there is evidence of a Mine-related effect on the littoral communities in Snap Lake. A baseline Epilithic Algal Special Study was completed in 2004 in Snap Lake; however, no epilithic algal sampling was completed in Northeast Lake prior to 2012. This Littoral Zone Special Study will provide useful supplementary information to the plankton and benthic invertebrate components of the AEMP.

This special study is based on five key questions:

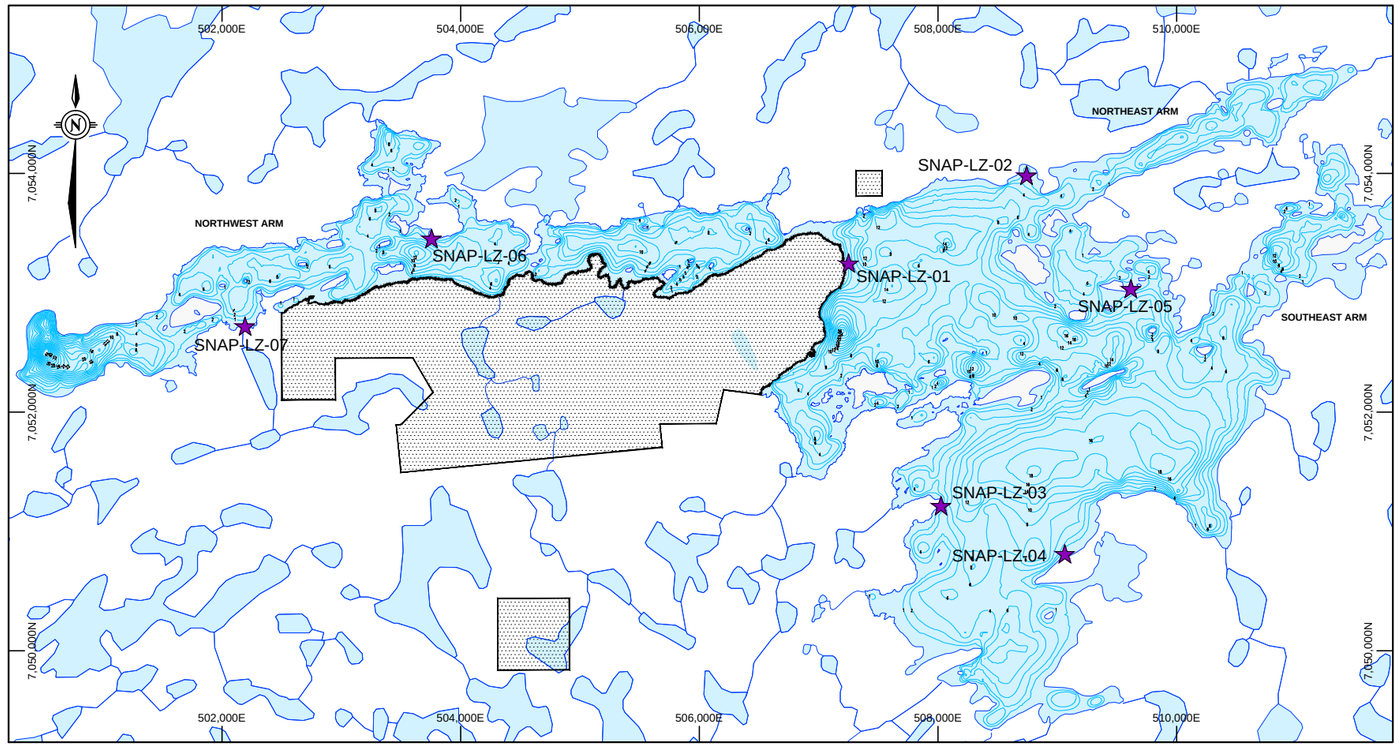
- Can littoral zone monitoring be conducted in Snap Lake and Northeast Lake, and does the inherent variability in the littoral zone allow the detection of Mine-related changes?
- What are the current ratios of particulate C:N, C:P, N:P, and C: chlorophyll *a,* and what is the current percent algal carbon in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? How do these values compare to baseline and what do these values indicate about Mine-related changes in nutrient status and food quality for invertebrates and fish? What is the current status, in terms of relative abundance and relative biomass, of the epilithic algal communities in the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect? What is the current invertebrate composition in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect?

5.1.2 Epilithic Algae Sampling Locations and Timing

Five stations in the main basin of Snap Lake, three stations in the northwest arm of Snap Lake, and five stations in Northeast Lake will be sampled (Figure 5.1-1; Table 5.1-1). Littoral zone sampling will occur annually between 2012 and 2014 (i.e., three years). It is anticipated that this sampling will be completed over a one-week period in August in Snap Lake and Northeast Lake.



NORTHEAST LAKE



SNAP LAKE

LEGEND

- LITTORAL STUDY STATION
- DEPTH CONTOUR (m)
- WATERCOURSE
- WATERBODY
- SNAP LAKE MINE FOOTPRINT

NORTHEAST LAKE REFERENCES

DIGITIZED FROM NTS TOPOGRAPHIC MAP 75 M/10 É 1985 HER MAJESTY THE QUEEN IN RIGHT OF CANADA. DEPARTMENT OF ENERGY, MINES AND RESOURCES. PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD27, COORDINATE SYSTEM : UTM ZONE 12.

REFERENCE LAKE OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

SNAP LAKE REFERENCES

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 OUTLINE AND ISLANDS WERE CORRECTED TO LANDSAT 7 SATELLITE IMAGE 45/15, DATED SEPTEMBER 2, 2000. PROVIDED BY GEOBASE.

BATHYMETRY WAS CREATED IN SURFER 8 USING SONAR DATA FROM THE 2002 NORTH LAKES PROGRAM (GOLDER) AND 2005 TRANSECT DATA FROM THE REFERENCE LAKE SEARCH PROGRAM (GOLDER).

SNAP LAKE PLANTSITE DRAWING OBTAINED FROM CLIENT. DATE: JUNE 12, 2012. "SNAPLAKE-08_STATMAP_2012". DRAWN BY Nampcy Solutions Ltd.

NOTES

MAP MOVED TO PROJECTION : TRANSVERSE MERCATOR, DATUM : NAD83, COORDINATE SYSTEM : UTM ZONE 12.

1 0 1
SCALE KILOMETRES

PROJECT
De Beers Canada
Snap Lake Mine

TITLE
LITTORAL SPECIAL STUDY MONITORING STATIONS IN SNAP LAKE AND NORTHEAST LAKE

Golder Associates

PROJECT	12.1337.0002.1100		FILE No.	12133700021100C015	
DESIGN	TD	2/10/1012	SCALE	AS SHOWN	REV. 0
CADD	JEF	23/10/2012			
CHECK	TD	30/10/2012			
REVIEW	PC	30/10/2012			

FIGURE: 5.1-1

Table 5.1-1 UTM Coordinates of Littoral Zone Sampling Stations in Snap Lake and Northeast Lake

Lake Description	Station	Zone	Easting	Northing
Snap Lake Main Basin	SNAP-LZ-01	12V	507250	7053242
	SNAP-LZ-02	12V	508741	7053978
	SNAP-LZ-03	12V	508024	7051210
	SNAP-LZ-04	12V	509070	7050770
	SNAP-LZ-05	12V	509615	7053028
Snap Lake Northwest Arm	SNAP-LZ-06	12V	503754	7053448
	SNAP-LZ-07	12V	502191	7052714
	SNAP-LZ-08	12V	506108	7053643
Northeast Lake	NEL-LZ-01	12V	508736	7059712
	NEL-LZ-02	12V	509921	7059851
	NEL-LZ-03	12V	511697	7058828
	NEL-LZ-04	12V	TBD	TBD
	NEL-LZ-05	12V	TBD	TBD

TBD = To be determined.

5.1.3 Design Rationale

The Littoral Zone Special Study design is based on the 2004 baseline Epilithic Algal Special Study. An August sampling period was selected for two reasons: (1) to replicate timing of the 2004 Epilithic Algal Special Study; and, (2) to allow sampling during the period of maximum productivity in mid-summer, which is typically August in the sub-Arctic region.

The littoral zones in Snap Lake and Northeast Lake consist mainly of large boulders and rock shelves, which provide abundant substrates for rock-associated algae[16]. Therefore, the rock-associated algae will be sampled rather than plant- or sediment-associated algae. *In situ* sampling of the rock-associated algae will be conducted to maintain consistency with sampling methods used during the 2004 baseline Epilithic Algal Special Study.

Invertebrates within the littoral zone will be sampled using a qualitative method to evaluate community composition and a quantitative method to estimate littoral invertebrate density, using Hester-Dendy Samplers. Invertebrates were not sampled during the 2004 baseline Epilithic Algal Special Study; therefore, comparisons to baseline cannot be made.

The littoral zone sampling stations in Snap Lake represent a subset of the stations sampled in 2004 and provide an approximately even distribution throughout the main basin and northwest arm (Table 5.1-1; Figure 5.1-1). Fewer stations will be sampled in Snap Lake between 2012 and 2014 compared to 2004 because the main basin of Snap Lake is well mixed, and the spatial resolution required in 2004 (12 stations) is no longer necessary.

The littoral zone sampling stations do not match AEMP water quality or plankton sampling stations, because those stations are located in deeper open-water areas. Therefore, water samples will be required from each littoral zone station for analysis of selected parameters to evaluate nutrient status.

16 Rock-associated algae is known as eplithic algae. Epilithic algae live in close-association with protozoans, metazoans, and bacteria that live on the rock-surface together this community is known as the epilithon.

5.1.4 Field Methods

Epilithic Algae Collection Methods

Sampling will be conducted by divers using self-contained underwater breathing apparatus, which is a widely accepted in-lake epilithic algal collection method (Turner et al. 1987). Special *in situ* rock-scrapers, based on a design created by Dr. Michael Turner and built by JS Micro Products, will be used to scrape the rock-associated algae. These scrapers are designed to minimize the amount of algae that can be lost during the scraping process and to sample an area of 5 square centimetres (cm^2). Samples will be collected following accepted protocols provided by Dr. Michael Turner and Fisheries and Oceans Canada, which are consistent with protocols used in 2004 (De Beers 2005a).

At each sampling station, three replicate composite samples, referred to in the current study as sampling areas, will each consist of five 5-cm^2 scrapings (Table 5.1-2). To reduce sampling bias, sampling areas within each station will be limited by depth to 2 m and a slope less than 10 degrees (°) within a 40-cm diameter rock area. If it is not possible to collect three sub-samples within the 40-cm area (e.g., if rock angles exceed 10° or the rock area is too small) then samples will be collected from an appropriate area just outside of the 40-cm area. Samples will be transported on ice back to the on-site laboratory in Whirlpak™ bags, and stored frozen until sample preparation.

A homogenous mixture will be prepared for each sample area, following protocols provided by Dr. Michael Turner and Fisheries and Oceans Canada. A 20-millilitre (mL) aliquot will be removed from each homogenized sample area, preserved with 4% Lugol's and 4% buffered formalin solutions, and analyzed for community composition and biomass. In addition, 10-mL aliquots will be filtered for duplicate chlorophyll *a* and particulate C, N and, P analyses. This volume is equivalent to a concentration of 0.5-cm^2 per filter. Chlorophyll *a* and particulate C, N, and P samples will be filtered onto separate pre-ignited Whatman 25-mm GF/C filters (glass fibre filters of 1.2-µm nominal pore size). The chlorophyll *a* and particulate C and N filters will be desiccated for 12 to 24 hours, wrapped in foil, and frozen prior to analysis. The particulate P filters will not be desiccated and will be kept cool, at approximately 4°C, prior to analysis.

Epilithic algal community composition and biomass samples will be submitted to Dave Findlay, Plankton R Us, in Winnipeg, MB, for analysis using standard algal biovolume measurements, assuming a specific gravity of 1. Chlorophyll *a* and particulate C, N, and P samples will be analyzed by the University of Alberta Biogeochemical Analytical Services Laboratory in Edmonton, AB.

Littoral Invertebrates – qualitative approach

Sampling for littoral invertebrates will occur after the epilithic algal sampling is complete. The littoral invertebrate samples will be collected at a depth of 2 m. A sampling area that will produce enough sample material for an approximately 100-mL sample volume from each station will be required. Each area will be swept with a coarse bristle broom to disturb the entire boulder area and detach the epilithon and associated invertebrates from the boulder surfaces. Once sufficient material is suspended in lake water, a 250-µm mesh net will be swept through the water to catch submerged material. The suspended material will be collected in the net and emptied into a 500-mL or 1-L plastic sample bottle, and preserved in 10% buffered formalin. In addition, visual observations will also be made on the types of invertebrates suspended from the epilithon and attached invertebrates residing on rock surfaces.

All littoral invertebrate samples will be sent to Jack Zloty PhD in Summerland, BC, for taxonomic analysis. Invertebrates will be identified to the lowest taxonomic level practical and the data will be presented as presence/absence (i.e., qualitative only).

Littoral Invertebrates – quantitative approach

Hester-Dendy artificial substrate devices will be used to quantitatively sample the littoral invertebrates. Three Hester-Dendy artificial substrates will be deployed at each station in the littoral zones of Snap Lake and Northeast Lake. The samplers will be retrieved after a suitable invertebrate colonization period (approximately 6 weeks) by SCUBA-divers. The samplers will consist of 14 square plates of tempered masonite separated by nylon spacers to provide varying distances between plates. The total surface area for each sampler will be 0.16 m^2. The Hester-Dendy samplers will be located at a depth of about 2 m, in areas subjected to similar exposure to sun and wind, both of which can effect invertebrate growth and habitat (Resh and Rosenberg 1984). Supporting environmental information will be collected at each sampling area when samples are deployed and retrieved. Supporting environmental data will include the following:

- Hester-Dendy sampler deployment and retrieval date and time;
- area location as UTM, determined with a handheld Global Positioning System (GPS) unit;
- a sketch of the location of each sampler;
- weather conditions (air temperature, wind velocity, cloud cover [%], and precipitation [presence/absence]);
- field water quality measurements (DO [milligrams per litre (mg/L)], pH, specific conductivity [µS/cm], water temperature [°C]), made with a field calibrated water quality meter, at the time of deployment;
- water depth and distance from shore (m);
- visual estimate of substrate size;
- sediment characteristics (i.e., colour, odour, organic content, evidence of anoxia) at the time of retrieval;
- notable site characteristics near the sampler;
- photos of the site at time of sampler deployment and retrieval; and,
- photos of Hester-Dendy samplers at time of deployment and retrieval.

Following retrieval, the sampler will be dismantled and cleaned in a carrying tub using a soft bristled brush. The water and sample material in the tub will then be rinsed through a 250 µm mesh screen. The material retained on the screen will be rinsed into a pre-labeled sample bottle and preserved in 10% neutral buffered formalin. Samples will be sent to J. Zloty, Ph.D, in Summerland, BC for identification and enumeration of invertebrates.

Supporting Environmental Information

Surface water samples will be collected and analyzed for TP, total dissolved phosphorus (TDP), total nitrogen, total dissolved nitrogen (TDN), dissolved inorganic carbon (DIC), and dissolved organic carbon (DOC). In addition, field water quality parameters (water temperature, DO, pH, and specific conductivity) will be measured using a YSI 600-QS multi-meter.

The total nitrogen and TP samples will be collected in 250-mL plastic bottles. The TDP and TDN samples will be filtered through 0.45-µm GF/C filters and the filtrates will be collected in pre-labelled 250-mL plastic bottles. The DIC and DOC samples will be filtered through Millipore cellulose nitrite filters and the filtrate will be collected in pre-labelled 250-mL ultra-clean plastic bottles. Water chemistry samples will be refrigerated at ~4°C prior to shipment to the University of Alberta in Edmonton, AB, for analysis.

Table 5.1-2 Littoral Zone Sampling Program

Component	Depth	Analysis	Number of Monitoring Stations[(a)]	Number of Sampling Areas per Monitoring Station	Total Number of Samples
Epilithic algae including Associated Bacteria and Detritus	2 m	Epilithic algal Community Composition, abundance, and Biomass	13	3	39
		QC samples	-	-	4
		Chlorophyll *a*	13	3	39
		Particulate C, N, P	13	3	39
Littoral Invertebrates	2 m	Littoral Invertebrate –Qualitative Analysis	13	1	13
		QC samples	-	-	1
		Litoral Invertebrate – Quantitative Analysis	13	3	39
		QC samples	3	1	3
Water Chemistry	Surface	Total N and P	13	1	13
		Dissolved N and P	13	1	13
		DIC and DOC	13	1	13

(a) Includes both Snap Lake and Northeast Lake samples.

"-" = not applicable; C = carbon, N = nitrogen; and P = phosphorus; DIC = dissolved inorganic carbon; DOC = dissolved organic carbon; QC = quality control.

5.1.5 Data Analysis

5.1.5.1 Approach

The Littoral Zone Special Study will be designed to answer the key questions listed in Section 5.1-1. An overview of the analysis approach associated with these five questions is provided in Table 5.1-3. Details relevant to data analysis methods to address each key question are provided in Sections 5.1.5.2 to 5.1.5.6.

Table 5.1-3 Overview of Analysis Approach for Littoral Zone Special Study Key Questions

Key Question	Overview of Analysis Approach
1. Can littoral zone monitoring be conducted in Snap Lake and Northeast Lake, and does the inherent variability in the littoral zone allow the detection of Mine-related changes?	This question will be answered after three years of the Littoral Zone Special Study. An annual assessment of the among-station and lake variability will be done. The coefficient of variation among the samples will be calculated for each station. Variability among samples will be examined in particulate C, N, P, ratios of C, N, and P, chlorophyll *a*, and epilithic algal abundance and biomass. In addition, within-lake variability will be described by examining among-station variability and spatial trends in Snap Lake and Northeast Lake.
2. What are the current ratios of particulate C:N, C:P, N:P, and C: chlorophyll a, and what is the current percent algal carbon in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? How do these values compare to baseline and what do these values indicate about Mine-related changes in nutrient status and food quality for invertebrates and fish?	Summary statistics will be calculated for particulate C, N, and P. The mean and standard error will be calculated for the molar ratios of C:N, C:P, N:P, C:chlorophyll *a*, and the percentage of algal carbon. These values will be examined at each station in each lake; values from the main basin of Snap Lake will be compared to values in the northwest arm of Snap Lake and Northeast Lake. Values in the main basin and northwest arm of Snap Lake will also be compared to baseline (2004) values. Nutrient ratios will be compared to values reported in the literature (Healey and Hendzel 1980; Hillebrand and Sommer 1999; Elser et al. 2000) that indicate nutrient status and food quality.
3. What is the current status, in terms of relative abundance and relative biomass, of the epilithic algal communities in the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect?	Summary statistics will be calculated for total epilithic algal biomass and abundance. Mean relative abundance and biomass will be calculated for each station, and stations in the main basin of Snap Lake will be compared to those in the northwest arm of Snap Lake and Northeast Lake.
4. What is the current invertebrate composition in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect?	Using the qualitative method, relative densities of the major invertebrate taxa will be examined for each station, and stations in the main basin of Snap Lake will be compared to those in the northwest arm of Snap Lake and Northeast Lake. Using the quantitative method, total densities, relative densities, functional feeding group densities, taxa richness, evenness, and relative densities of the major invertebrate and Diptera taxa will be examined for each station, and stations in the main basin of Snap Lake will be compared to those in the northwest arm of Snap Lake and Northeast Lake.

5.1.5.2 Key Question 1: Can littoral zone monitoring be conducted in Snap Lake and Northeast Lake, and does the inherent variability in the littoral zone allow the detection of Mine-related changes?

This question will be answered after three years of the Littoral Zone Special Study. An assessment of the among-station and lake variability will be done annually throughout the three special study. The coefficient of variation among samples will be calculated for each station. Variability among samples will be examined in particulate C, N, P, ratios of C, N, and P, chlorophyll *a*, and epilithic algal abundance and biomass. In addition, within-lake variability will be described by examining among-station variability and spatial trends in Snap Lake and Northeast Lake.

5.1.5.3 Key Question 2: What are the current ratios of particulate C:N, C:P, N:P, and C: chlorophyll a, and what is the current percent algal carbon in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? How do these values compare to baseline and what do these values indicate about Mine-related changes in nutrient status and food quality for invertebrates and fish?

Summary statistics will be calculated for particulate C, N, and P. The mean and standard error will be calculated for the molar ratios of C:N, C:P, N:P, C:chlorophyll *a*, and the percentage of algal carbon. These values will be examined at each station in each lake; values from the main basin of Snap Lake will be compared to values in the northwest arm of Snap Lake and Northeast Lake. Values in the main basin and northwest arm of Snap Lake will also be compared to baseline (2004) values. Nutrient ratios will be compared to values reported in the literature (Healey and Hendzel 1980; Hillebrand and Sommer 1999; Elser et al. 2000) that indicate nutrient status and food quality.

5.1.5.4 Key Question 3: What is the current status, in terms of relative abundance and relative biomass, of the epilithic algal communities in the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect?

Summary statistics will be calculated for total epilithic algal biomass and abundance. Mean relative abundance and biomass will be calculated for each station, and stations in the main basin of Snap Lake will be compared to those in the northwest arm of Snap Lake and Northeast Lake.

Epilithic algal abundance and biomass data will also be divided into taxonomic groups. Groups will comprise cyanobacteria, chlorophytes, diatoms, and others (when necessary). The relative proportion of total abundance and biomass accounted for by each group will be calculated separately for each station to evaluate spatial variability in community structure. In addition, summary statistics (i.e., sample size, arithmetic mean, median, minimum, maximum, SD, and SE) will be calculated for each of these groups for each station.

Quantitative comparisons (i.e., univariate statistical tests) will involve comparisons of Snap Lake data to baseline (i.e., 2004) data and to Northeast Lake and the northwest arm of Snap Lake.

Non-metric multidimensional scaling (Kruskal 1964; Cox and Cox 2001) will be run on the epilithic algae biomass data set to summarize the community and evaluate potential differences in community structure between the main basin of Snap Lake, the northwest arm of Snap Lake, and Northeast Lake following the three years of the special study. Non-metric multidimensional scaling is a nonparametric ordination method that allows for the reduction of a data set consisting of a large number of taxa to typically two or three new dimensions referred to as ordination axes (Clarke 1993). The analysis will be based on a station-by-station distance matrix and will provide a visual representation of ecological distances among stations.

A station-by-station Bray-Curtis distance matrix will be generated from the biomass data and used as the input for the ordination. The number of dimensions selected for the ordination will be determined by using a configuration that has a reasonably low stress level (less than 0.2). Non-metric multidimensional scaling will be run using SYSTAT 13.00.05 (SYSTAT 2009). The ordination results will be presented as two-dimensional scatter-plots of the sampling stations in ordination space.

5.1.5.5 Key Question 4: What is the current invertebrate composition in the littoral zones of the main basin of Snap Lake, northwest arm of Snap Lake, and Northeast Lake? Do these results provide any evidence of a Mine-related effect?

Using the qualitative method, relative densities of the major invertebrate taxa will be examined for each station, and stations in the main basin of Snap Lake will be compared to those in the northwest arm of Snap Lake and Northeast Lake. Using the quantitative method, total densities, relative densities, functional feeding group densities, taxa richness, evenness, and relative densities of the major invertebrate and Diptera taxa will be examined for each station, and stations in the main basin of Snap Lake will be compared to those in the northwest arm of Snap Lake and Northeast Lake.

5.1.6 QA/QC Procedures

QA/QC procedures will be applied during all aspects of the Littoral Zone Special Study to check that the data collected are of acceptable quality. In accordance with Golder QA/QC protocols, all data entered electronically will be reviewed for data entry errors and appropriate corrections will be made.

Ten percent of the epilithic algal samples will be re-counted by Plankton R Us in Winnipeg, MB. The inherent variability associated with epilithic algal samples prevents the establishment of a QC threshold value. For the purposes of the epilithic algae QC, the proportion of each major group will be calculated and the occurrence of dominant species will be used to assess consistency between the field and duplicate samples. In addition, the Bray-Curtis index and RPD will be used to assess the overall similarity between the field and duplicate samples. Due to high variability in species occurrence, these comparisons will be made at the major group level for abundance and biomass. The Bray-Curtis index allows for comparison between entire samples (i.e., based on all taxa), while the RPD compares abundance and biomass of each major group between pairs of duplicate samples. The data will also be reviewed for unusually high or low values (i.e., greater or less than 10 times typical lake values), which would suggest erroneous results. Unusually high or low results will be validated on a case-by-case basis. All invalidated data will be retained in the appendix tables, but a flag of “XC” will be appended to the data, indicating that the sample was considered contaminated or the results were designated as not correct based on review of the data.

Invertebrate sample sorting efficiency will be verified by performing spot-checks of left-over debris in randomly selected samples. Ten percent of the invertebrate samples will be re-sorted. The data quality objective for invertebrate samples is a minimum recovery of 90% of the total organisms. If more than 10% of the total number of organisms removed from a sample is found in the debris, then all samples will be re-sorted by a different individual than did the original sorting. In addition, if an entire taxonomic group is omitted by the sorter, then all samples will be re-sorted, again by a different individual.

5.2 Picoplankton Special Study

5.2.1 Objectives and Scope

The primary objective of the Picoplankton Special Study is to monitor changes in picoplankton abundance. The results of this special study provide supporting information to the phytoplankton AEMP component.

This special study is based on two key questions:

- What is the current status, in terms of abundance, of the picoplankton community in Snap Lake, Northeast Lake, and Lake 13, and do these results provide any evidence of Mine-related nutrient enrichment?
- How do any observed changes in the picoplankton community compare to changes observed in the phytoplankton community?

5.2.2 Sampling Locations and Timing

The Picoplankton Special Study will be completed in conjunction with the plankton monitoring program during the open water season (see Section 3.4). Sampling will occur at the same stations in Snap Lake, Northeast Lake, and Lake 13 that are monitored for the plankton component (see Table 3.3-1; Figures 3.3-2, 3.3-3, and 3.3-4). Sampling will be completed annually from 2013 to 2015 at a frequency of once per month during the open water season (i.e., July, August, and September) in Snap Lake, Northeast Lake, and Lake 13.

5.2.3 Design Rationale

The original phytoplankton monitoring design focused on larger species termed nano-phytoplankton (2.0 to 20 µm) and micro-phytoplankton (20 to 200 µm) (Stockner and Antia 1986). A special study was recommended in the 2007 AEMP Annual Report (De Beers 2008b) to incorporate monitoring picoplankton (0.2 to 2.0 µm) and augment the phytoplankton monitoring program. This special study was implemented in 2008 and has provided information supporting the current trends observed within the phytoplankton community; therefore, continuation of this special study was recommended as part of the AEMP Re-evaluation (De Beers 2012a).

Picoplankton includes two major groups, free living bacteria (heterotrophic) and small phytoplankton (autotrophic), with the most ubiquitous being pico-cyanobacteria. Picoplankton are important contributors to the “microbial loop,” which is a model of pathways for nutrient and carbon cycling by microbial components in the pelagic community (e.g., picoplankton, heteronano-flagellates, bacteria, and micro-ciliates). In addition, picoplankton provide a rich food source for zooplankton, which ultimately translates into food resources for fish.

Due to their small size and simple cellular structure, picoplankton have a high growth rate and efficient nutrient uptake (Schallenberg and Burns 2001). However, growth rates of single-celled autotrophic picoplankton in ultra-oligotrophic and mesotrophic lakes have been shown to be inhibited by additions of nutrients, particularly phosphorus (Stockner and Shortreed 1994; Schallenberg and Burns 2001). The exact cause of this decreased growth rate is not known, but it suggests that picoplankton may be sensitive indicators of nutrient enrichment (Munawar and Weisse 1989; Stockner 1991; Shallenberg and Burns 2001).

5.2.4 Field Methods

Picoplankton and flagellate samples will be collected from the composite water sample collected as part of the plankton monitoring program (Section 4.4.4). One picoplankton and one flagellate sample will be collected at each station, resulting in the following sample totals for each lake:

- nine picoplankton and nine flagellate samples per sampling event from Snap Lake;
- five picoplankton and five flagellate samples per sampling event from Northeast Lake; and,
- five picoplankton and five flagellate samples per sampling event from Lake 13.

Picoplankton samples will be submitted to Advanced Eco-solutions Inc. in Liberty Lake, WA, USA for analysis of abundance. Flagellate samples will be submitted to Eco-logic Ltd. in West Vancouver, BC for analysis of abundance.

5.2.5 Data Analyses

5.2.5.1 Approach

The Picoplankton Special Study is designed to answer the key questions listed in Section 5.2.1. An overview of the analysis approach associated with these two key questions is provided in Table 5.2-1. Details relevant to data analysis methods to address each key question are provided in Sections 5.2.5.2 and 5.2.5.3.

Table 5.2-1 Overview of Analysis Approach for the Picoplankton Special Study Key Questions

Key Question	Overview of Analysis Approach
1. What is the current status, in terms of abundance, of the picoplankton community in Snap Lake, Northeast Lake, and Lake 13, and do these results provide any evidence of Mine-related nutrient enrichment?	Qualitative reviews of the picoplankton and flagellate data will be completed as part of the annual AEMP reports, to evaluate changes in abundance and determine (a) whether there is growth inhibition, and (b) whether this may be related to nutrient enrichment within Snap Lake. Quantitative comparisons (i.e., statistical tests) will be completed following three years of data acquisition.
2. How do any observed changes in the picoplankton community compare to changes observed in the phytoplankton community?	Visual assessments of the spatial and temporal trends observed in the picoplankton, flagellate and phytoplankton communities will be conducted.

5.2.5.2 Key Question 1: What is the current status, in terms of abundance, of the picoplankton community in Snap Lake, Northeast Lake, and Lake 13 and do these results provide any evidence of Mine-related nutrient enrichment?

Qualitative reviews of the picoplankton and flagellate data will be completed as part of the annual AEMP reports, to evaluate changes in abundance and determine whether there is growth inhibition, and whether this may be related to nutrient enrichment within Snap Lake. Quantitative comparisons (i.e., statistical analyses) will be completed following three years of data acquisition. These quantitative comparisons will be presented in the 2016 Annual AEMP Report and will include comparisons to baseline (i.e., 2004) data as well as further temporal and spatial trend analyses in the form of comprehensive multi- and univariate statistical analyses, as appropriate.

5.2.5.3 Key Question 2: How do any observed changes in the picoplankton community compare to changes observed in the phytoplankton community?

Visual assessments of the spatial and temporal trends observed in the picoplankton, flagellate and phytoplankton communities will be conducted.

5.2.6 QA/QC Procedures

The QA/QC procedures will be applied during all aspects of the Picoplankton Special Study so that the data collected are of acceptable quality. In accordance with Golder QA/QC protocols, all data entered electronically will be reviewed for data entry errors and appropriate corrections will be made.

The data will be reviewed for unusually high or low values (i.e., greater or less than 10 times typical lake values), which would suggest erroneous results. Unusually high or low results will be validated on a case-by-case basis. All invalidated data will be retained in the appendix tables, but a flag of “XC” will be appended to the data, indicating that the sample was considered contaminated or the results were designated as not correct due to an internal review of the data.

Ten percent of the picoplankton and flagellate samples will be re-counted by a different individual than conducted the original counts to assess counting efficiency. Samples will be reanalyzed if 10% or more of the samples were counted incorrectly.

5.3 Downstream Lakes Special Study

5.3.1 Objectives and Scope

The objectives of the Downstream Lakes Special Study is to document the extent of treated effluent downstream of Snap Lake relative to the EAR predictions and to document current sediment and water quality characteristics in the first three lakes downstream of Snap Lake (Figure 3.2-1).

This special study is based on two key questions:

- What is the spatial extent of the treated effluent plume downstream of Snap Lake (i.e., plume delineation)?
- What are the current water and sediment quality characteristics in the three downstream lakes?

5.3.2 Study Area

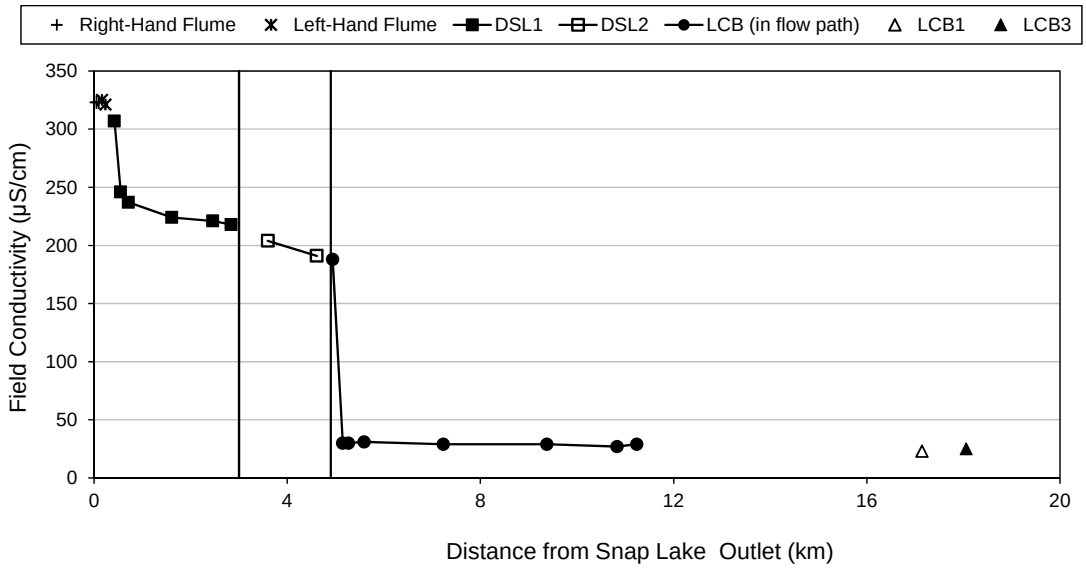
Three lakes, located immediately downstream of Snap Lake, will be included in the 2013 downstream sampling program based on evidence of treated effluent in these lakes during the 2011 downstream reconnaissance work (De Beers 2012c). For the purposes of this special study, the lakes will be referred to as downstream lakes DSL1, DSL2, and Lac Capot Blanc. Outflow from Snap Lake passes through two flume structures at the lake outlet (i.e., right-hand and left-hand flumes; Photos A-1 and A-2 in Appendix A), and two small ponds before reaching lake DSL1, which is the first lake to receive outflow from Snap Lake. The main flow path is then to lake DSL2, Lac Capot Blanc, and downstream through the Lockhart River watershed (Figure 3.3-2).

5.3.3 Design Rationale

Treated effluent is becoming evenly mixed throughout the main body of Snap Lake and, as predicted, is now present in lakes immediately downstream of Snap Lake.

Results of the downstream reconnaissance sampling program in 2011 indicated that concentrations of TDS, and by extension, other Mine-related constituents (i.e., field conductivity, major ions, and nitrate) decreased with distance downstream (Figures 5.3-1, 5.3-2, and 5.3-3), consistent with EAR and modelling predictions (De Beers 2002a; Golder 2011a). As total watershed areas and inflows to downstream lakes increase, the influence of the Mine's treated effluent is reduced. In 2011, presence of the treated effluent was detected throughout DSL1 and DSL2, and near the inlet of Lac Capot Blanc. Field conductivity at the inlet of Lac Capot Blanc was 188 µS/cm, and declined to approximately 30 µS/cm within an approximately 50 m distance from the inlet (Figure 5.3-1). Concentrations of TDS and nitrate were at background at 330 m from the inlet (Figures 5.3-2 and 5.3-3). Concentrations of Mine-related constituents reached background within 6 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.

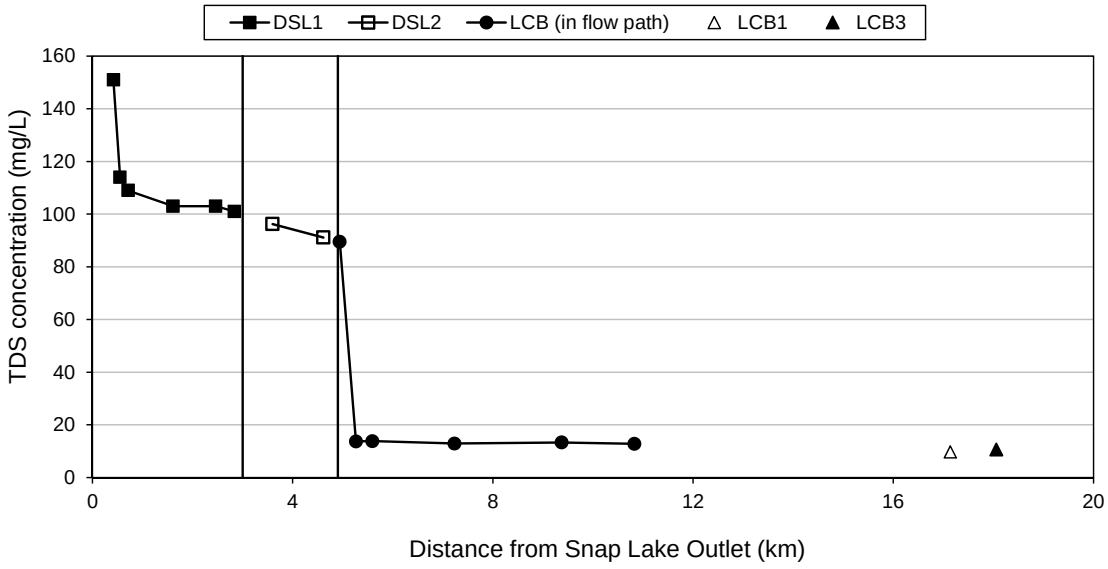
Figure 5.3-1 Field Conductivity Downstream of Snap Lake, 2011



Note: Lakes are separated by vertical lines.

µS/cm = microSiemens per centimetre; km = kilometre. Right-hand flume and left-hand flume refer to the connecting channels between Snap Lake and DSL1. LCB 1 and LCB 3 located in Lac Capot Blanc, but outside the main flow path between the inlet and outlet.

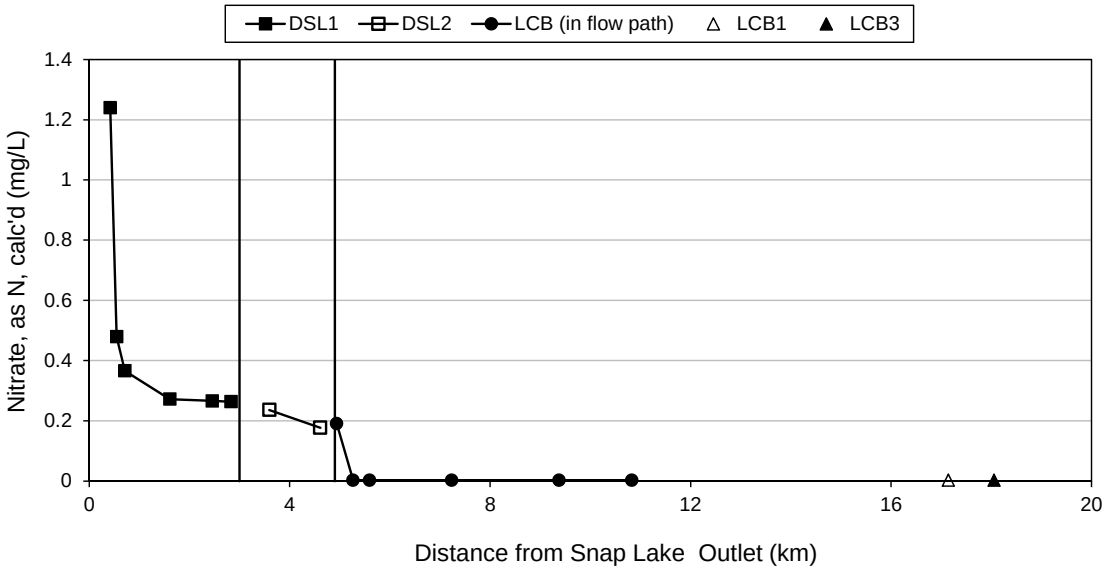
Figure 5.3-2 Total Dissolved Solids Concentrations Downstream of Snap Lake, 2011



Note: Lakes are separated by vertical lines.

mg/L = milligram per litre; km = kilometre; TDS = total dissolved solids LCB 1 and LCB 3 located in Lac Capot Blanc, but outside the main flow path between the inlet and outlet.

Figure 5.3-3 Nitrate Concentrations Downstream of Snap Lake, 2011



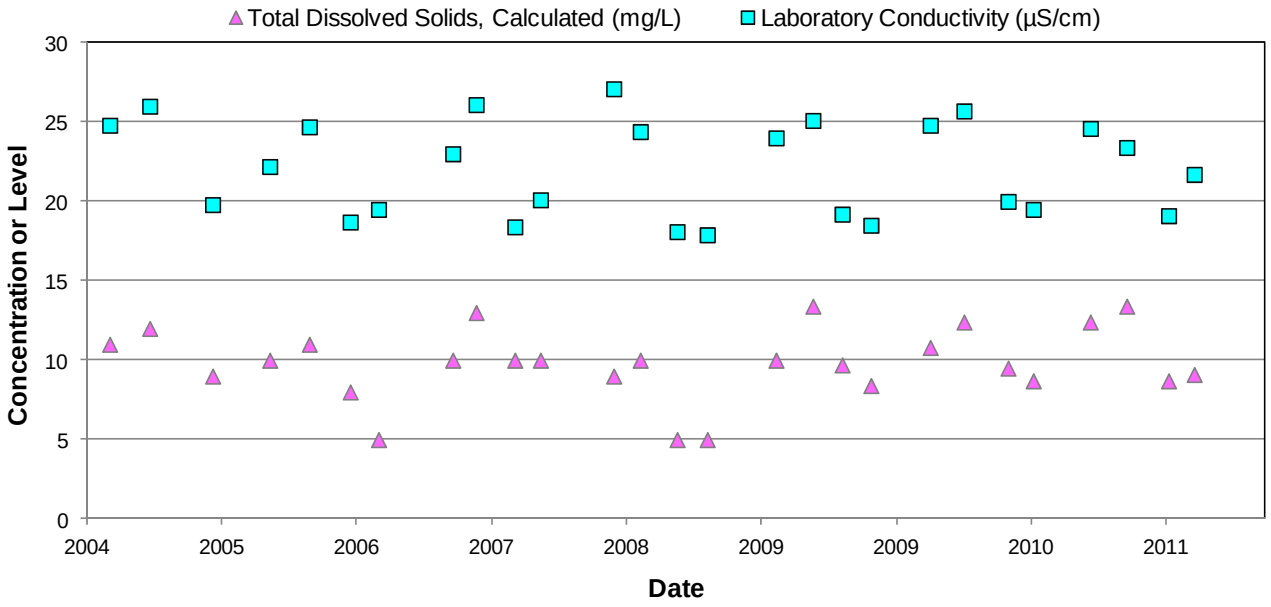
Note: Lakes are separated by vertical lines.

N = nitrogen; calc'd = calculated; mg/L = milligram per litre; km = kilometre. LCB 1 and LCB 3 located in Lac Capot Blanc (Lake 3).

Further downstream of Snap Lake at station KING01 (Figure 3.2-1), there is no evidence of increasing TDS concentration or conductivity from 2004 to 2011 (Figure 5.3-4); this station is located 25 km downstream of Snap Lake. These results are consistent with the results of the targeted downstream program in 2011, which indicate that Mine-related constituents reached background concentrations within 6 km downstream from Snap Lake. Additional volumes of low-TDS waters from the larger watershed at KING01 provide substantial dilution to inflows sourced from Snap Lake.

The 2013 downstream sampling program will gather information on the downstream spatial extent of the treated effluent plume and on water and sediment quality. Data from the 2013 downstream program will be incorporated into future downstream prediction updates.

Figure 5.3-4 Concentrations of Total Dissolved Solids and Conductivity at the Downstream Station KING01, 2004 to 2011



mg/L=milligrams per litre; µS/cm=microSiemens per centimetre.

5.3.4 Field Methods

5.3.4.1 Key Question 1: What is the spatial extent of the treated effluent plume downstream of Snap Lake (i.e., plume delineation)?

A survey of the inlets and outlets of each of the three lakes will be performed as part of the plume delineation component of the Downstream Lakes Special Study. Field measurements of conductivity, pH, DO, and temperature will be taken with a YSI 650 MDS water quality meter (or equivalent) and a YSI 600 QS multi-parameter water quality probe (or equivalent). Emphasis will be placed on conductivity to determine the extent of treated effluent to downstream lakes, because it is an indirect electrical measurement of TDS and its component ions. As treated effluent possesses a high TDS concentration compared to background waters, conductivity is considered a useful indicator of treated effluent exposure. Conductivity in the Northeast Lake is consistently below 30 µS/cm (De Beers 2012c); thus, higher conductivity would likely indicate the influence of treated effluent exposure. Other field data to be collected are ice thickness during ice-covered conditions and Secchi depth during open-water conditions. Ice thickness will be recorded to determine whether there is winter connectivity between the lakes and will be measured at each station using an ice-thickness gauge before sampling. Secchi depths will be measured using a Secchi disk, consistent with the method described in Wetzel (2001).

Inlet and outlet locations will be visited three times in 2013: once during the late ice-covered season (i.e., May), and twice during the open-water season (i.e., July and September). Conductivity dataloggers will be installed at the outlet of each lake in July, after ice breakup. The units will be programmed to collect continuous, real-time conductivity measurements throughout the open-water season and will be retrieved in September.

5.3.4.2 Key Question 2: What are the current water and sediment quality characteristics in the three downstream lakes?

One water quality station in each of DSL1 and DSL2, and five locations in Lac Capot Blanc will be sampled for detailed water quality (Table 5.3-1). At each station, field profile measurements will be collected at 1-m depth intervals, and a water quality sample will be collected and submitted to appropriate laboratories for analyses of physical and conventional parameters, TDS and major ions, nutrients, chlorophyll *a* and total metals (refer to Section 4.2 for AEMP water quality parameter suite). An additional deep-water station will be established in Lac Capot Blanc for DO comparisons. Station number, UTM coordinates, water depth, date, time of collection, and weather will also be recorded at each station.

Sediment samples will be collected during late summer (i.e., early to mid-September) at three stations in DSL1 and DSL2 and five stations in Lac Capot Blanc (Table 5.3-1). Sample collection procedures will be the same for stations in Snap Lake and Northeast Lake, sampling the top 5-cm sediment layer. Sediment grab samples will be collected using an Ekman grab sampler (15 x 15 cm; 0.0232-m^2 area). Three grab samples collected at each station will be combined in the field to yield one composite sample per station. Sediment samples from each station will be analyzed for particle size, TOC, nutrients, and total metals (refer to Section 4.3 for AEMP sediment parameter suite).

Table 5.3-1 Proposed 2013 Downstream Lake Sampling Program

Component	DSL1	DSL2	Lac Capot Blanc	Season	Data Collected	Rationale
Plume Delineation	Inlet and outlet tributaries			Winter (May)	Ice thickness; if portion of water column is unfrozen near inlets and/or outlets, then collect field measurements	Check whether there is winter connectivity (i.e., whether open or closed system)
				Summer (July)	Field measurements with YSI; install conductivity dataloggers and sondes at outlets of DSL1, DSL2 and Lac Capot Blanc	Determine extent of plume in 2013
				Fall (September)	Field measurements with YSI; retrieve conductivity loggers	Determine extent of plume in 2013
Water Quality	1[(a)]	1[(a)]	6[(b)]	Winter (May)	Profile water column for field measurements Mid-depth water sample; AEMP parameter suite[(c)]	Collect information on current conditions and support future development of AEMP monitoring stations.
				Fall (September)		
Sediment Quality	3	3	5	Fall (September)	Profile water column for field measurements AEMP parameter suite[(d)]	Collect information on current conditions and support future development of AEMP monitoring stations.

(a) Assume station location consistent with that sampled in 2012.

(b) Five water quality stations within Lac Capot Blanc (at same locations as sediment component), and one deep-water profile station for dissolved oxygen comparisons.

(c) Dissolved metals will be archived and only analyzed if an AEMP benchmark is exceeded. Refer to Section 4.2 for AEMP water quality parameter suite.

(d) Refer to Section 4.3 for AEMP sediment parameter suite.

DSL1 = first lake downstream of Snap Lake; DSL2= second lake downstream of Snap Lake.

5.3.5 Data Analyses

5.3.5.1 Key Question 1: What is the spatial extent of the treated effluent plume downstream of Snap Lake (i.e., plume delineation)?

Field measurements of conductivity will primarily be used to map the spatial patterns of the treated effluent plume downstream of Snap Lake. The extent of the plume will be assessed by plotting:

- Water quality data with distance downstream, and visually examining the data to identify the location of the plume. Figures showing the plume as snap-shots through time may be prepared to show the horizontal spatial patterns in water quality. For these figures, conductivity between sampling stations (i.e., inlet tributaries, in-lake stations, outlet tributaries) will be estimated using an inverse distance weighted method of interpolation in a GIS similar to that used in Snap Lake.
- Vertical profiles to investigate the portion of water column in each downstream lake potentially influenced by treated effluent.
- Continuous, real-time conductivity measurements from the dataloggers over the open-water season to determine seasonal changes.

5.3.5.2 Key Question 2: What are the current sediment and water quality characteristics in the three downstream lakes?

Water quality data collected from DSL1, DSL2, and Lac Capot Blanc in each season will be compared to reference lake data (i.e., concentrations in Northeast Lake and Lake 13) and AEMP benchmarks applicable to Snap Lake (Section 4.2). Where possible, data will be reviewed to identify potential changes for stations sampled over multiple years. Annual maximum TDS concentrations will be compared to maximum concentrations predicted in the EAR.

Sediment quality data for each lake will be summarized separately in terms of the whole-lake mean, median, minimum, maximum, and SD for each parameter. Sediment quality data will be compared to the ISQGs and PELs developed by the CCME (1999 with updates through 2012). CCME ISQGs are currently available for seven metals analyzed for the Snap Lake AEMP (Table 4.3-5). The ISQG is the concentration of a substance below which an adverse effect on aquatic life is unlikely, and the PEL is the concentration of a substance above which adverse effects are expected to occur frequently, but not always. In practice, the application of generic numerical guidelines has yielded a high percentage of false positives (Chapman and Mann 1999). The observation of a sediment concentration above the PEL value for a given parameter should not be interpreted as an indication that actual ecological harm has occurred or will occur, but rather that this is a possibility.

5.3.6 QA/QC Procedures

The QA/QC procedures currently implemented for the water and sediment components of the AEMP have been effective for assessing potential sample contamination, field precision, and accuracy associated with the environmental data collected. Results from the QA/QC assessments are used to make adjustments, when necessary, to the program to improve data quality. QA/QC procedures implemented for the Downstream Lakes Special Study will be similar to those used for the water and sediment sampling in Snap Lake (Sections 4.2 and 4.3, respectively).

5.4 Lake Trout Population Estimate Special Study

5.4.1 Objectives and Scope

Understanding the effects of ongoing sampling programs on the relative abundance of a key fish species, Lake Trout, requires an estimate of the number of Lake Trout in Snap Lake. Specific Water Licence conditions relevant to the Lake Trout Special Study component of the AEMP in the Water Licence MV2011L2-0004 [Part G, Schedule 6, Item 1a (iv) and 1d of MVLWB (2013)] are:

> a) *Monitoring for the purpose of measuring Project-related effects on the following components of the Receiving Environment:*
>
> iv. *fish population, and year-class strength and community composition using standard methods;*
>
> d) *Procedures to minimize the impacts of the AEMP on fish populations and fish habitat.*

To sample the fish community of Snap Lake, the BsM standard netting program will be used (Section 4.10). It is proposed that this program be conducted every three years given the possibility of sampling-related effects on Lake Trout populations. This program requires nets to be set overnight and is a lethal program that captures approximately 100 Lake Trout per study lake. A special study to estimate the size of the population of Lake Trout in Snap Lake such that the effects of lethal programs can be calculated is proposed for 2013. This study will also allow the catch rate from the net program to be calibrated against the estimated number of fish in the lake.

The primary objective of the Lake Trout Population Estimate Special Study is to estimate the size of the Lake Trout population in Snap Lake. A mark-recapture method of population estimate was begun in 2012 and will be finalized in 2013. In 2012, Lake Trout were collected by angling during the summer months throughout Snap Lake. Fish were tagged with an internal passive integrated transponder (PIT) tag and were live released. Angling efforts will be repeated in 2013. The initial number of fish tagged and the number of tagged fish that are recovered will be used as a proportion of the total number of fish collected, providing an estimate of the number of Lake Trout in Snap Lake.

This special study is based on one key question:

- How many Lake Trout of fishable size (>250 mm FL), are estimated to be in Snap Lake and what is the level of confidence of that estimate?

5.4.2 Sampling Locations

Fishing will occur throughout Snap Lake. Fishing locations will be based on preferred habitat (depth, water temperature) and the locations of successful catches in 2012.

5.4.3 Design Rationale

A reference point of the absolute number of Lake Trout in Snap Lake is required for the BsM method, because the BsM method only provides a relative measure (CPUE) of the number of Lake Trout. In addition, the number of Lake Trout and their size distribution are important elements in the development of demographically explicit stochastic population models that can effectively predict population-level responses based on individual–level effects of environmental perturbations (VanKirk and Hill 2007; Gledhill and VanKirk 2011). Understanding the

effects of changes in the relative abundance of Lake Trout in Snap Lake from the BsM method and of ongoing sampling programs on the sustainability of the Snap Lake Lake Trout population requires knowledge of the number of Lake Trout in Snap Lake. To provide an estimate of the size of the Snap Lake Lake Trout population a mark-recapture study using internally applied PIT tags initiated in 2012 will be completed in 2013. This mark-recapture study was to be completed in 2012; however, insufficient fish were recaptured to provide an estimate within acceptable limits. Accordingly, additional sampling will be conducted in 2013 to complete the study

5.4.4 Field Methods

5.4.4.1 Work in 2012

A total of 218 of a target of 400 Lake Trout were collected and tagged from Snap Lake in July 2012. The target size of fish was 150 mm in length or greater, which is the size of older juveniles and adults. In late August/September after marked Lake Trout had sufficient time to mix with unmarked Lake Trout, fishing was conducted again to try to capture a sufficient number of tagged fish to calculate the population size. While an additional 88 fish were captured in fall, only 13 had previously been tagged. With insufficient fish recaptured to calculate the population size, the 2012 fall program was considered as a second marking (tagging) period. A recapture period is thus required and is proposed for early summer (July) 2013.

5.4.4.2 Sample Collection and Processing

Areas having the highest abundance of fish in 2012 will be targeted again in 2013. Fish will be captured by angling during the month of July, a period that yielded the highest catch of Lake Trout in 2012. Timing of capture will occur before the BsM program such that tagged fish are not disturbed before the population estimate is complete.

Barbless hooks will be used. This method is inefficient as approximately 75% of fish that are captured on a hook are not able to be ‘landed and tagged’ (i.e., they are only very loosely caught on the hook and often escape). However, by using this method there will be almost no mortality of captured and tagged fish.

At the time of collection a fish, while still hooked, will be guided into a processing cradle at the side of the boat and restrained as necessary. Fish will be measured for length (±1 mm) and weight (±1 g), and have a pelvic fin removed for aging if they have not been sampled previously. Fish will be checked for the presence of a PIT tag and the tag number will be recorded. Fish will be released live into the lake by lowering the processing cradle and allowing the fish to swim away of its own volition. A photographic record of the process will be maintained. The UTM coordinates of each fish collected and the depth at which it was collected will be recorded. If mortality occurs, fish will be measured for length and weight as above and have a pelvic fin ray removed and, in addition, will be examined internally for sex, state of maturity, and any anomalies as specified in Section 4.7 for the BsM method.

5.4.4.3 Data Analysis

All samples collected during the 2012 and 2013 period will be pooled and estimates of the number of Lake Trout in Snap Lake and an estimate of error around this estimate made using the program MARK (Irvine et al. 2007).

5.5 Stable Isotope Food Web Analysis Special Study

5.5.1 Objectives and Scope

Information on the food web of Snap Lake is limited. It is important to understand the food web structure to understand how the effects of potential nutrients or contaminants from the treated effluent may affect aquatic organisms in Snap Lake directly or indirectly (Figure 2.2-1). Stable isotope analysis is proposed for 2013 to collect preliminary information to describe the food web in Snap Lake. As this is the first time this information is being gathered in Snap Lake and the certainty that each sample type can be collected is not known, this special study is considered a pilot study.

There are three objectives for the Stable Isotope Food Web Analysis Special Study:

- determine whether stable isotopes can be used to describe the aquatic food web in Snap Lake;
- describe the aquatic food web in Snap Lake and the relative importance of benthic, littoral, and pelagic pathways, using $\delta^{15}N$ and $\delta^{13}C$ isotopes; and,
- determine the trophic level, diet composition, and niche size of fish species in Snap Lake.

This special study will address the following two key questions:

- What eats what in Snap Lake?
- Is the Snap Lake food web planktonically or benthically driven?

5.5.2 Sampling Locations

Samples will be collected within the main basin of Snap Lake. Sample collection will be harmonized with other AEMP components. For invertebrates actual sample sites will be determined on the basis of the amount of biomass available. Where biomass is limited, samples may need to be composited over a relatively large area to provide samples of sufficient size to meet analytical requirements.

5.5.3 Design Rationale

Analysis of data collected by the AEMP from 2005 to 2011 indicated evidence of nutrient enrichment from treated effluent discharge to Snap Lake. Predicting and understanding the effects of this nutrient enrichment on the Snap Lake fish community is contingent on understanding trophic relationships and sources (e.g., benthic or planktonic) of carbon or energy within the fish community. Although the fish community of Snap Lake has a very complex and key role in the aquatic food web (i.e., fish may occupy multiple trophic levels, consume diverse food resources, and feed on both pelagic, littoral, or benthic food webs), information on trophic position and diet for the Snap Lake fish community is currently lacking. While it is possible to establish the role of individual fish species within Snap Lake using conventional stomach content analysis, this requires extensive sampling to capture variation related to diel and seasonal variation, ontogeny, depth, temperature, and habitat type. For a relatively low productivity lake such as Snap Lake, such sampling could have deleterious effects on the lake's fish populations. Further, such an approach does not provide information on assimilation.

Stable isotope analysis has been used extensively to describe aquatic food webs. The ratio of the stable isotopes of nitrogen (^{15}N:^{14}N) is positively correlated with trophic level, and the ratio of carbon stable isotopes (^{13}C:^{12}C) provides information about the production base or carbon sources integrated over a much longer time period than the 'snap-shot in time' provided by stomach content analyses. Mixing models provide a means by which the stable isotope values of nitrogen and carbon can be used to estimate the contribution of various prey sources to a consumer's diet. Although several mixing models exist, those that use a Bayesian approach such as MixSIR are superior as they include the ability to account for variation in the stable isotope values of both prey and consumer as well as variation in discrimination factor or the amount of change in either $\delta^{13}C$ or $\delta^{15}N$ between prey and consumer. The resulting information on trophic structure can be used to help identify components of the aquatic food web that may be susceptible to adverse effects from the Mine's treated effluent. This work will also provide an important basis for comparison with future states of the Snap Lake aquatic food web that may change as a result of Mine-related effects and for other lakes that may serve as reference points for Snap Lake.

5.5.4 Field Methods

5.5.4.1 Sample Collection and Processing

Samples required for stable isotope analysis (fish, benthic invertebrates, phytoplankton, zooplankton, and epilithic algae) will be collected in conjunction with the 2013 fish, plankton, and benthic monitoring programs. The BsM sampling (Section 4.7) will be the largest source of fish samples (Table 5.5-1), although other sampling methods will also be employed as needed to achieve the required number of samples for each of the fish species.

Table 5.5-1 Fish Species to be Collected for Stable Isotope Analysis and Target Sample Sizes

Species	Sample Collection Timing	Size Class	Tissue Type	Sample Size
Lake Trout	July	adult	Muscle	10
Round Whitefish	July	adult	Muscle	10
Burbot	July	adult	Muscle	10
Longnose Sucker	July	adult	Muscle	10
Slimy Sculpin	July	n/a	Whole body	10
Lake Chub	July	n/a	Whole body	10

For each fish species, the total length (±1 mm) and weight (±1 g) will be determined and a 0.5 g skinless boneless dorsal muscle sample will be removed and transferred to a labelled glass vial. The stomach will be removed from all fish, placed in a labelled whirlpak™ bag, sealed and held on ice until it can be transferred to a freezer (-20ºC). Locations of all fish species collected and processed and corresponding sample numbers will be recorded.

Details of invertebrate (benthos, littoral, and zooplankton) and plant (phytoplankton, epilithic algae) sampling are provided in Table 5.5-2. Due to the low biomass expected, it will be necessary to composite multiple samples to obtain the required sample weight for analysis. It may be necessary periodically to use a four decimal place electronic scale to measure the sample weight provided for a number of samples in order to determine how many samples (e.g., plankton hauls, Ekman grabs) in total need to be composited to achieve the required

sample weight. The final sample weight will be recorded on the sample label as well as in the field notes. Percent moisture will be assumed to be 80% for all biological samples and, therefore, sample mass required for stable isotope analysis will be corrected to dry weight, as required for the laboratory stable isotope analyses. To maintain sample integrity, samples will be kept on ice at all times with all samples transferred to a freezer in the laboratory. All shells will be removed from gastropods and pisidiids prior to analysis. Depending on time and conditions it may be necessary to perform this task in the laboratory using a set of forceps and dissecting microscope.

Table 5.5-2 Details of Sampling Methods for Invertebrates and Plants for the Stable Isotope Study

Component	Sampling Method[(a)]	Weight Required Per Sample (Shell-Free)	Number of Samples	Sample Processing	Sampling Period
Phytoplankton (specific method details to be optimized at time of sampling)	Multiple vertical hauls with a 0.5-m diametre 80-µm plankton net composited until enough material for a sample is collected	5-10 mg wet weight (if possible)	5	Filtered through a 53-µm sieve and collected on a 10-µm sieve. Transferred to 10-µm Nitex to remove water	Late summer
Zooplankton (specific method details to be optimized at time of sampling)	Multiple vertical hauls with a 0.5-m diametre 80-µm plankton net composited until enough material for a sample is collected	5-10 mg wet weight (if possible)	5	Filtered through a nested set of Nitex sieves consisting of 253, 163, 53, and 10 µm. The 253-(Fraction 1) and 163-µm (Fraction 2) fractions are filtered onto 10 µm Nitex to remove water. The 10 to 53 µm fraction is used above to collect the phytoplankton fraction	Late summer
Benthos: Amphipods	Picked by hand in littoral zone by divers using the sweep and scoop method. Composited until enough material for a sample is collected.	5-10 mg wet weight	5	Rinsed of any debris	Late summer
Benthos: Caddisflies	Picked by hand in littoral zone by divers using the sweep and scoop method. Composited until enough material for a sample is collected	5-10 mg wet weight	5	Rinsed of any debris	Late summer
Benthos: Gastropods	Picked by hand in littoral zone by divers using the sweep and scoop method. Composited until enough material for a sample is collected	5-10 mg wet weight	5	Remove shell	Late summer
Benthos: Pisidiids	Multiple composited Ekman grabs. Composited until enough material for a sample is collected	5-10 mg wet weight	5	Remove shell	Late summer
Benthos: Chironomids	Multiple composited Ekman grabs. Composited until enough material for a sample is collected	5-10 mg wet weight	5	Rinsed of any debris	Late summer
Oligochaetes	Multiple composited Ekman grabs. Composited until enough material for a sample is collected	5-10 mg wet weight	5	Rinsed of any debris	Late summer
Epilithic algae	Multiple composited epilithic algalscrapes using a SCUBA-based rock-scraping technique	5-10 mg wet weight	3-10	Samples filtered and dessicated, resulting dried biomass will scraped into preweighed glass vials	Late summer

(a) zooplankton, phytoplankton, epilithic algae, and benthic invertebrate replicates represent composites; gastropods and pisidiids represent shell-free tissue.

mg = milligram; µm= micrometre; all samples will be stored in preweighed glass vials to facilitate sample processing; vials will be weighed after sampling and before analysis to check whether there is adequate sample weight for analysis.

All fish will be weighed (±0.01 g), measured (±0.1 mm), and sexed based on external features. A skinless, boneless dorsal muscle sample of approximately 0.5 g will be excised from all individual fish and frozen at -20°C until analyzed for stable isotopes. For mollusks and other shelled invertebrates, only soft tissue will be retained for stable isotope analysis.

5.5.5 Laboratory Methods

5.5.5.1 Sample Analysis

After sample collection and processing all further sample handling will be done at the analytical laboratory at the University of Waterloo in Ontario. Samples will be shipped on dry ice. For $\delta^{13}C$ and $\delta^{15}N$ analysis, fish muscle, plant, and invertebrate samples will be freeze-dried for 48 h and ground using a mortar and pestle. For each fish and invertebrate sample, 250 to 300 µg of tissue (dw) will be weighed into 5 mm × 9 mm tin cups. Samples and standards will be analyzed using an isotope-ratio mass spectrometer equipped with an elemental analyzer to quantify the abundances of $\delta^{13}C$ and $\delta^{15}N$. Samples will not be lipid-extracted, although for fish samples, $\delta^{13}C$ will be corrected for lipid content using the C:N ratio. The abundances of carbon and nitrogen isotopes in each sample will be expressed in delta notation relative to a standard, using Equation 11:

$$\delta R\ (‰) = R_{sample} / R_{standard} - 1) \times 1000 \qquad \text{Equation 11}$$

where R is the ratio $^{15}N/^{14}N$ or $^{13}C/^{12}C$. The standard reference material will be Pee Dee Belemnite carbonate for carbon dioxide and atmospheric nitrogen for N_2. Every 10^{th} sample will be repeated and internal sample standard materials analyzed at the beginning, middle, and end of each sample run. Additional C and N standards will be included with each run.

5.5.6 Data Analysis

The data analysis is designed to answer the key questions listed in Section 5.5.1. An overview of the analysis approach associated with these questions is provided in Table 5.5-3. Specific details relevant to data analysis methods to address each key question are provided in Section 5.5.7

Table 5.5-3 Overview of Analysis Approach for Food Web Isotope Key Questions

Key Question	Overview of Analysis Approach
1. What eats what in Snap Lake?	Use biplots of $\delta^{13}C$ and $\delta^{15}N$ to qualitatively examine food web structure in the Snap lake food web Use MixSIR software to quantitatively determine the proportion of prey fish for each fish consumer Calculate the trophic level for each individual fish species and analyze differences among fish species using 1-way ANOVA
2. Is the Snap Lake food web planktonically or benthically driven?	Use the $\delta^{13}C$ and $\delta^{15}N$ biplots above to qualitatively examine the relative importance of benthic or planktonic prey to fish consumers. Using the MixSIR results above calculate the total estimated prey consumption for benthic and pelagic prey for each fish species

5.5.7 Diet Estimates

Estimates of relative diet contributions of all prey for each fish species in Snap Lake will be made using the mixing model software MixSIR (Semmens and Moore 2008). Uninformative priors will be used so that estimates are unbiased, and prey items will be assumed to be *a priori* equally likely to contribute to the stable isotope composition of the consumer. For $\delta^{13}C$, a diet tissue fractionation factor of 1.0 ± 0.4 parts per thousand (‰) will be used and for $\delta^{15}N$, a tissue fractionation factor of 3.4‰ ± 1.1‰ will be used (Post 2002), with 1,000,000 model iterations (Semmens and Moore 2008). To account for the variability in the proportional contribution of prey sources, the 50th (median) and 95th percentiles will be used.

To estimate trophic position from stable isotopes, $\delta^{15}N$ will be used with the equation of Cabana and Rasmussen (1996):

$$\text{Trophic position} = (\delta 15N_{consumer} - \delta 15N_{baseline})/3.4+2 \qquad \text{Equation 12}$$

where $\delta^{15}N_{consumer}$ is the stable isotope value of the fish species, $\delta^{15}N_{baseline}$ is the baseline organism (sphaerids or gastropods), 3.4 is the diet enrichment factor (Post 2002), and 2 refers to the trophic level of the baseline organism. An ANOVA will be used to assess variation in fish species trophic position. To evaluate changes in either $\delta^{13}C$ or $\delta^{15}N$ related to ontogeny, linear regression will be used with either age or length used as the independent variable.

To estimate niche size for each fish species, individuals will be graphed in $\delta^{13}C$ -$\delta^{15}N$ space and quantitative metrics calculated for each population. The measure of niche width employed will be based on the area of the convex hull bounding a sub-set of individuals of the population. The TA (total area) will be calculated as the total area encompassed by the smallest convex polygon containing these individuals in $\delta^{13}C$ and $\delta^{15}N$ space. The TA is a direct measure of population niche width, as it is a composite metric that reflects variation along both the $\delta^{13}C$ and $\delta^{15}N$ niche dimensions (Layman et al. 2007). Convex hull areas will be calculated using Arc View GIS.

6.0 AEMP RESPONSE FRAMEWORK

6.1 Regulatory Requirements

This section describes the Response Framework for the Snap Lake AEMP. The Response Framework links monitoring results to actions with the purpose of maintaining the Assessment Endpoints described in Section 2 (Conceptual Model) within an acceptable range. The framework provides a systematic approach to responding to the results of the AEMP. The framework herein was developed with guidance from the Draft Guidelines for Adaptive Response Framework for Aquatic Effects Monitoring (WLWB 2010).

This section is provided to comply with the following specific Water Licence conditions [Part G, Schedule 6, Item 2(e) of MVLWB (2013a)]:

> *e) A description of an AEMP Response Framework that will link the results of the AEMP to those actions necessary to ensure that Project-related effects on the Receiving Environment remain within an acceptable range. The Response Framework shall include:*
>
> *i. definitions, with rationale, for Significance Thresholds and tiered Action Levels applicable to the aquatic Receiving Environment of the Project; and*
>
> *ii. for each Action Level:*
>
> *a) a description of the rationale including, but not limited to, a consideration of the predictions and conclusions of the Environmental Assessment as well as AEMP results to date;*
>
> *b) a description of how exceedances of Action Levels will be assessed; and*
>
> *c) a general description of what types of actions may be taken if an Action Level is exceeded.*

6.2 Definitions and Approach

An “effect” is a change that follows an event or cause. An effect is not inherently negative or positive. A linkage must be established between a measured change and a cause (e.g., mining activity) before appropriate management actions can be determined. Should an effect be detected during the Snap Lake AEMP, a corresponding “action” will occur. The type of action taken depends on the magnitude or severity of an effect relative to an assessment endpoint. This is termed the *Action Level*.

The goal of the Response Framework is to systematically respond to monitoring results such that the potential for significant adverse effects is identified and any necessary mitigation actions are undertaken. This is accomplished by implementing appropriate mitigation at predefined Action Levels, which are triggered before a significant adverse effect could occur. A level of change that, if exceeded, would result in a significant adverse effect is termed a *Significance Threshold*.

The magnitude of an effect is determined by comparing measurement endpoints between exposure areas and either reference areas, background values, or benchmark values. A magnitude of effect that falls within the normal range of variability for Snap Lake or is well below an applicable benchmark value would not lead to action and is termed a *Negligible Action Level*. A magnitude of effect that falls outside the range of normal variability for Snap Lake but is considered to be of low ecological consequence would be classified as a *Low Action Level* and constitutes a “red flag” for careful scrutiny and possible proactive management actions.

Effects at the *Medium Action Level* are greater than those predicted in the EAR; however, not all effects greater than those predicted in the EAR will fall within this Action Level. For example, subsequent analysis could find that, although greater than EAR predictions, the magnitude of the effect is not sufficiently severe to warrant mitigation (i.e., ecological consequences are minimal). However, any effect that falls within the *Medium Action Level* poses a potential threat to the Snap Lake ecosystem and must be dealt with by management actions that begin with further investigation to determine both significance and causation, and thus allow effective management intervention if such is required. Should the initial management intervention not be sufficient to remove the potential threat to the Snap Lake ecosystem, then the magnitude of the effect is classified as a *High Action Level* and further, timely management intervention to reverse the effect will be required.

The two hypotheses described in Sections 2 and 7 (toxicological impairment and nutrient enrichment) also apply to the Significance Thresholds and Action Levels for ecological function described in the following sections. For each of the ecological function components there are two separate sets of Action Levels:

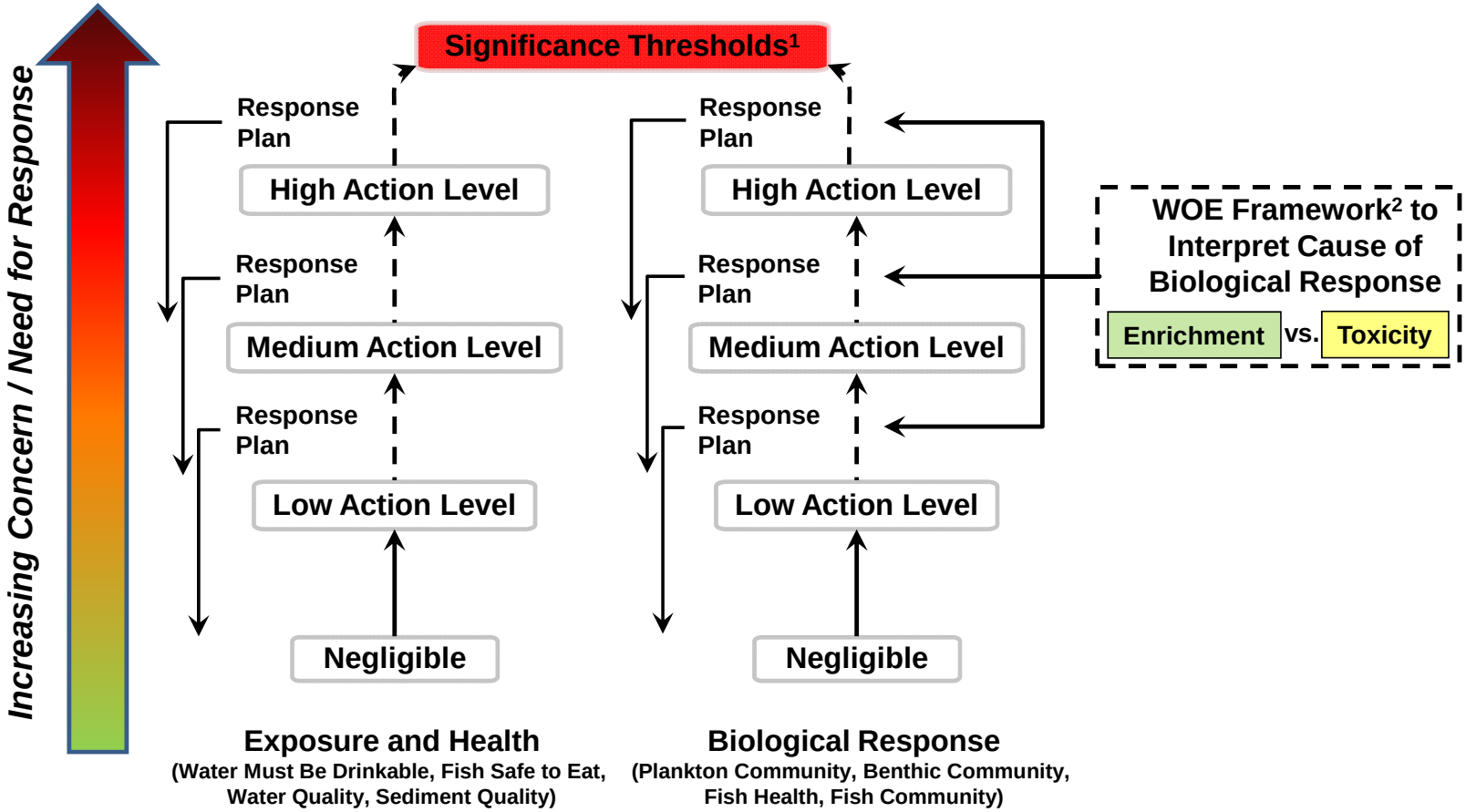
- those that address possible toxicological impairment effects; and,
- those that address possible nutrient enrichment effects.

In the EAR for Snap Lake, which formed the basis for approval of the Project, some mild nutrient enrichment effects were considered likely, whereas potential toxicological impairment effects were considered unlikely. Consistent with this approach, the Action Levels for toxicological impairment are “triggered” at a lower level of change than the Action Level for nutrient enrichment. Consequently, when a change is observed in one of biological components of Snap Lake (i.e., the plankton community, benthic community, or fish community), it is important to understand which type(s) of effect is occurring, so that the appropriate set(s) of Action Levels are considered.

The Weight of Evidence (WOE) Integration described in Section 7 provides a systematic process for determining the degree of support for each hypothesis by examining linkages between exposure and biological responses, and causality with respect to the Mine and Mine-related effects. Figure 6.2-1 presents the conceptual process of the Response Framework, distinguishing between the process for Exposure and Health components, and Biological Response Components of the AEMP. Briefly, the process involves:

- Action Levels are evaluated on the basis of AEMP findings in a given year.
- When an Action Level is met, a Response Plan is developed to better understand the variable that triggered the Action Level and then, if necessary, to reduce the degree of change.

Figure 6.2-1 Overview of the AEMP Response Framework



[1]Significance Thresholds have been set for individual components (e.g., Fish Safe to Eat), and in some cases for multiple components combined (e.g., Ecosystem Function)

[2]The purpose of the WOE Framework is to examine the potential causes of biological responses (nutrient enrichment versus toxicological impairment) and linkages to the Mine and Mine Activities (via exposure in water and sediments, which may be influenced by Mine Effluent).

- Action Levels related to Health (water is safe to drink, and fish are safe to eat) are not set for each hypothesis because they are based on measured chemical concentrations. Therefore, where a linkage exists, it is relatively simple to link chemical concentrations to Mine effluent and activities and develop response plans accordingly (i.e., metals, ions, nutrients come directly from Mine, so whatever substance reaches an Action Level, must be managed).

- Action Levels related to Exposure (water quality, fish tissue, sediment quality) are set for each hypothesis; however, the chemicals that would be responsible for any effects under each hypothesis are relatively well known (e.g., metals would cause toxicity effects whereas nutrients would cause enrichment effects). Therefore, where a linkage exists, it should be relatively simple to link chemical concentrations to Mine effluent and activities and develop response plans accordingly (i.e., metals, ions, nutrients come directly from Mine, so whatever substance reaches an Action Level, must be managed).

- Evaluation of Action Levels related to Biological Responses is less straight forward and knowledge of the cause of observed responses which trigger Action Levels is critically important. Ecosystem components (plankton, benthos, fish) may exhibit toxicity and/or enrichment responses. The degree of support for each hypothesis determined by the WOE framework helps guide whether Action Levels for enrichment or toxicity (or both) are met. WOE conclusions regarding which type of effect is occurring, and the chemical cause of the effect, inform response planning.

Note that the WOE Framework does not prevent an Action Level from being triggered. A role of the WOE Framework is to determine whether to trigger the Action Levels for toxicological impairment or nutrient enrichment. For example, if there were a decrease in richness at a Low Action Level, but the WOE Framework indicated that this was clearly due to nutrient enrichment, then only the Action Level for nutrient enrichment would be triggered.

Consistent with WLWB (2010) draft guidance on AEMP Frameworks, the Response Framework initially involves definition of conditions for Low Action Levels. Medium and High Action Levels will be identified for a component if the Low Action Level is reached for that component, and will be dependent on the factor(s) that cause the Low Action Level. For example, in the case of water quality, the Medium and High Action levels might be highly specific where only one parameter was causing the conditions that led to the Low Action Level.

Note that Action Levels were not developed for every substance and organism type being measured in the AEMP. For example, the amount of fat in fish liver is measured to support understanding of fish liver size but action is not taken on the liver fat measurement alone. Action Levels were focussed on the key indicators of possible significant adverse effects.

The Response Framework thus consists of Action Levels and Significance Thresholds for key indicators as well as types of action that may be taken. The specific action to be taken will depend on the type and severity of effect detected. Specifics on the Significance Thresholds, Action Levels, and types of actions that may be taken are outlined below. This is the first Response Framework that has been developed for the Snap Lake AEMP; it is anticipated that future development and consultation will result in refinement of this Response Framework.

6.2.1 Identification of Significance Thresholds

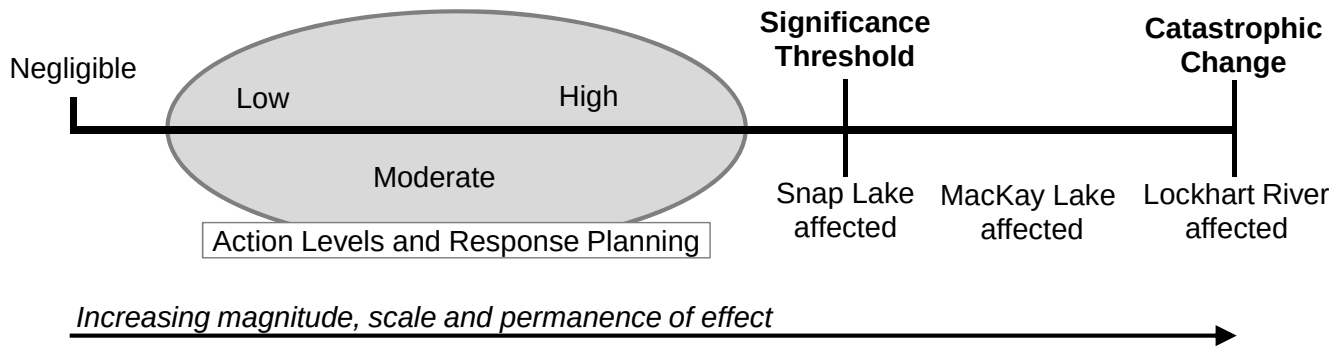
Significance Thresholds were not explicitly defined in the EAR for the Snap Lake Project and as such had to be developed for this framework. They were developed from the EAR predictions, the Traditional Knowledge Study from the EAR, the EAR Reasons for Decision from the MVEIRB (MVEIRB 2003), and commitments made by De Beers during the Environmental Assessment (EA) process and in the subsequent Environmental Agreement between De Beers, federal and territorial governments, and governments of affected communities (De Beers 2004).

Descriptions of what could constitute significant adverse effects to certain aspects of Snap Lake were provided during the EA process as well as in technical meetings during the development of the Response Framework:

- Possible proliferation of toxic cyanobacteria was identified as a potentially significant adverse response to enrichment; however, the proportion of cyanobacterial species in the algal community required to constitute a significant adverse response was not specified;
- TDS concentrations in excess of those predicted by De Beers were considered likely to generate significant adverse effects to the aquatic community in Snap Lake and toxic conditions for sensitive aquatic life throughout Snap Lake;
- Sediment quality must be maintained because clean-up of contaminated sediment is difficult and mines in the north have often left contaminated sediment *in situ*; and,
- Loss of mixing in deep areas of Snap Lake could lead to the accumulation of TDS and associated discharge constituents such as metals that could exceed predictions. If that occurred, then loss of habitat for use by aquatic life might exceed predictions, and might be significant.

It was also discussed during the EA process that some level of change to Snap Lake was acceptable. However, changes to downstream lakes such as Mackay Lake, where more traditional land use as well as hunting and fishing lodges are present were not deemed acceptable (Figure 6.2-2). Changes to the Lockhart River and to the East arm of Great Slave Lake were also deemed unacceptable, if not “catastrophic” (Figure 6.2-2). The Significance Threshold and Action Levels were therefore designed around changes in Snap Lake only, since such changes would precede possible downstream changes.

Figure 6.2-2 Conceptual overview of Action Levels relative to Significance Threshold



During the review process, the discussion of the significance of predicted effects centered on ecological stability or function of the Snap Lake system. The MVEIRB (2003) concluded that "the assessment methods and criteria used by De Beers to assess aquatic effects of the [project] were sufficient to conclude that no significant adverse impacts to the ecological stability of the Snap Lake system are likely". Indian and Northern Affairs concluded "that while the project is very likely to have environmental effects greater than those predicted by De Beers, we believe that Snap Lake will largely recover thirty to forty years after mining ceases. Changes in the species numbers, composition and ecosystem structure will occur, and, while recovery is not likely to be to pre-development conditions, these effects are tolerable in our view" (MVEIRB 2003). On the basis of the above pre-development discussion of the ecological stability of Snap Lake, one set of Significance Thresholds focused on the ecological stability/function of Snap Lake.

The two core values of concern (valued ecosystem components) that were identified in the EAR were drinking water and fish (Section 2). Significance adverse effects to these two core values would not be acceptable.

The Significance Thresholds were broadly organized into four categories centered around key "values" or Assessment Endpoints (Section 2):

1) Water is safe to drink;

2) Fish are safe to eat;

3) Sediment quality is maintained; and,

4) The ecological function of Snap Lake (i.e., the "ecosystem services" it provides including fish health and community) is preserved.

A single Significance Threshold and set of Action Levels is proposed for drinking water and fish consumption. Significance Thresholds were set around ecological function including thresholds for each of:

- Water Quality;
- Sediment Quality;
- Food for Fish (Plankton and Benthic Invertebrate communities);
- Fish Health; and,
- Fish Community.

The major exposure pathway relevant to the AEMP is direct contact of aquatic organisms with metals and nutrients, and with TDS and associated ions in the surface waters of Snap Lake. As described in Section 2, the types of effects that could occur from exposure to the treated effluent are hypothesized to be either toxicological impairment or nutrient enrichment. Therefore, the Response Framework includes a separate set of Significance Thresholds and Action Levels for each hypothesis.

6.3 Significance Thresholds

The Significance Thresholds for the Snap Lake AEMP are provided in Table 6.3-1. These thresholds encompass the conditions representing a significant adverse effect to the ecosystem component and, in turn, the assessment endpoint being evaluated. The rationale for each significance threshold is further discussed in Section 6.3.1.

Table 6.3-1 Snap Lake AEMP Significance Thresholds

Value	Component	*Plain Language – Threshold (due directly or indirectly to the Mine)*[(a)]	*Comments*
Water Must be Drinkable	Drinking Water	Water in Snap Lake not drinkable	Aesthetics will be considered through the action levels, but the significance threshold is based on a human health and/or wildlife risk assessment for any measured parameter in Snap Lake.
Fish Safe to Eat	Fish Consumption	Fish in Snap Lake not edible	Fish palatability will be considered through the action levels, but the significance threshold is based on the identification of an unacceptable human health or wildlife risk for any measured parameter in fish tissue in Snap Lake (see Section 6.3.1.1).
Sediment Quality Not Impaired	Sediment Quality	Sediments contaminated to concentrations at which adverse effects are likely but not certain	Exceeding Probable Effect Level(s)[(b)] at outlet of Snap Lake **OR** an alternate appropriate location for indicating the potential effects on downstream sediment quality
Ecological Function Maintained	Water and Sediment Quality Plankton Community Benthic Community Fish Health Fish Community	Inadequate food for fish in Snap Lake **OR** Fish in Snap Lake unable to survive, grow, or reproduce **OR** Sustained absence of a fish species	The significance threshold(s) for ecological function are defined based on biological responses that provide a direct indication of actual effects in Snap Lake due to the Mine. Information from exposure endpoints, which are indirect indicators of a potential for effects to these biological components, is used to assess both causation and appropriate responses. Significance Thresholds for water quality, sediment quality, and tissue chemistry are not defined individually with respect to ecological function. However, Action Levels are defined for these components as these exposure endpoint groups (i.e., water and sediment quality) provide "early warning" indicators of potential adverse effects to plankton and benthos, which are food for fish; fish health; and, the fish community.

(a) Significance Thresholds apply during Mine operations and post-closure.

(b) Probable Effect Level defined by Canadian Council of Ministers of the Environment.

EAR = Environmental Assessment Report

6.3.1 Rationale for each Significance Threshold

6.3.1.1 Water Safe to Drink and Fish Safe to Eat

Considerations for the significance threshold "Water must be drinkable":

- The water intake for the Mine camp facilities is located in the northwest arm, which is less affected by treated effluent than the main basin of Snap Lake. Nonetheless, the Significance Threshold is set based on any location in Snap Lake that could conceivably be used by wildlife or humans for drinking water. The under-ice portion of the lake near the diffuser is thus excluded from consideration, as this location would not be used by either wildlife or humans for drinking water.
- Parameters with aesthetic objectives will be considered in the Response Framework (i.e., Action Levels); however, the Significance Threshold is based on a human health and/or wildlife risk assessment for drinking water.

Considerations for the significance threshold "Fish safe to eat":

- The Significance Threshold applies to metal concentrations in edible fish tissues from fish collected from Snap Lake, and is based on a human health and/or wildlife risk assessment of measured fish tissue parameters in Snap Lake as compared to the reference lakes.
  - The significance threshold is not considered exceeded if one fish sample is above Canadian Food Inspection Agency (CFIA) guidelines, which exist for only three metals, mercury, lead and arsenic (CFIA 2009). The reason for this is that potential for toxicity is based on a sufficient dose, which would not be met for one fish. Further, fish tissue concentrations of mercury in the region are already above the commercial food inspection guidelines in some large piscivorous fish, such as Lake Trout; this is largely due to local bedrock geology and/or atmospheric deposition and is unrelated to the operation of Snap Lake mine.
  - In determining the Significance Threshold, consideration will be given to mercury, lead, arsenic concentrations, for which there are commercial food inspection guidelines (CFIA 2009). However, each metal parameter that is measured will be considered, and guidelines from other jurisdictions (e.g., US EPA Region 3 Screening Benchmarks) will be considered where available, and applicable. Metals without CFIA (2009) or other applicable guidelines would be considered via a risk assessment process, according to applicable Health Canada and Environment Canada guidance.
  - It is anticipated that human health and/or wildlife risk assessment activities would be initiated as part of response planning in the event that a Low Action level was reached. Risk assessments are typically tiered, with initial stages aimed at selecting and applying generic screening benchmarks, and subsequent stages becoming more detailed and site-specific. Response planning at the Low Action level would focus on selecting benchmarks for parameters that have increased beyond the Low Action level (i.e., 75% of the reference normal range), and setting Medium and High Action Levels. Medium and High action levels may be based on generic guidelines or site-specific risk-based guidelines, depending on the parameter of concern, the availability of guidelines, and applicable Health Canada and Environment Canada policies and guidance. It is not possible to initiate risk assessment activities until a Low Action Level is reached for a specific parameter, at which time that specific parameter would

drive the risk assessment focus. This is consistent with the process for other Significance Thresholds where a change that could be of concern is identified prior to setting medium and high action levels and developing response plans.

- The fish edibility Significance Threshold does not consider palatability. Fish taste and texture will be considered through the action levels but a Significance Threshold for fish taste/texture is not included. This is thought to be appropriate as action will be taken on changes in taste/texture but that a threshold cannot be set for individual preference for taste/texture.

6.3.1.2 Sediment Quality is Not Impaired

Considerations for the significance threshold "Sediment quality is not impaired":

- The Significance Threshold applies to confirmed metals concentrations in whole sediment collected from Snap Lake and is based on protection of freshwater aquatic life.
- The Significance Threshold is based on the PEL and applies at the outlet to Snap Lake (i.e., Station SNAP08, which is the AEMP station closest to the outlet but still located in a depositional area) with the intent that downstream aquatic communities will be protected. An exceedance of the PEL does not automatically mean that adverse biological effects will occur, but that their likelihood is increased. Adverse effects on the benthic invertebrate community as a result of exposure to increased concentrations of sediment contaminants may result in a decrease in the amount of food available to fish.

6.3.1.3 Ecological Function Maintained

Considerations for the Significance Threshold "Ecological function maintained":

As described in the Conceptual Model (Section 2), the ecological function of Snap Lake is dependent on multiple complex interactions between primary productivity (epilithic algae and phytoplankton), the trophic levels that provide food for fish (zooplankton and benthic invertebrates), fish feeding on zooplankton and benthic invertebrates, and predatory fish feeding on smaller fish. The Mine-related stressors that may have an effect on these components are: contaminants (TDS and a number of metals); nutrients (phosphorus, nitrogen [N] and some constituents of TDS); and, acidifying substances. The pathways by which the above-identified stressors may influence the aquatic ecosystem are both direct (e.g., toxicity to fish as a result of exposure to an elevated concentration of an ion or a metal) and indirect (e.g., toxicity to invertebrates reducing the amount of food available for fish).

One of the central principles of the AEMP design is that both exposure to stressors and resulting biological responses in plankton, benthos and fish are monitored in Snap Lake. Monitoring of biological responses focusses directly on the receptors of concern in the Lake, but effect to the receptors of concern would "link back" to the Mine via stressor exposure, since the Mine does not directly "release" biological response such as "impaired fish health" but rather introduces stressors which might cause this. Thus, monitoring of the biological components indicates the actual level of effect on receptors of potential concern, whereas monitoring of stressor exposure (i.e., water quality, sediment quality, tissue chemistry) helps to indicate the cause of any unacceptable effects and inform management responses.

While it is well known that as exposure to contaminants or nutrients increases toward critical levels, the potential for serious effects on the biological system increases, the exact tipping point is difficult to establish in advance. Changes to water and sediment quality and to tissue chemistry are indicators of exposure to Mine-related stressors but the threshold at which ecological function would be compromised is uncertain because of complex interactions of exposure and toxicity modifying factors (physicochemical and biological), acclimation/adaptation of natural populations to contaminants/nutrients, and the resiliency/redundancy of natural communities. Therefore, the significance threshold(s) for ecological function are defined based on biological responses, which are a direct indicator of actual effects in Snap Lake as opposed to the exposure endpoints groups, which are indirect indicators of a potential for effects to these biological components.

Although Significance Thresholds for water quality, sediment quality, and tissue chemistry are not defined individually with respect to ecological function, Action Levels are defined for these components. These exposure endpoint groups provide "early warning" indicators of potential adverse effects to plankton and benthos which are food for fish, to fish health, and to the fish community. Exposure to Mine-related stressors directly or indirectly must be the cause of the change for management intervention to occur.

The Significance Threshold is therefore defined as one or more of the following conditions occurring in Snap Lake:

- inadequate food for fish in Snap Lake;
- fish in Snap Lake unable to survive, grow or reproduce; or,
- sustained absence of a fish species;

The Significance Thresholds are conceptual because it is not possible to account for the nature, extent, and magnitude of all possible types of effects in Snap Lake that might trigger through Low, Medium, and High Action Levels, in a single narrative statement. However, it is possible to give a preliminary definition of what types of changes might indicate loss of ecological function. It is anticipated that these would be refined as system understanding improves (e.g., via the special studies on the littoral zone and stable isotopes) and as monitoring intensity and focus increases if Low, Medium and High Action Levels are triggered. Examples of the types of changes in Snap Lake that are sufficiently severe to indicate the Significance Threshold include:

Inadequate food for fish in Snap Lake:

- For the plankton community, this could include the following types of changes:
  - a persistent decline in total phytoplankton abundance or biomass beyond the level of natural variability; and,
  - a persistent absence of cladocerans from Snap Lake.
- For the benthic invertebrate community, this could include the following types of changes:
  - sustained absence of normally dominant major taxonomic group(s) that are important to ecosystem function and services, combined with a severe decline in richness (i.e., community dominated by a few tolerant species).

Fish in Snap Lake unable to survive, grow, or reproduce:

- Year class structure and age frequency distributions would be indicators of ability to survive, and will be considered in conjunction with fish presence/absence surveys and supporting evidence from other biological components that may be indicative of a shift in Snap Lake to conditions that are unsustainable for fish (e.g., water quality, food availability or quality, habitat).
- Fish health endpoints such as condition factor and length frequency distributions would be indicators of ability to grow.
- Fish health endpoints such as gonadosomatic index (GSI) combined with information from fecundity and gonad histology would be indicators of ability to reproduce.
- Fish health endpoints (e.g., year class structure, age frequency distributions, condition, GSI, fecundity) are key indicators considered in the fish health and fish community action levels (see Section 6.2.2). Changes in fish health endpoints, either increases or decreases, are included in the definition of the Low Action Level. If the Low Action Level were triggered, these endpoints would be further investigated in a Management Response Plan, with definition of the Medium or High Action Level required as part of that Plan. The result is a tiered response framework guided by changes that are observed in the fish population indicative of detrimental fish health effects. Accordingly, fish health impairment will be identified at a sufficiently early stage that action will be taken to reverse these changes well in advance of irreversible changes occurring in fish populations.

Sustained absence of a fish species:

- Sustained absence of a fish species from consecutive sampling programs is considered as an indication of a loss of a fish species from Snap Lake and, therefore, represents an unacceptable change to Snap Lake (i.e., this is the Significance Threshold for fish community). An absence of a species in one sampling program would be considered a Low Action Level. However, an absence of a fish species in one sampling effort would be immediately (or, at the soonest possible opportunity) followed up by additional, focused fishing efforts at relevant times (e.g., spring, fall), in appropriate habitat (e.g., littoral zone, deep water), and with appropriate fishing gear to target the absent fish species to confirm presence/absence of the species from Snap Lake.
- The condition of sustained absence is considered to have occurred with the absence of a fish species on three separate and consecutive follow-up sampling programs after an initial non-detection or absence in a single sample effort. Sampling may occur within one year or in consecutive years (if logistics prevent fishing efforts within the same year).
- The current design of the fish community program is to use a standard gill netting program that targets small- and large-bodied fish, known as the Broad Scale Community Netting Program (see Section 4 for details). It is possible that some species in the lake will not be caught by netting. For example, Burbot and Arctic Grayling are traditionally less vulnerable to gill netting than other fishing methods. The ‘catchability’ and effectiveness of the netting methods will be evaluated in 2013. Future fish community programs will be adjusted to include additional fishing methods (gear, locations, time of year), if necessary, to maximize the ability to collect each fish species in Snap Lake.

6.4 Action Levels

The following sections provide tabular summaries of the proposed Significance Thresholds and Action Levels. Each table includes the following information:

- **Key Information** - Summarizes which measurement endpoints are assessed for each assessment endpoint.
- **Negligible** - The conditions under which the Low Action Level would not yet be reached
- **Low Action Level** - The conditions under which the Low Action Level would be reached.
- **Comment/Rationale** – The rationale for the Low Action Level.

6.4.1 Sensitivity of the Action Levels

Toxicological Impairment

Potential toxic effects on biota resulting from increased concentrations of TDS and its constituent ions, and metals, if observed, would be predominantly negative. The EAR predicted no toxicity-related effects to the aquatic biota of Snap Lake; thus, the Action Levels are set to be relatively sensitive to the first indication of direct impairment in the biological communities, triggering the Low Action level. However, reaching a Low Action level for water quality or sediment quality does not result in the same, higher, level of concern as when the Low Action level is reached for actual biological responses in the plankton, benthic invertebrate, or fish communities of Snap Lake from exposure to substances of toxicological concern. This is because water and sediment quality are indirect measures of potential effects to plants and animals living in Snap Lake.

Nutrient Enrichment

An increased supply of nutrients is initially positive resulting in enhanced algal growth in the epilithic algae and phytoplankton communities providing increased food supply to zooplankton and benthic invertebrates, which in turn increases food for fish. However, as enrichment progresses, the likelihood of a shift in overall trophic status of the lake, harmful alteration of the plankton community to less edible species for invertebrates and, in turn, for fish, or possible oxygen depletion, increases. It is at this stage that enrichment could lead to harmful alteration of the Snap Lake ecosystem. The EAR predicted mild nutrient enrichment of Snap Lake, with some mild effects on the biological community but no change in trophic status. Because low levels of nutrient enrichment can have 'positive' rather than 'negative' effects, the Action Levels for biological responses to enrichment are set to be less sensitive than for toxicological impairment. Similar to toxicological impairment responses, reaching a Low Action level for water quality (i.e., increased nutrients) does not result in the same level of concern as when the Low Action level is reached for actual biological responses in the plankton, benthic invertebrate, or fish communities of Snap Lake from nutrient exposure.

6.4.2 Water Safe to Drink and Fish Safe to Eat

The proposed Action Levels for the categories of Drinking Water and Fish Safe to Eat are presented in Table 6.4-1. Key considerations for the Action Levels are:

Water Safe to Drink

- The Drinking Water Action Level category applies to parameters with aesthetic objectives related to palatability, Health Canada drinking water guidelines, and CCME livestock watering (wildlife health) guidelines.
- Action Levels for drinking water exclude consideration of coliforms; Health Canada recommends disinfection of all surface waters prior to consumption.
- The low action level of "water safe to drink" is based on concentrations in one sample for any parameter at any location in Snap Lake.
- Drinking water guidelines for both humans and wildlife are generally higher than aquatic life guidelines, so action will likely be taken earlier under the Toxicological Impairment Action Levels (Section 6.4.2).
- Microcystin-LR (amino acids lysine [L] and arginine [R]) concentrations from depth-integrated AEMP samples and mid-depth samples from one SNP station (SNP 02-15, the drinking water intake for Snap Lake) will be considered.
- Recommended action would vary depending on the parameter. For example, the action implemented if Microcystin-LR concentrations were to approach the drinking water guideline would be different (i.e., more urgent) than for a parameter with an aesthetic objective. As well, temporal (i.e., changes over time) and spatial (i.e., proximity to the camp water intake) trends will be considered when recommending action.
- Prior to reaching the Significance Threshold for "water safe to drink", an unacceptable human health risk would need to be determined. Therefore, it is anticipated that the responses to Medium and High Action Levels for both categories would involve varying degrees of human health risk assessment.

Fish Safe to Eat

- The Fish Safe to Eat Action Level category applies to metal concentrations in edible fish tissue, and to texture and taste, as determined with input from the Fish Tasting program.
    - The negligible action level of "fish taste and texture is good" is based on ratings of "good to very good" from the annual fish tasting program at Snap Lake.
    - The low action level of "fish taste and/or texture is not acceptable" is based on any one fish receiving a "not good / not acceptable" rating from any one Elder during the annual fish tasting program at Snap Lake.
    - No extensive mitigation is anticipated in response solely to a taste and texture low action level trigger in the absence of supporting low action level triggers from supporting components (i.e., water quality, fish health, fish community). However, triggering of this low action level would result in further investigation (i.e., confirmation of unacceptable fish taste and / or texture) including causation.
- The 'Metals in Edible Fish Tissue' Action Level is based on a comparison of metal concentrations in fish from Snap Lake to normal ranges of metal concentrations in fish from the reference lakes in any given sampling year.

- For example, Lake Trout fish tissue metal concentrations in Snap Lake will be compared to Lake Trout fish tissue metal concentrations in the reference lakes. This comparison will utilize the statistical mean metal concentrations from Snap Lake and compare them to “normal range”, or the pooled reference area fish tissue metal concentrations that represent normal variability in the region.
- The appropriate method for calculating normal range is currently being developed; the AEMP Design Plan currently defines normal range for fish tissue as the pooled reference mean plus or minus two standard deviations (SD). Normal range as currently calculated may be insensitive to capture change in Snap Lake fish tissue metal concentrations that are biologically meaningful. It is expected the normal range calculations for fish tissue chemistry will be defined as a 95% prediction interval of the reference lake fish tissue metal concentrations; this should provide a stronger basis for determining concentrations that are likely to indicate impairment of fish usability to humans or wildlife.

- Canadian commercial fish consumption guidelines (CFIA 2009) for mercury, arsenic, and lead concentrations will be considered, but will not alone trigger a low action level. These benchmarks are set for commercial consumption of fish products; therefore, Lake Trout, for example, from Snap Lake being consumed by traditional fishers would be a misapplication of the commercial consumption guideline. Further, Lake Trout from Snap Lake already contain mercury concentrations in exceedance of the mercury CFIA guidelines, a condition which is normal for larger piscivorous fish and consistent with baseline conditions in Snap Lake. Comparison of tissue metal concentrations in these fish relative to the reference condition provides the best identification of any mine-related effects.

Table 6.4-1 Proposed Action Levels – Drinking Water and Fish Safe to Eat

Tiered Action Level	Drinking Water for Humans *Water Must be Drinkable*	Fish Consumption by Humans *Fish Safe to Eat*
Key Information	Drinking water parameters (metals, nutrients, and major ions) measured in AEMP samples (all stations) and SNP samples (Station SNP 02-15 only) Microcystin-LR measured in AEMP samples (all stations) and SNP samples (Station SNP 02-15 only)	Fish taste and texture Metal concentrations in edible fish tissue
Negligible	Drinking water parameters <75% Health Canada human health and aesthetic drinking WQG **AND** Microcystin-LR <75% of Health Canada human health drinking WQG **AND** Drinking water parameters <75% CCME wildlife health WQG	Taste and texture good (TK input) **AND** Metals in edible fish tissue below 75% of upper limit of normal range[(a)]
Low	Drinking water parameters at any location are above 75% of Health Canada human health or aesthetic drinking WQG **OR** Microcystin-LR at any location is above 75% of Health Canada human health drinking WQG **OR** Drinking water parameters at any location are above 75% of CCME wildlife health WQG,	Fish taste and/or texture not acceptable. **OR** Metals in edible fish tissue above 75% of upper limit of normal range[(a)].
Medium	*TBD*[(b)]	*TBD*[(b)]
High	*TBD*[(b)]	*TBD*[(b)]
Comment/Rationale	■ Action Levels for drinking water exclude consideration of coliforms. Health Canada recommends disinfection of all surface waters prior to consumption. ■ Action Levels apply to any one drinking water parameter in any one sample collected from any location in Snap Lake. ■ CCME livestock watering guidelines will be used for wildlife health. ■ Microcystin-LR concentrations from depth-integrated AEMP samples and mid-depth samples from one SNP station (SNP 02-15, the drinking water intake for Snap Lake) will be considered. ■ Temporal (i.e., changes over time) and spatial (e.g., proximity to the camp water intake) trends will be considered when recommending action. ■ See bullets in Section 6.4.2 for details.	■ Negligible action level of “fish taste and texture is good” is based on a satisfactory outcome from the annual fish tasting program ■ The low action level of “fish taste and/or texture is not acceptable” is based on any one fish receiving a ‘not good/unacceptable rating’ from any one participant of the fish tasting program ■ The low action level of “metals in edible fish tissue” is based on the mean concentration for any metal in Snap Lake fish tissue observed above 75% of the upper limit of normal range ■ See bullets in Section 6.4.2 for details.

(a) The definition of Normal Range for fish endpoints is currently in development.

(b) TBD – to be determined if Low Action Level is reached.

AEMP = Aquatic Effects Monitoring Program; SNP = Surveillance Network Program; <= less than; % = percent; TK = Traditional Knowledge; HC = Health Canada; CCME = Canadian Council Ministers of the Environment; WQG = water quality guideline.

6.4.3 Ecological Function

The proposed Action Levels for the category of Ecological Stability are presented in Table 6.4-2 for Toxicological Impairment and Table 6.4-3 for Nutrient Enrichment.

Water Quality

Toxicological Impairment Action Levels

- For the Toxicological Impairment Action Levels (Table 6.4-2), conservative benchmarks are used as one of the conditions for reaching a Low Action level: CCME water quality guidelines (WQGs) and, for cadmium, copper, and chromium, site-specific benchmarks developed in the EAR. Collectively, these benchmarks are termed "AEMP Benchmarks" (see Section 4.2 for further discussion). While these generic guidelines are available for comparison, exceedances would not definitively result in significant adverse effects. Increases in parameter concentrations were predicted in Snap Lake and, for some parameters, to concentrations that would exceed CCME WQG (e.g., nitrate and chloride). Therefore, site-specific benchmarks will be considered when assessing effects. Exceedance of a site-specific benchmark for any one parameter at any location in Snap Lake would result in timely management intervention. However, such an exceedance would not necessarily result in impairment of overall ecological function; further investigation (e.g., examination of trends in biological endpoints) would be undertaken to determine the significance of this exceedance. The new site-specific objectives being developed as required by the water licence (i.e., strontium, nitrogen [ammonia and nitrate], and TDS [including fluoride and chloride]) will be grouped with the AEMP Benchmarks, but clearly labeled as site-specific benchmarks and considered as such in the Response Framework.
- For water quality, the normal range is defined as baseline water quality measurements in Snap Lake between 1999 and 2004 ± 2SD (standard deviations). The reference range is defined as reference lake measurements (Lake 13 and Northeast Lake combined) ± 2SD. An appropriate combination of statistical comparisons and/or visual comparisons will be applied to identify differences between Snap Lake and the normal and reference ranges.
- The Low Action Level for water quality is intended to apply to those parameters that are increasing due to the Mine and are approaching an AEMP Benchmark. The Low Action Level would be triggered if the average concentration from the three diffuser stations (i.e., SNP 02-20d, e, f) during one sampling event was greater than 75% of the AEMP Benchmark, and concentrations were increasing and were outside of the normal and reference range lake-wide (main basin only). Treated effluent concentrations, temporal trends (i.e., changes over time), and spatial trends (e.g., proximity to diffuser) will be considered when recommending action. There may be an occasion when an anomalous result approaches or exceeds or, in the case of dissolved oxygen (DO) and pH, decreases below an AEMP Benchmark. If no source from the Mine was identified (i.e., not due to the Mine), a temporal trend did not exist (either visually or confirmed with a statistical test; Section 4.2.5.4), and/or the spatial pattern was unexpected (e.g., the exceedance only occurred in the northwest arm as opposed to near the diffuser where concentrations of treated effluent-related parameters tend to be elevated), the result may be due to an analytical error, contamination of the sample, or other unidentified source. Individual anomalous or erroneous results would not trigger a Low Action Level but would be further investigated as appropriate.

- Observations of mixing zone toxicity are treated as exposure endpoints under the water quality category because the toxicity testing is not synoptic with biological sampling and therefore it cannot be linked directly to observed biological responses (i.e., dilution and toxicity modifying factors would act on the mixing zone water, as it comes into contact with receptors in Snap Lake). Rather, mixing zone toxicity is an indicator of the potential cumulative exposure to substances of toxicological concern.
- Persistent sublethal toxicity is defined as two concurrent or two consecutive sublethal test results (i.e., sublethal toxic effects) in the laboratory toxicity tests performed with *Ceriodaphnia dubia* and *Pseudokirchneriella subcapitata* on mixing zone samples. Sublethal toxic effects are defined as an IC_{25} less than the highest test concentrations (i.e., <100% for *C. dubia* and <97% for *P. subcapitata).*
- Sublethal toxicity (i.e., IC_{25} less than 100%) in any Fish Early Life Stage test performed on a mixing zone sample.

Nutrient Enrichment Action Levels

- Nutrient enrichment was predicted in the EAR; therefore, the EAR predictions for nutrients (e.g., TDS, nitrogen and phosphorus parameters) will be considered as part of the Nutrient Enrichment Action Levels. Whole-lake average concentrations (main basin only) will be compared against maximum whole-lake average concentrations predicted in the EAR (De Beers 2002a) and updated predictions such as those completed for the 2011 Water Licence Renewal Application (De Beers 2011a). Results from both mid-depth samples (water quality component) and depth-integrated euphotic zone samples (plankton component) will be considered. For key parameters, observed concentrations will plotted together with the relevant EAR predictions for the equivalent time period to identify any potential divergence. Comparisons to new predictions will be made as they become available; however, the comparisons to the EAR predictions will continue to be the focus of the assessment.
- For the Nutrient Enrichment Action Levels (Table 6.4-3), AEMP Benchmarks refer to concentrations of nitrogen or phosphorus that could result in a trophic shift in Snap Lake. Nutrient enrichment AEMP Benchmarks are only available for total phosphorus: a range of 10.9 – 95.6 micrograms per litre (µg/L) for ‘mesotrophic lake status’, based on standard limnology definitions of eutrophication (Wetzel 2001). De Beers will use 75% of the lower end of the range (10.9 ug/L) as the Low Action Level. This would be based on an upward trend in the whole lake average of the main basin. If other benchmarks become available (e.g., in the published literature), they will be considered when defining Action Levels.

Sediment Quality

Toxicological Impairment Action Levels

- For the Toxicological Impairment Action Levels (Table 6.4-2), conservative benchmarks are used as one of the conditions for reaching a Low Action level. For sediments, these are CCME sediment quality guidelines (SQGs) for seven metals: arsenic, cadmium, chromium, copper, lead, mercury, and zinc. No site-specific benchmarks have been developed for sediments in Snap Lake, and no specific predictions were defined in the EAR with respect to changes in sediment quality in Snap Lake. Although these generic SQGs are available for comparison, they are not definite. In other words, exceedances will not necessarily result in significant adverse effects. Concentrations of cadmium, chromium, copper, and zinc have exceeded SQGs in Snap Lake since 2004 baseline monitoring and in Northeast Lake since monitoring began, and indicate

the natural mineralization in the area. Concentrations of arsenic occasionally exceed the SQG but only at one station at the head of the northwest arm, which appears unrelated to Mine activity. Lead and mercury concentrations are below their respective SQGs.

- For sediment quality, the normal ranges for particle size, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total nitrogen, and metals are expressed as the mean ± 2SD calculated from the 2004 baseline sediment chemistry data for each parameter. Additional nutrients added to the target parameter list in 2005 (available nitrate, available phosphate, available potassium, and available sulphate) and 2006 (available ammonium) did not have 2004 baseline data. Instead, normal ranges for these additional parameters were calculated using data collected during the first year of monitoring, from stations that had not yet been exposed to treated effluent discharge (i.e., those stations with bottom conductivity less than 50 microSiemens per centimetre [µS/cm]). Antimony, mercury, selenium, silver, and tin were undetected in 2004 baseline sediment samples and therefore their normal ranges are equal to their respective detection limits (DLs); this means that any detected concentrations measured in subsequent years are likely to fall outside the normal range and need to be interpreted with caution (i.e., considered in conjunction with the magnitude and frequency of detection, and the presence of temporal trends). The reference range is defined as the mean of reference lake measurements (e.g., Lake 13 and Northeast Lake combined) ± 2SD. The fact that mean concentrations of approximately half of the parameters analyzed are higher in Northeast Lake sediments than in Snap Lake reflects naturally elevated concentrations in the region, and is thus a confounding factor with respect to interpretation of the results. However, using Northeast Lake as a reference lake is appropriate for assessing long-term regional trends. A combination of statistical comparisons and/or visual comparisons will be applied to identify differences between Snap Lake and the normal and reference ranges.
- The Low Action Level for sediment quality is intended to apply to those parameters that are increasing due to the Mine and are approaching both their respective SQG and the upper limit of their normal range. The Low Action Level would be triggered if the mean concentration for the main basin stations (excluding the diffuser) was greater than 75% of the SQG, the concentration was increasing, and was outside of the normal range. If no source from the Mine was identified (i.e., not due to the Mine), a temporal trend did not exist (either visually or confirmed with a statistical test), and/or the spatial pattern was unexpected (e.g., the exceedance only occurred in the northwest arm as opposed to near the diffuser where concentrations of treated effluent-related parameters tend to be elevated), the result may be due to an analytical error, contamination of the sample, or other unidentified source. Individual anomalous or erroneous results would not trigger a Low Action Level but would be further investigated as appropriate.

Nutrient Enrichment Action Levels

- Action Levels for nutrient enrichment are not applicable for sediment quality and therefore have not been defined.

Plankton Community

- Plankton communities are inherently variable (Figure 6.4-1) therefore persistent changes need to be observed before action is taken.

- Changes are considered ecologically important or persistent if they are maintained for three or more years. The time-frame of three years is necessarily given the naturally high variability in the plankton community as reflected in AEMP monitoring to date (Figure 6.4-1).
- A change is documented if differences are observed between Snap Lake and the reference lakes, or if current indicators of change are outside the normal range.
- The normal range is currently defined as the mean of the background data (2004) plus or minus two standard deviations (± 2 SDs); however, this may not be a conservative measure of the normal range because ± 2 SDs may be too wide a range and the low end of the normal range often equals zero when calculated using this method. In addition, this single year of background data is likely not appropriate for calculating a normal range for plankton data because the year-to-year variability inherent in the plankton community is not captured. Therefore, the normal range for plankton indicator data will be assessed throughout the current design and a new normal range will be suggested in a separate report in 2014.

Toxicological Impairment Action Levels

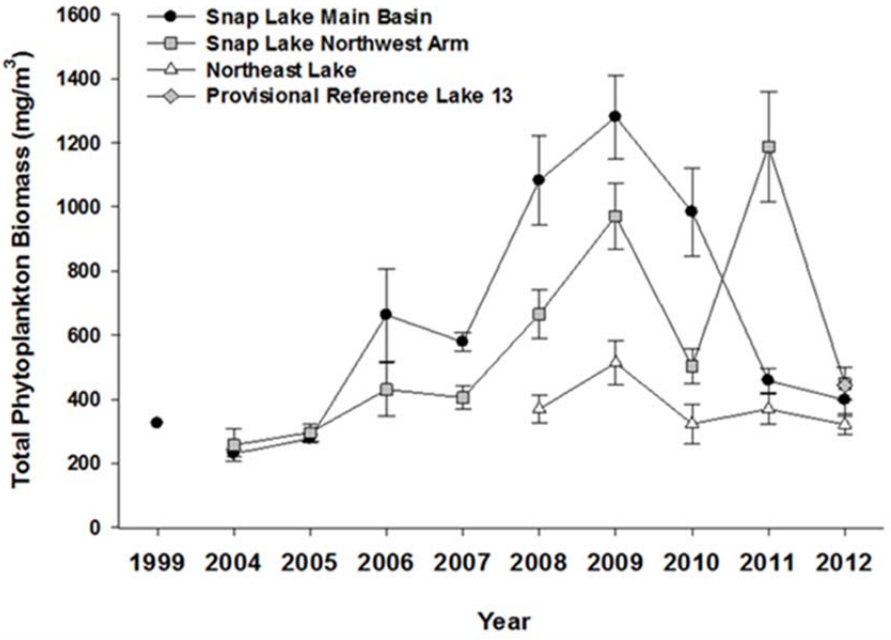
- For the Toxicological Impairment Action Levels (Table 6.4-2), total phytoplankton biomass was selected as the overall indicator for the phytoplankton community, while for the zooplankton community, cladoceran abundance and biomass were selected.
- Toxicological impairment is assumed if a persistent (i.e., >3 years) decline is observed below the normal range. The time-frame of three years is necessary given the naturally high variability in the plankton community as reflected by AEMP results to date (Figure 6.4-1).

Nutrient Enrichment Action Levels

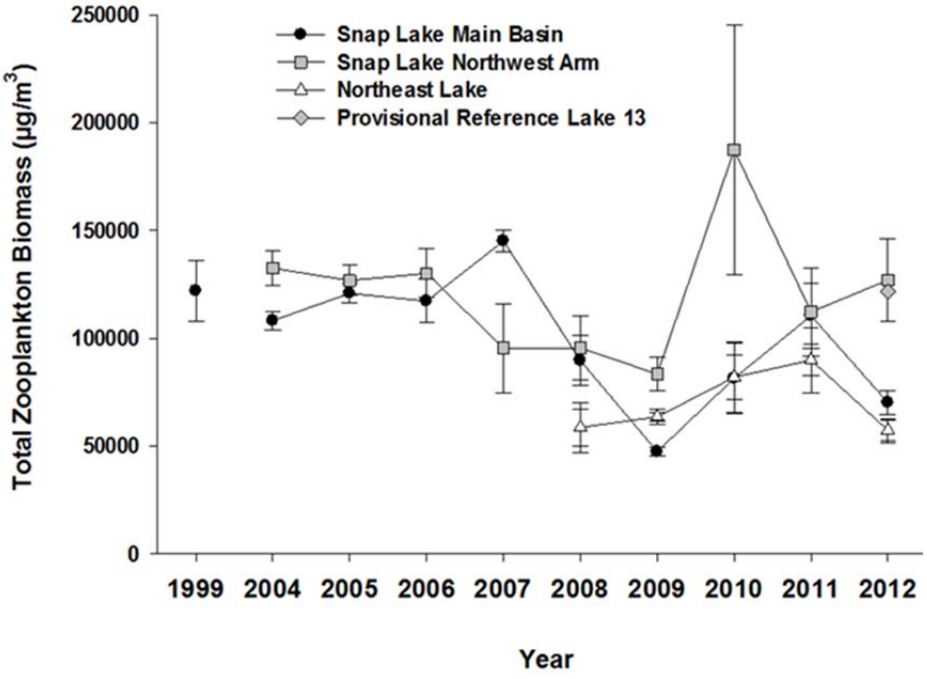
- For the Nutrient Enrichment Action Levels (Table 6.4-3), total phytoplankton and zooplankton taxonomic richness, and community structure were selected as the overall indicators of phytoplankton and zooplankton community function. Taxonomy and community structure are likely conservative indicators of function since functional redundancy is not considered.
- In addition, for the Nutrient Enrichment Action Levels (Table 6.4-3), total phytoplankton biomass and total zooplankton biomass were selected as indicators for the phytoplankton and zooplankton communities, respectively. Biomass is clearly an important endpoint relative to predation.
- Some level of nutrient enrichment is expected and, at low levels, nutrient enrichment may be beneficial to the plankton community. Thus, a more persistent effect on the plankton community is required to reach the Low Action Level for nutrient enrichment, compared to the Low Action Level for toxicological impairment.
- Nutrient enrichment is assumed if a persistent (i.e. >3 years) increase is observed above the normal range. The time-frame of three years is necessary given the naturally high variability in the plankton community as reflected in AEMP monitoring to date (Figure 6.4-1).
- A shift in community structure is an indicator of change; changes at the “major” group level of phytoplankton or zooplankton community composition are considered important. The “major” group-level refers to the Class level of biological organization for phytoplankton and the Phylum (i.e., Rotifera) or Order level (i.e., Cladocera, Calanoida, Cyclopoida) of biological organization for zooplankton. Changes at the species or genus-level occur regularly from year to year within the plankton community; therefore, examining the community at a higher level of biological organization in required.

Figure 6.4-1 Variability in (a) Total Phytoplankton and (b) Zooplankton Biomass in Snap Lake and Reference Lakes

(a)



(b)



Benthic Community

- Total richness and densities of dominant taxa were selected as indicators of effects on the benthic invertebrate community for both toxicological impairment (Table 6.4-2) and nutrient enrichment (Table 6.4-3). Total richness is calculated at the genus level, because the benthic communities in Snap Lake and the reference lakes are dominated by the family Chironomidae (midges), with the remainder consisting of very few other families; therefore, using the family level would provide very low taxonomic resolution to base action levels on. Dominant taxa are defined as those accounting for greater than 5% of the total density in the entire study area, including the reference lakes.
- The normal range for the benthic invertebrate community is currently defined as ± 2SD of the mean of reference lake stations and stations that were considered unaffected by mine effluent, based on conductivity as an effluent tracer, during the early stages of Mine development. The normal range will be re-evaluated as AEMP monitoring proceeds, based on data from reference lakes.

Toxicological Impairment Action Levels

- Statistically significant differences (P<0.1) below the normal range for richness and densities of dominant taxa between the Snap Lake main basin and the reference lakes will be used to evaluate possible effects on the benthic invertebrate community.
- A downward trend in richness and densities of dominant taxa in the Snap Lake main basin compared to the reference lakes will be considered an indication of an effect on the benthic invertebrate community.

Nutrient Enrichment Action Levels

- Statistically significant differences (P<0.1) above the normal range for richness and densities of dominant taxa between the Snap Lake main basin and the reference lakes will be used to evaluate possible effects on the benthic invertebrate community.
- An upward trend in richness and densities of dominant taxa in the Snap Lake main basin compared to the reference lakes will be considered an indication of an effect on the benthic invertebrate community.

Fish Health and Fish Community

- It is anticipated that fish health and fish community Action Levels would be combined at the Medium and High Action Levels (i.e., to reach one of these levels, fish health effects and possible community-level effects would need to be observed).
- Key fish health endpoints are condition, relative gonad size (GSI), relative liver size (LSI), age distribution, and size-at-age. It is assumed that if a sub-sample of male and female small-bodied fish from a wild population show normal growth, reproduction, and age distribution, that these data are sufficient to confirm that the fish population is healthy and that existing conditions are within the capacity of the ecological system to absorb without detriment (Munkittrick et al. 2000).
- If a Low Action Level for fish health endpoints were triggered in small bodied fish, the Management Response Plan would include the addition of a large bodied fish health special study to determine whether large bodied fish health was consistent with the change observed in the small bodied fish health program.

- The method for calculating normal range for fish health endpoints is under review. Normal range as currently calculated is mean ± 2 SD, which might not be appropriate to detect changes in Snap Lake fish health endpoints that are biologically meaningful (e.g., too broad to be early warning). Data transformations (i.e., $\log_{10}$ transforming data prior to normal range calculations) may also be considered in optimizing normal range calculations.
- The best statistic or metric for use in comparing Snap Lake fish health changes to the normal range is currently under review. The arithmetic mean of the population, maximum values, and a proportion of the data from the population which fall above or below the normal range are currently under consideration for use as a Low Action Level trigger.
- Fish tissue chemistry comparisons to normal range will only be performed for metals with greater than or equal to (≥) 50% of the samples measured above the DL. For example, if fish tissue arsenic concentrations are below DLs in 12 out of 20 samples from Snap Lake, the mean arsenic concentration in Snap Lake will be calculated and reported, but no comparison to normal range will be made for arsenic as part of the Response Framework. In contrast, if 8 out of 20 samples are below DLs, those samples below the DL will be assigned a value of 0.5×DL, and a mean will be calculated and compared to the normal range for arsenic in fish tissue from the reference lakes.
- Mercury accumulates in fish tissue to concentrations proportional to the size of the fish, such that smaller or young fish will have lower concentrations of mercury than larger or older fish, such as Lake Trout. Fish tissue mercury concentrations are, therefore, interpreted only after normalizing to fish size. As a result, the normal range comparisons for mercury may be handled differently than other metals with respect how non-detects are handled in smaller sized fish (i.e., where concentrations of mercury are expected to be lower, and potentially below DL).
- Statistically significant change is defined as a statistically significant difference (P<0.1) in fish health endpoints between fish collected in Snap Lake and fish collected in the reference lakes when compared parametrically (e.g., analysis of variance or analysis of covariance) or non-parametrically (e.g., Kruskal-Wallis). A statistically significant change could represent an increase or a decrease in the fish health endpoint in Snap Lake relative to the pooled reference lakes.
- A magnitude of change that is indicative of an impairment to fish health is defined as a difference in fish health endpoints (as a percentage (%) of the pooled reference lake mean) that exceeds the critical effect sizes defined by Environment Canada's Metal Mining Effluent Regulations Guidance Document (Environment Canada 2012). Critical effect sizes are defined for weight-at-age, relative fish gonad size (GSI), relative liver size (LSI), and age at ± 25%, and ± 10% for condition.
- Change as it relates to fish community and a change in the relative abundance of a fish species relative to reference lakes has not yet been defined, and is currently under development pending completion of the 2013 fish community program on Snap Lake and the reference lakes.

Table 6.4-2 Proposed Action Levels - Toxicological Impairment

Tiered Action Level	Water Quality (substances of potential toxicological concern and measured toxicity) *Ecological Integrity Maintained*		Sediment Quality *Ecological Integrity Maintained*
Key Information	Differences between Snap Lake and reference lakes or normal range AEMP Benchmarks	Toxicity results for edge of mixing zone	Differences between Snap Lake and reference lakes or normal range CCME sediment quality guidelines
Negligible	Concentration not exceeding AEMP Benchmarks[(a)] where they exist, or if exceeding, not due to Mine **AND** Within normal range lake-wide	No persistent sublethal toxic effects to test organisms in mixing zone samples	Not exceeding CCME interim sediment quality guidelines (ISQG) or, if exceeding, not due to the Mine **AND** Within normal range lake-wide
Low	Concentration greater than normal and reference range lake-wide supported by a temporal trend **AND** Exceeding 75% of AEMP Benchmark[(a)] at the edge of the mixing zone (i.e., diffuser station)	Persistent sublethal toxic effects to test organisms in mixing zone samples **OR** Sublethal toxic effects for Fish Early Life Stage test in mixing zone samples	Exceeding 75% of ISQG in Snap Lake as a result of Mine operation **AND** Greater than normal range
Medium	*TBD*[(b)]	*TBD*[(b)]	*TBD*[(b)]
High	*TBD*[(b)]	*TBD*[(b)]	*TBD*[(b)]
Comment/Rationale	■ AEMP Benchmarks refers to benchmarks currently used in the AEMP to which substance concentrations are compared (i.e., EAR benchmarks and CCME guidelines). ■ Exceeding 75% of AEMP Benchmark at the edge of the mixing zone (i.e., diffuser station) = the average concentration from the three diffuser stations (i.e., SNP 02-20d, e, f) in any one sampling event is >75% of the AEMP Benchmark. ■ Lake-wide refers to all locations in the Main Basin. ■ Temporal (i.e., changes over time) and spatial (i.e., proximity to diffuser) trends will be considered when recommending action. ■ Persistent sublethal toxicity is defined as two concurrent or two consecutive sublethal test results (i.e., sublethal toxic effects). Sublethal toxic effects are defined as IC25 less than highest test concentrations (i.e., <100% for *C. dubia* and <97% for *P. subcapitata.* ■ Fish Early Life Stage test indicates results from the 30-day test. ■ See bullets in Section 6.4.3 for details.		■ ISQG is highly protective so is an appropriate trigger value. ■ This will be triggered based on comparison of mean concentration from main basin stations. ■ See bullets in Section 6.4.3 for details.

Table 6.4-2 Proposed Action Levels - Toxicological Impairment (continued)

Tiered Action Level	Plankton Community *Ecological Integrity Maintained*	Benthic Community *Ecological Integrity Maintained*	Fish Health *Ecological Integrity Maintained*	Fish Community *Ecological Integrity Maintained*
Key Information	Differences between Snap Lake and reference lakes or normal range	Differences between Snap Lake main basin and reference lakes or normal range; trends over time in Snap Lake main basin and reference lakes	Differences between Snap Lake and reference lakes or normal range	Differences between Snap Lake and reference lakes or normal range
Negligible	No persistent decline beyond the normal range in total phytoplankton biomass or cladoceran abundance and biomass	No statistically significant changes (P>0.1) in Snap Lake main basin extending below the normal range for richness and densities of dominant taxa **AND** No divergence of trends in richness and densities of dominant taxa in Snap Lake main basin compared to reference lakes	No changes in fish health endpoints [(c)] or fish tissue chemistry in Snap Lake beyond the normal range **AND** Changes are of magnitude[(d)] that would not indicate an impairment to fish health	No indication from catch rates of a change[(e)] in number of fish of any species from Snap Lake
Low	A persistent decline beyond the normal range in total phytoplankton biomass within the main basin of Snap Lake **OR** A persistent decline beyond the normal range in cladoceran abundance **or** biomass within the main basin of Snap Lake	Statistically significant changes (P<0.1) in Snap Lake main basin extending below the normal range for richness **OR** Statistically significant changes(P<0.1) in Snap Lake main basin extending below the normal range for densities of dominant taxa **OR** Downward trend in richness and densities of dominant taxa in Snap Lake main basin, but not in reference lakes	Statistically significant difference (P<0.1) in fish health endpoints[(c)] or fish tissue chemistry that is beyond normal range **AND** Change is in direction, and of magnitude[(d)], that is indicative of an impairment to fish health	Indication from catch rates of a change[(e)] in number of fish of a species from Snap Lake
Medium	*TBD*[(b)]	*TBD*[(b)]	*TBD*[(b,f)]	
High	*TBD*[(b)]	*TBD*[(b)]	*TBD*[(b,f)]	

Table 6.4-2 Proposed Action Levels - Toxicological Impairment (continued)

Tiered Action Level	Plankton Community *Ecological Integrity Maintained*	Benthic Community *Ecological Integrity Maintained*	Fish Health *Ecological Integrity Maintained*	Fish Community *Ecological Integrity Maintained*
Comment/Rationale	■ Plankton communities are inherently variable therefore persistent trends need to be observed before action is taken. ■ Persistent is defined as a sustained increase or decrease equal to or greater than 3 years. ■ The normal range is defined as the background data (2004) mean ± 2 SDs. ■ See bullets in Section 6.4.3 for details.	■ Toxicity generally causes a downward trend in richness and density of benthic invertebrates. ■ The normal range is defined as ± 2 SD of the mean of reference stations and unaffected stations (identified based on conductivity as and effluent tracer) in Snap Lake during the early years of the mine. ■ Dominant taxa are defined as those accounting for more than 5% of the total invertebrates across all stations. ■ See bullets in Section 6.4.3 for details.	■ See bullets in Section 6.4.3 for details.	

Note: "Normal Range" is currently determined based on ± 2SD in Snap Lake Main Basin baseline and ±2SD in reference lakes, and/or other appropriate considerations.

(a) Benchmarks currently used in the AEMP to which substance concentrations are compared (i.e., EAR benchmarks and CCME guidelines).

(b) TBD – to be determined if Low Action Level is reached.

(c) Key fish health endpoints are: condition, relative gonad size, and relative liver size. They will be assessed between Snap Lake and the reference lakes.

(d) Definition of a magnitude of change that is indicative of impairment to fish health is based on the critical effect sizes defined by Environment Canada's Metal Mining Effluent Regulations Guidance Document (Environment Canada 2012) and refers to an increase or a decrease in fish health endpoints.

(e) Definition of "change" to be developed, but anticipates comparison of relative abundance (i.e., catch per unit effort) between lakes.

(f) It is anticipated that fish health and fish community would be combined at the Medium and High Action Levels.

EAR = Environmental Assessment Report; AEMP = Aquatic Effects Monitoring Program; CCME = Canadian Council of Ministers of the Environment; ISQG = Interim Sediment Quality Guideline; PEL = probable effect level; Mine = Snap Lake Mine; >= greater than; % = percent; SD = standard deviation.

Table 6.4-3 Proposed Action Levels - Nutrient Enrichment

Tiered Action Level	Water Quality (Nutrients) *Ecosystem Function*	Plankton Community *Ecosystem Function*
Key Information	Differences between Snap Lake and reference lakes or normal range AEMP Benchmarks and site-specific benchmarks	Differences between Snap Lake and reference lakes or normal range
Negligible	Consistent with EAR prediction **AND** If AEMP Benchmark exists, below the benchmark	No consistent ecologically-important changes in richness and community structure
Low	Exceeding EAR Predictions supported by temporal trend **AND** Exceeding >75% AEMP Benchmark, if it exists	Persistent increase beyond the normal range in total phytoplankton or zooplankton biomass in the main basin of Snap Lake **AND** Minor shift in phytoplankton or zooplankton community composition (based on major[(b)] groups) in the main basin of Snap Lake
Medium	*TBD*[(a)]	*TBD*[(a)]
High	*TBD*[(b)]	*TBD*[(a)]
Comment/Rationale	■ Whole-lake average concentrations (main basin only) will be compared against maximum whole-lake average concentrations predicted in the EAR and updated predictions. ■ Comparisons to new predictions will be made; however, the comparisons to the EAR predictions will be the focus. ■ AEMP Benchmark for total phosphorus = Mesotrophic status defined by phosphorus levels of 10.9 -95.6 micrograms per litre (Wetzel 2001). The low action level refers to > 75% of the low end of this range (i.e., 10.9 micrograms per litre) (see text).	■ Plankton communities are inherently variable therefore persistent trends need to be observed before action is taken. ■ Persistent is defined as a sustained increase or decrease equal to or greater than 3 years. ■ The normal range is defined as background data (2004) mean ± 2 SDs. ■ See bullets in Section 6.4.3 for details.

Table 6.4-3 Proposed Action Levels - Nutrient Enrichment (continued)

Tiered Action Level	Benthic Community *Ecological Integrity Maintained*	Fish Health *Ecological Integrity Maintained*	Fish Community *Ecological Integrity Maintained*
Key Information	Differences between Snap Lake main basin and reference lakes or normal range; trends over time in Snap Lake main basin and reference lakes	Differences between Snap Lake and reference lakes or normal range	Differences between Snap Lake and reference lakes or normal range
Negligible	No statistically-significant changes (P>0.1) in Snap Lake main basin extending beyond the normal range for richness and densities of dominant taxa **AND** No divergence of trends in richness and densities of dominant taxa in Snap Lake compared to reference lakes	No changes in fish health endpoints or fish tissue chemistry in Snap Lake beyond the normal range **AND** Changes are of magnitude[(c)] that would not indicate an impairment to fish health	No indication from catch rates of a change[(d)] in number of fish of any species from Snap Lake
Low	Statistically significant changes(P<0.1) in Snap Lake main basin extending beyond the normal range for richness **OR** Statistically-significant changes (P<0.1) in Snap Lake main basin extending beyond the normal range for densities of dominant taxa **OR** Upward trend in richness and densities of dominant taxa in Snap Lake, but not reference lakes	Statistically significant difference (P<0.1) in fish health endpoints or fish tissue chemistry that is beyond normal range **AND** Change is in direction, and of magnitude[(c)], that is indicative of an impairment to fish health	Indication from catch rates of a change[(d)] in number of fish of a species from Snap Lake
Medium	*TBD*[(a)]	*TBD*[(a,e)]	
High	*TBD*[(a)]	*TBD*[(a,e)]	
Comment/Rationale	■ Mild nutrient enrichment generally causes an upward trend in richness and density of benthic invertebrates. ■ The normal range is defined as ± 2 SD of reference stations and unaffected stations (identified based on conductivity as and effluent tracer) in Snap Lake during the early years of the mine. ■ See bullets in Section 6.4.3 for details	■ Tissue chemistry parameters which are relevant to the nutrient enrichment criteria are sodium, potassium and phosphorus (as listed in Table 4.8-1).	

Note: "Normal Range" is determined based on ±2SD in Snap Lake Main Basin baseline and ± 2SD in reference lakes, and/or other appropriate considerations.
(a) TBD – to be determined if Low Action Level is reached.
(b) "Major" indicates a change at the Class level of biological organization for phytoplankton and a combination of Phylum and Order levels for zooplankton.
(b) Key fish health endpoints are: condition, relative gonad size, and relative liver size. They will be assessed between Snap Lake and the reference lakes.
(c) Definition of a magnitude of change that is indicative of impairment to fish health is based on the critical effect sizes defined by Environment Canada's Metal Mining Effluent Regulations Guidance Document (Environment Canada 2012) and refers to an increase or a decrease in fish health endpoints.
(d) Definition of "change" to be developed, but anticipates comparison of relative abundance (i.e., catch per unit effort) between lakes.
(e) It is anticipated that fish health and fish community would be combined at the Medium and High Action Levels.
AEMP = Aquatic Effects Monitoring Program; EAR = Environmental Assessment Report; SD = standard deviation.

6.5 Suggested Responses

Table 6.5-1 provides a summary of suggested responses to be taken (Actions) when an Action Level is reached. For any Action Level, the following AEMP "Best Practices" will be followed each year when interpreting the AEMP findings:

- assess cause/linkage to Mine;
- examine trends;
- predict trends and predict time to reach a potential next Action Level, where appropriate;
- examine WOE assessment for strength of linkage between exposure, toxicity, and field biological responses;
- examine ecological significance; and,
- confirm that existing benchmarks are appropriate, and revise if warranted.

Additional responses detailed in the Response Plan will depend on the component affected (e.g., water quality, plankton community), the likely cause of the effect as determined in the WOE assessment (i.e., toxicological impairment versus nutrient enrichment), and the type and magnitude of effect.

Table 6.5-1 Suggested Types of Actions to be Taken if an Action Level is Exceeded

Action Level	Suggested Types of Actions
Negligible	**Response Actions that would be taken:** ■ AEMP best-practices
Low	**Response Actions that would be taken:** ■ AEMP best-practices ■ Confirm Low Action level ■ Set Medium and High Action Levels ■ Develop Response Plan **Potential additional Response Actions:** ■ Revise Low Action level, if warranted and scientifically defensible ■ Set site-specific benchmarks if appropriate ■ If trending towards Medium, identify potential mitigation options ■ Increase monitoring frequency for plankton, benthos, and/or fish to confirm findings ■ Desk-top or field special study to examine ecological significance, causation, and/or linkage to Mine

Table 6.5-1 Suggested Types of Actions to be Taken if an Action Level is Exceeded (continued)

Action Level	Suggested Types of Actions
Medium	**Response Actions that would be taken:** ■ AEMP Best-practices ■ Develop Response Plan ■ Confirm Medium Action Level ■ If Medium Action Level confirmed, implement mitigation(s) to stop or slow trend **Potential additional Response Actions:** ■ Desk-top or field special study(ies) to examine ecological significance, causation, and/or linkage to Mine ■ Maintain increased monitoring frequency for plankton, benthos, and/or fish to confirm that mitigation is working ■ Refine Medium and High Action Levels if warranted and scientifically defensible
High	**Response Actions that would be taken:** ■ AEMP Best-practices ■ Confirm High Action level ■ Develop Response Plan ■ If High Action Level confirmed, implement appropriate mitigations on a priority basis to reverse trend **Potential additional Response Actions:** ■ Special study to examine effectiveness of mitigation, and long-term monitoring of mitigation effectiveness ■ Special study to examine ecological significance and reversibility, causation, and/or linkage to Mine

AEMP (Aquatic Effects Monitoring Program) Best Practices: evaluate causation/linkage to Mine; examine trends; predict trends where appropriate; examine WOE assessment linkage between exposure, toxicity, and field biological responses; examine ecological significance; confirm that existing benchmarks are appropriate and revise if warranted.

6.6 AEMP Response Plan

If an Action Level of the AEMP Response Framework is triggered, an AEMP Response Plan must be submitted to the Board. Additional consultation with regulators and communities may be required prior to completion and approval of an AEMP Response Plan, depending on the severity of the monitoring result. The specific Water Licence conditions for Response Plans are as follows [Part G, Item 9 and Part G, Schedule 6, Item 5 of MVLWB (2013a)]; De Beers has committed to meeting these conditions:

> *Item 9. If any Action Level as defined in the approved AEMP Design Plan is exceeded, the Licencee shall notify the Board within 30 days of when the exceedance is detected. The licensee shall also submit to the Board for approval, within a time specified by the Board an AEMP Response Plan which shall satisfy the requirements of Schedule 6, Item 5.*
>
> *Schedule 6. Item 5. The AEMP Response Plan referred to in Part G, Item 9 shall contain the following information for each parameter that has been reported in the AEMP Annual Report to have exceeded an Action Level:*
>
> *a. A description of the parameter, its relation to Significance Thresholds and the ecological implication of the Action Level exceedance;*
>
> *b. A summary of how the Action Level exceedance was determined and confirmed;*
>
> *c. A description of likely causes of the Action Level exceedance and potential mitigation options if appropriate;*
>
> *d. A description of actions to be taken by the Licencee in response to the Action Level exceedance including:*
>
> *i. a justification of the selected action which may include a cost/benefit analysis;*
>
> *ii. a description of timelines to implement the proposed actions,*
>
> *iii. a projection of the environmental response to the planned actions, if appropriate;*
>
> *iv. a monitoring plan for tracking the response to the actions, if appropriate; and,*
>
> *v. a schedule to report on the effectiveness of actions and to update the AEMP Response Plan as required.*
>
> *e. Any other information necessary to assess the response to an Action Level exceeda25nce or that has been requested by the Board*

7.0 WEIGHT OF EVIDENCE INTEGRATION

WOE is the way of considering types of evidence in the AEMP for a given year while considering how good each piece of evidence is at telling us what is happening and what may happen in the Snap Lake ecosystem.

This section describes the WOE integration approach for the Snap Lake AEMP, which (i) integrates the findings for individual AEMP components in a given year to examine the type(s) of effects, if any, which are occurring in the lake, and (ii) supports the AEMP Response Framework. The WOE approach is provided to comply with the following specific Water Licence conditions [Part G, Schedule 6, Item 4(f) of MVLWB (2013a)]:

> *f) an analysis that integrates the results of individual monitoring components collected in a calendar year and describes the ecological* significance of the results" (Water Licence).

Also, as described in Section 6.2, integration of the annual findings supports the AEMP Response Framework by distinguishing between nutrient enrichment and toxicological impairment as the cause of any observed biological responses. Thus, when the Action Level conditions are met for a given biological component, the WOE approach informs which Action Level group is triggered (i.e., Action Levels for Toxicological Impairment, for Nutrient Enrichment, or both), and then contributes this system understanding to inform response planning. Figure 6.2-1 summarizes the relationship between the AEMP Response Framework and the WOE integration.

Note that the WOE approach is intended to apply to Snap Lake only, with the purpose of determining the support for each hypothesis within Snap Lake, but a similar approach could be applied to the downstream monitoring program as it develops. Given that this document represents a significant re-design of the AEMP, it is also proposed that, initially, the WOE approach will involve a *qualitative* integration of the endpoints to arrive at WOE conclusions, but that over the first three years of the revised AEMP, an attempt will be made to develop a *semi-quantitative* WOE approach, using principles similar to those applied at Diavik Diamond Mine (DDMI 2011). In future, a similar approach could be applied for the down-stream monitoring program as it develops.

The proposed WOE approach is considered preliminary at this stage, with refinements expected to harmonize conclusions and best professional judgement. The overall goal is to have completed development and refinement of a semi-quantitative WOE approach by completion of the next AEMP cycle in 2016, to the extent possible. Ideally, traditional knowledge (TK) will also be incorporated as a separate line of evidence; however, such incorporation requires specific recommendations for TK lines of evidence from the Aboriginal communities.

7.1 Overview

The WOE approach provides a systematic approach to distinguish between, and determine the strength of, support for the Nutrient Enrichment and Toxicological Impairment hypotheses, presented in Section 2.5. It balances technical quantitative approaches and less technical qualitative approaches, can include multiple types of evidence (of varying degrees of quantitative rigour), and is based on guidance that is accepted and in use in Canada.

WOE includes *"any process used to aggregate information from different lines of scientific evidence to render a conclusion regarding the probability and magnitude of harm". This definition encompasses a range of practice, ranging from best professional judgment (BPJ) assessments to complex quantitative methods."* (Azimuth 2012). It is a well-established and accepted method for integrating complex data generated in environmental assessment programs (e.g., Chapman and Anderson 2005; McDonald et al. 2007), and guidance on WOE methods have been developed and are in use in Canada both provincially (e.g., SAB 2008; Environment Canada and Ontario Ministry of the Environment 2008) and federally (Azimuth 2012).

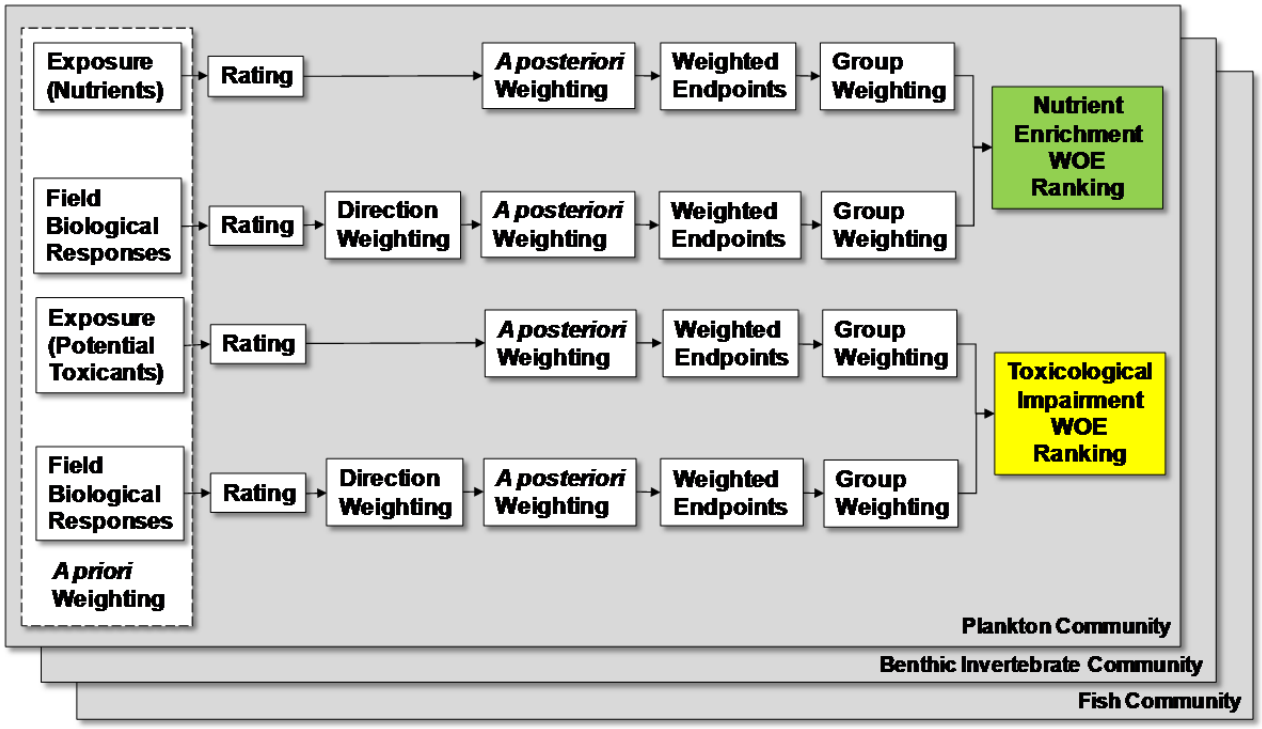
Important characteristics of WOE assessments) are that they integrate multiple lines of evidence (represented by measurement endpoints and endpoint groups) to understand, to the extent possible, the cumulative effects of any environmental changes. Figure 7.1-1 provides an overview of the WOE integration process. In general terms, the WOE approach involves the following steps:

1) The endpoints (i.e., AEMP results indicating exposure and biological response to nutrients, or substances of toxicological concern) are *rated* according to a series of decision criteria;

2) *Each endpoint is weighted* to reflect the strength and relevance of the evidence they bring to the assessment; and,

3) The *rated* and *weighted* endpoints are then *integrated* to provide an overall ranking of the degree of support for each hypothesis.

Figure 7.1-1 Conceptual Integration Process Applied in the WOE Assessment



The following subsections describe the key components that make up the design of the proposed WOE assessment, specifically endpoints, endpoint response ratings, weighting considerations, and integration.

7.2 Definitions and Approach

7.2.1 Endpoints

The AEMP includes parameters and testing representing the following types of information: water quality (nutrients and chemical contaminants); chronic toxicity at the edge of the treated effluent mixing zone; sediment quality; fish tissue chemistry; plankton (phytoplankton and zooplankton communities); benthic invertebrates; fish health; and, fish community. The parameters and biological variables are formulated into endpoints that are consistent with the key questions addressed by each component section. As discussed in Section 2.6, the endpoints will be further categorized into the following endpoint groups representing similar types of evidence:

- **Exposure:** Measures of the potential exposure of receptors to Mine-related chemicals and nutrients, including surface water and sediment. In the nutrient enrichment integration, this category also includes indicators of food supply for mid- and upper trophic levels (e.g., for fish, zooplankton biomass, and benthic invertebrate biomass).
- **Field Biological Responses:** Observationally based measures of potential ecological changes, including measures of plankton biomass and community structure, and benthic invertebrate abundance and community structure, and fish health and community structure.

Data analysis occurs primarily for the individual AEMP components described in Section 4 and includes individual endpoints that are specific to a particular measurement of the status of the ecosystem. For many of the endpoint groups, multiple endpoints are measured in the AEMP that encompass different stressor types, media, levels of biological organization, and data analysis methods - providing a “battery” approach for assessing the degree of effect associated with each group. The first two columns of Table 7.2-1 provide a list of the endpoint groups and individual endpoints that will be included in the WOE assessment.

7.2.2 Endpoint Response Ratings

The starting point for the WOE assessment is rating of the endpoint results from each component according to a series of decision criteria. The observed changes, differences, trends, and/or exceedances of benchmarks in exposure, and field biological response endpoints will be classified using semi-quantitative descriptions of the responses or degree of changes observed in Snap Lake. The ratings indicate the degree of change in exposure relative to reference or baseline conditions, or degree of biological response. These endpoint ratings then “feed into” the WOE analysis, where they are weighted, and then combined to obtain the overall conclusion.

Rating schemes can vary from assessment to assessment. WOE assessments by Chapman and coauthors (e.g., Chapman et al. 2002; Chapman and McDonald 2005) use non-numerical rating systems in which endpoint results are assigned to one of a ranked series of categories. Conversely, Menzie et al. (1996) proposed numerical ratings based on a set of attributes scored between 1 and 5 according to a series of causal criteria.

The WOE integration will use a semi-quantitative rating system presented in presented in Table 7.2-1. These ratings will be applied and, where necessary refined, over the next three years of the AEMP cycle. Increasingly large and/or statistically significant responses in Snap Lake will receive progressive ratings of “No response” (represented by 0), “Rating 1” (represented by “↑” or “↓”), “Rating 2” (represented by “↑↑” or “↓↓”), or “Rating 3” (represented by “↑↑↑” or “↓↓↓”) depending on the magnitude and direction of the response.

Table 7.2-1 Preliminary Response Ratings for the Weight of Evidence Assessment

Endpoint Group	Endpoint	No Response	Rating 1 ↑/↓	Rating 2 ↑↑/↓↓	Rating 3 ↑↑↑/↓↓↓
Exposure – Water Quality (substances of toxicological concern and mixing zone toxicity)	**Comparison to Benchmarks** (where they exist)	<EAR Prediction	>AEMP Benchmark[(a)]	>Site-specific guideline[(b)]	Rating 2 in at least two endpoints. **OR** Persistent lethal toxicity
	Trends Snap Lake compared to reference lakes	No difference	Trend difference between Snap Lake and reference	Trend difference outside confidence interval (if applicable)[(c)]	
	Comparison to normal range	No difference	Difference in mean concentration	Snap Lake mean >baseline normal range[(e)]	
	Toxicity at edge of mixing zone	No persistent toxicity	Sublethal toxicity observed at edge of mixing zone in 2 or more consecutive monitoring events	Persistent sublethal toxicity with trend to increasing in frequency or severity	
Exposure – Water Quality (nutrients)	**Comparison to AEMP Benchmarks** (where they exist)	<EAR Prediction	>AEMP Benchmark	>Site-specific guideline	Rating 2 in at least two endpoints. **OR** Rating 1 in a downstream lake
	Trends Snap Lake compared to reference lakes	No difference	Trend difference between Snap Lake and reference	Trend difference outside confidence interval (if applicable)	
	Comparison to baseline normal range	No difference	Difference in mean concentration	Snap Lake mean >baseline normal range	
Exposure – Sediment Quality (substances of toxicological concern)	**Comparison to Benchmarks** (where they exist)	<ISQG	>ISQG	>PEL	Rating 2 in at least two endpoints.
	Comparison to normal range	No difference	Snap Lake mean >baseline mean **OR** Statistically significant increase in Snap Lake relative to reference	Snap Lake mean >baseline normal range **OR** Statistically significant increase beyond reference normal range	
	Temporal Trends	No trend	Statistically significant increasing trend in Snap Lake	Statistically significant increasing trend in Snap Lake, at a magnitude of toxicological concern[(d)].	
Exposure – Fish Tissue Chemistry (substances of toxicological concern)	**Snap Lake compared to reference lakes**	No difference	Difference in mean concentration	Snap Lake mean >normal range	Rating 2 in both endpoints
	Snap Lake compared to baseline	No difference	Difference in mean concentration	Snap Lake mean >normal range	

Table 7.2-1 Preliminary Response Ratings for the Weight of Evidence Assessment (continued)

Endpoint Group	Endpoint	No Response	Rating 1 ↑/↓	Rating 2 ↑↑/↓↓	Rating 3 ↑↑↑/↓↓↓
Field Responses – Plankton Community	**Trends Snap Lake compared to reference lakes** Chlorophyll *a*, Phytoplankton Abundance/Biomass, Zooplankton Abundance/Biomass	No trend difference	Trend difference between Snap Lake and reference	Trend difference outside confidence interval (if applicable)	Rating 2 in at least two endpoints
	Snap Lake compared to Baseline (i.e., 2004) Phytoplankton Abundance/Biomass, Zooplankton Abundance/Biomass	No difference	Difference (mean vs mean) outside the normal range	Exceeding EA predictions	
	Community Structure Phytoplankton and Zooplankton Communities	No difference	Minor shift in community structure (i.e., at species/genus level)	Moderate shift in community structure (i.e., at class or functional group level)	
Field Responses – Benthic Community	**Trends Snap Lake compared to reference lakes** Density, Richness, Densities of Dominant taxa, Community Structure Variable	No difference	Trend difference between Snap Lake and reference	Trend difference outside confidence interval (if applicable)	Rating 2 in at least two endpoints
	Snap Lake compared to reference lakes Density, Richness, Densities of Dominant taxa, Community Structure Variable	No difference	Statistical difference (P<0.1)	Statistical difference (P<0.1) beyond normal range	
	Community Structure Benthic Community	No change	Minor shift in community structure (i.e., at genus level)	Moderate shift in community structure (i.e., at major group level)	
Field Responses – Fish Health and Community	**Fish Health** Condition, Relative Gonad Size, Relative Liver Size	No difference	Statistical difference(P<0.1)	Statistical difference beyond normal range (P<0.1)	To be developed
	Fish Community Endpoints to be developed	No difference	To be developed	To be developed	To be developed

(a) Benchmarks currently used in the AEMP to which substance concentrations are compared (i.e., EAR benchmarks and CCME guidelines).

(b) Site-specific benchmarks for Snap Lake that may be developed under the AEMP Response Framework.

(c) Note that this Rating criterion is hypothetical at this stage because statistical methods for trend analysis have yet to be established.

(d) To be determined on a substance-by-substance basis considering proximity to or exceedance of benchmarks and the normal range.

(e) "Normal Range" is determined based on +/- 2SD in Snap Lake Main Basin baseline and +/- 2SD in reference lakes, and/or other appropriate considerations.

The up and down arrows provide a visual description of the direction of response (i.e., ↑ = increase, ↓ = decrease); both up and down arrows will be applied for endpoints where the direction of response is not as apparent, such as metrics of community structure. Narrative descriptions of the ratings are provided below:

- **No Response –** Typically, a finding of no exceedance of a prediction or benchmark, no visual and/or statistical difference, no trend, or no difference in trend (Snap Lake versus reference lakes) will indicate a rating of "no response".
- **Rating 1 –** This rating indicates that a change, response, or trend in exposure may be apparent in Snap Lake or that a conservative numerical benchmark has been exceeded, but that the linkage to biological responses is low. It also includes indications of minor shifts (i.e., at the species or genus level) in the abundance, richness or community structure of the phytoplankton, zooplankton, or benthic communities as well as minor changes/trends in fish population and health indicators.
- **Rating 2 –** This rating includes situations where greater changes, responses, or trends in exposure (i.e., outside normal range[17]) and exceedances of less conservative numerical values such as generic water quality or sediment quality guidelines have occurred, and the changes appear to be linked to the Mine. It also includes indications of moderate shifts (i.e., at the class or functional group level) in the abundance, richness, or community structure of the phytoplankton, zooplankton, or benthic communities as well as more marked changes/trends in fish population and health indicators.
- **Rating 3 –** This rating indicates the strongest level response in exposure or biological response endpoints. At this preliminary stage, it is anticipated that this rating will be applied when multiple endpoints within a group are found to be at Rating 2, indicating a strong level of evidence for response for a given indicator of exposure (water quality, sediment quality, or fish tissue chemistry) or biological response (plankton community, benthic community, or fish community/health). None of the endpoints in the qualitative integration conducted in the 2011 AEMP were judged to be at this rating. As additional years of AEMP data are obtained, the conditions under which this rating is applied will be developed further and/or refined.

A key challenge in WOE assessments is "calibrating" the relative level of evidence provided by the rating of varying endpoints. A given endpoint may be more indicative of change than for others and, therefore, it is expected that the ratings may undergo refinement as the WOE assessment is further developed.

7.2.3 Weighting Considerations

Because there are no "perfect" tools for assessing effects on ecosystems, the multiple "imperfect:" measurements included in the AEMP are weighted to account for the strengths and weakness of each endpoint. Weighting of endpoints and endpoint responses will initially be qualitative, and conducted in a fashion similar to that used for the Qualitative Integration in the 2011 and 2012 AEMP reports (De Beers 2012c, 2013). However, as the WOE assessment is developed, it is anticipated that a numerical weighting system will be developed that can be combined with numerical values assigned to the Response Ratings.

[17] "Normal Range" is determined based on +/- 2SD in Snap Lake Main Basin baseline and +/- 2SD in reference lakes, and/or other appropriate considerations.

Three sets of weighting considerations will be applied to the endpoint results:

- ***A priori***[18] **weighting:** *A summary of professional judgement regarding the strength and relevance of the evidence contributed by a particular endpoint.* These weightings are established *a priori* and apply to an endpoint regardless of the endpoint result. Once established, they remain the same year to year to allow for comparison of WOE results from year to year. The overall purpose of the *a priori* weighting is to capture the "ability" of an endpoint to indicate Mine effects in Snap Lake. Based on the available science, actual biological responses in Snap Lake are deemed to provide a more direct indicator of potential effects in the aquatic ecosystem than indicators of exposure to nutrients and chemicals, and will therefore have higher *a priori* weighting (supporting discussion provided below). **Direction-weighting:** *Considerations applied to field biological response endpoints to reflect the degree of support that an observed biological response contributes to alternative effect hypotheses.* These apply only to field biological responses and will be contingent on the observed direction of change or relationship. They provide proportional support for each effect hypothesis as indicated by the direction of change. For example, increases in plankton biomass would typically only be expected as a result of nutrient enrichment and therefore provide 100% support for this hypothesis. Conversely, changes in plankton community structure might be expected as a result of either nutrient enrichment or toxicological impairment, and therefore provide proportional support for each hypothesis but at a level less than 100%.
- ***A posteriori***[19] **weighting** – *Additional "up-" or "down-weighting" that may be applied to reflect additional insight gained during data collection and analysis.* This consideration reflects best professional judgement regarding the AEMP findings in a given year. Two relevant factors include consistency in response among the individual endpoints within an endpoint group, and strength of linkage to treated effluent release (for exposure endpoints) and exposure (for biological response endpoints). Where *a posteriori* weighting is applied in the WOE assessment, a discussion of the rationale will also be provided.

With respect to *a priori* weighting, higher weighting for field biological response endpoints is consistent with guidance from the literature that field-based effect studies should be weighted higher than laboratory and chemistry-based analyses (Chapman and Anderson 2005; Wenning et al. 2005; Environment Canada and Ontario Ministry of the Environment 2008; Chapman and Smith 2012). Water and sediment chemistry indicate exposure but do not predict toxicity, because they do not consider the dose-response relationship between exposure and response, or factors that affect bioavailability and toxicity under natural conditions. Laboratory toxicity testing is conservative (worst case) because the laboratory cultures used in toxicity testing are often more sensitive than typically more tolerant natural populations, meaning that responses observed in the laboratory may not occur or be as pronounced in natural systems. Assessing resident organisms is subject to natural variability that can make it difficult to determine subtle effects, but where effects are detected, these responses provide the strongest evidence of actual ecosystem effects.

[18] i.e., "before-hand"

[19] i.e., "after the fact"

7.2.4 Integration

The final step in the WOE approach involves integration of the rated and weighted endpoint results to determine the level of support for each effect hypothesis (nutrient enrichment versus toxicological impairment) with conclusions separated by ecosystem component (plankton community, benthic invertebrate community, fish community). Table 7.2-2 lists the endpoint groups that will be integrated for each ecosystem component and hypothesis.

The outcome of the integration for each component will be a WOE Ranking that indicates of the strength of support for each hypothesis according to the following scheme:

- **WOE Rank 0** – Hypothesis not supported by the combined endpoint findings;
- **WOE Rank 1** – Hypothesis has weak support from the combined endpoint findings;
- **WOE Rank 2** – Hypothesis has moderate support from the combined endpoint findings; and,
- **WOE Rank 3** – Hypothesis has strong support from the combined endpoint findings.

Table 7.2-2 Summary of the Endpoint Groups Integrated for Each Hypothesis

Hypothesis	Ecosystem Component	Exposure Endpoint Group	Biological Response Endpoint Group
Nutrient Enrichment	Plankton Community	Water Quality (nutrients)	Plankton Community
	Benthic Invertebrate Community	Water Quality (nutrients, including chlorophyll *a*)	Benthic Community
	Fish Community	Water Quality (nutrients, including chlorophyll *a* and zooplankton biomass)	Fish Health and Community
Toxicological Impairment	Plankton Community	Water Quality (potential toxicants)	Plankton Community
	Benthic Invertebrate Community	Sediment Quality **AND** Water Quality (potential toxicants)	Benthic Community
	Fish Community	Fish Tissue Chemistry **AND** Water Quality (potential toxicants)	Fish Health and Community

The rankings are intended to reflect the analyses in the component reports and response ratings specific to each endpoint. In particular, they will provide an indication of the relative strength of evidence associated with apparent Mine-related changes, responses, or effects by a particular ecosystem component. A higher rank represents a higher strength of support for a particular hypothesis. The ranking for each hypothesis will be interpreted to draw conclusions with respect to the nature of any effects that are most likely occurring in Snap Lake.

An important consideration is that the WOE Rankings are not intended to indicate the ecological significance of observed effects. For example, it is possible that there could be moderate evidence (WOE Rank 2) for a particular effect hypothesis in Snap Lake, but that the magnitude and significance with respect to the ecological

integrity of Snap Lake could be relatively mild. This is an important distinction between the WOE assessment and the AEMP Response Framework described in Section 6. The WOE assessment describes potential linkages from exposure to observed biological differences and changes in Snap Lake, and actively supports decision-making in the AEMP Response Framework, which sets specific levels of acceptable/unacceptable effects or effects with respect to the ecological function of Snap Lake.

7.3 Application and Refinement

It is proposed that, initially, the WOE assessment will involve *qualitative integration* of the endpoint findings following the approach that was applied in the AEMP Re-Evaluation and the 2011 and 2012 AEMP Annual Reports (De Beers 2012a, c, 2013b.) The Response Ratings described in Table 7.2-1 will be applied to the endpoints from each AEMP component and then the information will be integrated for each ecosystem component and hypothesis, applying best professional judgement to account for *a priori* direction, and *a posteriori* weighting considerations.

During the next three years of the AEMP cycle, a *semi-quantitative* WOE assessment will be developed and calibrated, to the extent possible, using principles similar to those applied at Diavik Diamond Mine (DDMI 2011). It will be a hybrid of the numerical and non-numeric systems to exploit the strengths of each. In the future, a similar approach could be applied for the down-stream monitoring program as it develops.

8.0 REPORTING

8.1 Overview

An annual AEMP report will be submitted to the MVLWB for review and approval by May 1 of each calendar year. Each annual report will include the key questions, methods, results, and applicable action levels and management actions associated with the AEMP components as described in Sections 4 and 6. Response Plans will be submitted to separately to the MVLWB for approval, under the timeframe described in the water licence. The next Aquatic Effects Re-Evaluation Report will be submitted October 2016, and will present updated trends from baseline to current conditions. An updated AEMP Design Plan will then be submitted prior to the end of 2016 for approval for 2017 to 2020. All reports will be submitted as outlined in the MVLWB Document Submission Standards (MVLWB 2012).

8.2 Report Organization

8.2.1 Annual Report

The AEMP annual reports will provide results and interpretation updates for the AEMP components monitored in those years. A summary of the most important results will be communicated in a plain-language summary that will be presented at the front of the AEMP as an executive summary.

A series of technical sections within the AEMP will provide the technical and scientific description of the analyses conducted and the results obtained. The sections will consist of:

Section 1 – Introduction;

Section 2 – Site Characterization and Supporting Environmental Variables;

Section 3 – Water Quality;

Section 4 – Sediment Quality;

Section 5 – Plankton;

Section 6 – Benthic Invertebrates;

Section 7 – Fish Health;

Section 8 – Fish Community;

Section 9 – Fish Tissue;

Section 10 – Fish Tasting;

Section 11 – Special Studies

Section 12 – Weight of Evidence; and,

Section 13 – Action Levels.

8.2.2 AEMP Re-Evaluation Report

Every four years, an integrated AEMP Re-Evaluation report will be produced and submitted to the MVLWB. The primary goal of this report is to meet the objectives of the Water Licence:

- describe the Project-related effects on the receiving environment as measured from project inception and compared against EAR predictions;
- update predictions of Project-related effects on the receiving environment based on monitoring results obtained since project inception; and,
- propose, as necessary and appropriate, updates to the AEMP design with supporting rationale including, but not limited to, the updated effect predictions.

Another objective of the re-evaluation is to address the requirements specified in Part G, Item 7 of the Water Licence. To meet these objectives, the re-evaluation will compare key variables for each component of the AEMP over time and between study lakes.

9.0 CONFORMITY TABLES

9.1 MVLWB Comments

A list of comments received from the MVLWB on the monitoring portion of the Draft 2013 AEMP Design Plan (MVLWB 2013b) and on Sections 6 and 7 (MVLWB 2013d) are provided in Table 9.1-1. Each comment was addressed in the Final 2013 AEMP Design Planand the confirmith between the comments and where they are addressed is listed herein. References to sections of this report where the comments are addressed are indicated in the final column of the tables.

Table 9.1-1 MVLWB Recommendations from the 2013 AEMP Design Plan Review (MVLWB 2013b, d)

Reviewer Comment/Recommendation	De Beers Response	Location in Report
It is very important to preserve consistency in gear choice, sampling date, etc. as much as possible. Try to be consistent with historical baseline studies, as well as past and current monitoring studies. In particular, I don't think you should change the April water quality sampling to May (pg. 40). It would be better to keep it in April, to maintain the consistency in your data set and allow more accurate trend analyses.	De Beers agrees that, while consistency is important, the exact sample timing should not focus on the calendar month. The 'worst-case' chemistry conditions for the under-ice period are thought to be late April or early May. The exact date of sampling (late April or early May) will depend on weather conditions. De Beers proposes that this sampling be considered as the 'late winter' sampling regardless of whether it occurs in late April or early May. The AEMP Design Plan will be revised to April/May for "late winter" sampling period; likely sampling will commence in April and, if needed, continue into May.	Section 4.2.3.1; Table 4.2-1 and 4.2-3
The spatial/temporal domains for assessment of water and sediment quality have been clarified, as suggested. Water quality will be assessed in the main basin for comparison to normal range, and as an average of mixing zone stations for comparison to the AEMP benchmark. The domain for sediment quality is not mentioned in Table 6.4-2, but the text in Sec. 6.4.3 p.18 specifies a mean for the main basin. For clarity, it would be preferable to specify the sediment quality domain in Table 6.4-2	De Beers agrees with this comment. Wording will be added to Table 6.4-2 to clarify that a Low Action Level for sediment quality would be triggered based on comparisons of mean concentrations for the main basin stations.	Table 6.4-2
A lake outlet is usually not depositional, and would not reflect the likely poorer sediment quality in depositional basins, so we would likely end up using the alternate (downstream?) location. This is a condition to be avoided in Snap Lake. Exceeding PEL in Snap Lake should be considered significant.	In Section 6.3.1.2, De Beers will identify the location at which sediment Potential Effect Levels (PELs) should not be exceeded, (and that, therefore, downstream aquatic life will remain protected) will be assessed sometime after a low action level is exceeded.	Section 6.3.1.1
In Table 6.4-2, for the low" action level for the benthic community, the phrase "dominant taxa" is used. The comment row should indicate that dominant taxa are those representing more than 5% of total density, as noted in Sec. 6.4.3 p.21.	De Beers agrees. The final AEMP Design Plan will be revised accordingly.	Table 6.4-2
The spatial domain for assessment of difference seems to be lacking for the fish health criterion in the "low" action level in Table 6.4-2. The text in Sec. 6.4.3 p.22 refers to endpoint differences between Snap Lake and reference lakes. The comment in the table refers to Sec. 6.4.3, but it would be preferable to clarify the domain within the table itself. In Table 6.4-2, for the “low” action level for fish health (toxicological), footnote (c) should clarify that the difference is assessed between Snap Lake and reference lakes.	De Beers agrees. Footnote (c) of Table 6.4-2 will be updated to state that the spatial domain of the fish health criterion is assessed between Snap Lake and the reference lakes.	Table 6.4-2
The "low" action level benchmark for phosphorus (enrichment) has been defined, as suggested, but not very precisely. It is stated that 10.9 to 95.6 ug/L (the mesotrophic range based on Wetzel 2001) will be the benchmark. Exceeding 75% of this level will be one criterion (we must also exceed EAR predictions and have an upward trend). It will be necessary to define a specific concentration as the benchmark. I would assume that this concentration will be 10.9 ug/L. In Table 6.4-3, for water quality (enrichment), both “negligible” and “low” action levels refer to an AEMP benchmark. Negligible is “within” benchmark, and “low” is >75% of benchmark. The comment row says that the AEMP benchmark for phosphorus is the mesotrophic range (10.9 – 95.6 ug/L). It is unclear where 75% of this range would be. The term “within” suggests that anywhere in the range is negligible. Since our objective is to not shift the lake to mesotrophic status, I suggest that the term “within” should be changed to “below”, and that the comment row should define the phosphorus benchmark at the low end of the mesotrophic range (10.9 ug/L). Exceeding 75% of this value and the EAR predictions would be needed to trigger the low action level.	De Beers agrees with the recommendation to change the text to indicate that a low action level for nutrient enrichment would be triggered if whole-lake average (main basin only) total phosphorus concentrations: demonstrate an upward trend; exceed EAR predictions; and, are >75% of 10.9 µg/L (i.e., approaching the lower end of the mesotrophic range). Text related to the total phosphorus benchmark will be updated in the final version of the AEMP Design Plan (See response to MVLWB 8).	Table 6.4-3

Table 9.1-1 MVLWB Recommendations from the 2013 AEMP Design Plan Review (MVLWB 2013b, d)

Reviewer Comment/Recommendation	De Beers Response	Location in Report
The "low" action level for water quality (enrichment) in Table 6.4-3 refers to "exceeding EAR Predictions or updated EAR Predictions (as appropriate)". The exceedance is also required to be supported by temporal trend, which is reasonable. However, the phrase about "updated EAR predictions" implies that any change to nutrient levels may be considered acceptable without action as long as the change is modelled first. The "as appropriate" phrase is ambiguous. The comment says that "comparisons to the EAR predictions will be the focus," however this does little to clarify. The language in the table should make absolutely clear what must be exceeded to trigger the "low" action level. I would suggest that an exceedance of the original EAR prediction is the appropriate trigger. In Table 6.4-3, for water quality (enrichment), both “negligible” and “low” action levels refer to an AEMP benchmark. Negligible is “within” benchmark, and “low” is >75% of benchmark. The comment row says that the AEMP benchmark for phosphorus is the mesotrophic range (10.9 – 95.6 ug/L). It is unclear where 75% of this range would be. The term “within” suggests that anywhere in the range is negligible. Since our objective is to not shift the lake to mesotrophic status, I suggest that the term “within” should be changed to “below”, and that the comment row should define the phosphorus benchmark at the low end of the mesotrophic range (10.9 ug/L). Exceeding 75% of this value and the EAR predictions would be needed to trigger the low action level.	Please see response to AANDC 9 and MVLWB 4. The text in Table 6.4-3 for water quality will be updated to the following: Low Exceeding EAR predictions supported by temporal trend AND Exceeding >75% AEMP Benchmark, if it exists Comment/Rationale - Whole-lake average concentrations (main basin only) will be compared against maximum whole-lake average concentrations predicted in the EAR and updated predictions. - Comparisons to new predictions will be made; however, the comparisons to the EAR predictions will be the focus. - AEMP Benchmark for total phosphorus = Mesotrophic status defined by phosphorus levels of 10.9 - 95.6 micrograms per litre (Wetzel 2001). The low action level refers to >75% of the low end of this range (i.e., 10.9 micrograms per litre).	Table 6.4-3
The "low" action level for plankton (enrichment) has defined the criterion for shift in "major groups", as suggested. The shift would have to be at the Class level. This may be appropriate for phytoplankton, but is probably inappropriate for zooplankton. For example, a shift in the cladocera (an important fish food group) might not qualify since the cladocera are an Order within the Class crustacea. At least for zooplankton, I would consider a shift at the Order level (e.g. cladocera) to be of major importance. The degree of shift required has not been specified, except to say that a "minor" shift meets the criterion. I would infer from this that any statistically demonstrable shift at the stated taxonomic level will qualify. In Table 6.4-3, for the “low” action level for the plankton community (enrichment), footnote (b) defines “major” group at the Class level. This may be appropriate for phytoplankton, but the Order level (e.g. cladocera) would be more appropriate for zooplankton. It would be helpful to also define “minor” shift.	The "major" groups for phytoplankton are defined in Section 4.4.6.3 (page 81) and are based on the Class level. The "major" groups for zooplankton defined in Section 4.4.6.4 (page 82) are based on a combination of Order (calanoid copepod, cyclopoid copepod, and cladocera) and Phyum (rotifers) taxonomic levels. The footnote to Table 6.4-3 will be modified accordingly to clarify these definitions of "major" groups.	Table 6.4-3
The spatial domain seems to be lacking in the phytoplankton criterion in the "low" action level for the plankton community (toxicological). The domain for cladocera is stated as the main basin. Perhaps the same domain is intended for phytoplankton, but it should be explicitly stated. In Table 6.4-2, for the “low” action level for plankton community (toxicological), the criteria should probably specify “persistent” decline, as mentioned in the text of Sec. 6.4.3 p.19. In addition, the phytoplankton criterion should specify the main basin, as for the cladoceran criterion.	De Beers agrees; the document will be revised accordingly.	Table 6.4-2
In Table 6.4-3, for fish health (enrichment), both "negligible" and "low" action levels refer to "tissue chemistry". It is unclear what tissue chemical parameters will be measured that pertain to nutrient enrichment. The text in Sec. 6.4.3 p.22 refers to metals in fish tissue, and mentions arsenic and mercury, but these parameters seem to be unrelated to nutrient enrichment. Either the tissue chemistry component should be removed from fish health (enrichment) criteria, or the relevant tissue chemistry parameters should be identified and justified.	The tissue chemistry parameters that are measured in fish tissue which are relevant to the enrichment criteria are sodium, potassium, and phosphorus (as listed in Table 4.8-1 of the Snap Lake AEMP Design Plan). A footnote will be added to Table 6.4-3 for fish health (enrichment) indicating that these parameters are specifically considered relevant to nutrient enrichment.	Table 6.4-3

Table 9.1-1 MVLWB Recommendations from the 2013 AEMP Design Plan Review (MVLWB 2013b, d)

Reviewer Comment/Recommendation	De Beers Response	Location in Report
GNWT Recommendation 3 (Toxicological Impairment Action Levels) and 4 (Fish and Fish Community) 'Statistically Significant' and 'Downward Trend' need to be further defined.	De Beers references discuss what is considered the normal range for water and sediment quality with respect to toxicological impairment, but do not indicate what would be considered statistically significant differences, nor are downward trends really defined. More detailed information is available in Section 4 of the AEMP Design Plan; however, it is not easily accessible when looking at the action levels. For Ecological Function action levels that are based on significant differences and/or trends, these terms should be numerically defined (based on the information in Section 4), either in the text of Section 6.4.3, or in Tables 6.4-2 and 6.4-3.	Section 6
It is important that the AEMP is reported within a response framework rather than treating them as two separate entities. AEMP reports/re-evaluations should include applicable action levels and management actions for each required component, providing a summary of whether current monitoring results show that an action level has been reached or not and if it has, what management action is being taken.	De Beers agrees that action levels be discussed in the AEMP Annual Report and that Response Plans be submitted separately to the Board for approval.	Section 8.2.1
Table 6.5-1 mentions AEMP best practices, which include annual examination of trends and predicting future trends; however there is no specific mention of projected time to reach the next action level. This projected time should be a consideration in developing the response plan, and should probably be mentioned somewhere in Section 6.5.	De Beers agrees. The final AEMP Design Plan will be revised accordingly.	Section 6.5
Section 6.3.1.1, Water Safe to Drink and Fish Safe to Eat - Considerations. Pg 8 - "Regarding the mention of fish health and mercury content, it has been mentioned in later sections that reference lakes have been used. This would provide clarity on whether the levels were related or unrelated to Snap Lake operations" Please explicitly mention that reference lakes are being used to monitor differences in metal concentrations within Snap Lake fish.	This clarification will be added to Section 6.3.1.1 in the final AEMP Design Plan.	Section 6.3.1.1
Section 6.3.1.3. Ecological Function Maintained - Inadequate Food for Fish in Snap Lake. Pg 10. - "Sustained absence", "severe decline", and "persistent absence" are not defined in this section, although they may be defined later. The NSMA suggests ongoing definition of temporal/ effect scale terms used whenever possible during the report, to avoid unnecessary searching for clarification.	De Beers agrees with this comment. Ongoing definitions will be added to the final AEMP Design Document. Sustained absence of fish refers to the absence of a fish species on three separate and consecutive follow-up sampling efforts after an initial non-detection or absence in a single sampling effort. The follow-up sampling gear, season, and habitat would be optimized for the species in question. The bullet referring to plankton in the text of Section 6.6.1.3 will be revised to state: "A persistent decline in total phytoplankton abundance or biomass beyond the level of natural variability. Persistent refers to a change in the plankton community that is maintained for three or more years. The time-frame of three years is necessary given the high natural variability in these plankton communities, as reflected in AEMP monitoring to data. A persistent change is defined in Section 6.4.3 of the subject document.	Section 6.3.1.3 and Section 6.4.3
In various locations related to the determination on whether "fish are safe to eat", there is a reference to the requirement of a future risk assessment to determine the various contaminant levels at which fish consumption would become a risk. Without a determination on these levels, a significance threshold related to this parameter cannot be determined. AANDC recommends that a risk assessment regarding fish consumption be initiated to aid in determining actual significance thresholds related to these endpoints.	The inferred significance threshold in question is that "fish in Snap Lake are not edible". This is a narrative statement at this time because there is no easy way to quantify whether fish are edible or not without a risk assessment of some kind. De Beers is making the point that such an exercise is not warranted at this stage. However, the language in the Response Framework is confusing. For example, on page 8 it states: "It is anticipated that a human health and/or wildlife risk assessment would be initiated upon exceedance of a medium or high action level, which would provide the definitive determination of whether fish are safe to eat by human or wildlife consumers." However, we don't know what the medium and high action levels are yet and it seems that waiting until a medium or high action level is reached before doing a risk assessment (and therefore finally defining, quantitatively, what the significance threshold is) is too late. De Beers shall clarify this and related statements in the Response Framework chapter of the final AEMP Design Plan document.	Section 6.3.1.1
AANDC recommends that additional detail be provided on the sample size that would trigger the action level - similar to those outlined for water quality.		Section 6.4.2

9.2 Updates to the Final 2013 AEMP Design Plan

Since the approval of the monitoring sections of the Draft 2013 AEMP Design Plan (MVLWB 2013b), (Section 1 to 5), minor updates have been made to various aspects of the monitoring design. These updates do not affect the overall integrity of the approved design; however, they have been included here to facilitate ease of tracking. A list of these updates and the respective rationale for the update, are provided in Table 9.2-2. References to the sections of this report where the updates have been applied are indicated in the tables.

Table 9.2-2 Updates to the Final 2013 AEMP Design Plan

Update to the Design Plan	Rationale	Location In Report
Periphyton' changed to 'epilithic algae'	Epilithic algae is the more accurate terminology for the community being sampled.	All sections where periphyton was previouslyused
Water quality sampling clarification	Added text to describe sampling in locations less than 5 m deep.	Table 4.2-2
Littoral zone special study key questions	Updated Littoral Zone Special Study Key Questions following consultation with external littoral zone expert	Section 5.1
Littoral invertebrate sampling methods	Following 2012 field sampling it was decided that quantitative sampling methods were needed; therefore, quantitative methods were added in 2013 and will be included as part of the special study in subsequent years.	Section 5.1.4
Lake Trout population estimate special study key questions	Wording to the key questions revised.	Section 5.4
Stable isotope food web analysis special study key questions	Wording to the key questions revised.	Section 5.5
Annual report organization	Traditional Knowledge removed as its own section and will be included within each respective section as available.	Section 8.2.1
Removal of recruitment from fish community section	Recruitment removed from the updated version of the Water Licence # MV2011L2-0004 (MVLWB 2013a)	Section 4.7

m = metre.

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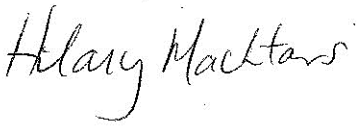

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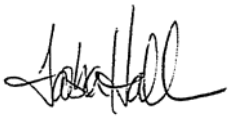

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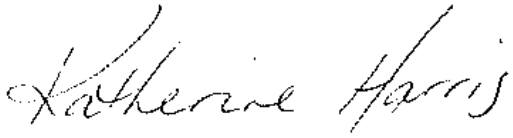

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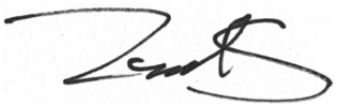

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APPENDIX A

Photographs

APPENDIX A
Photographs

Photo A-1: H1 downstream view of inlet to flume, May 2012.

Photo A-2: Site H2 view of inlet to flume A and B, May 2012.

Photo A-3: Snap Lake Main Basin, July 2009

Photo A-4: Snap Lake looking west, July 2009

Photo A-5: Downstream Lake 1 - Inlet stream, August 2011

Photo A-6: Downstream Lake 2 – Inlet stream, August 2011

Photo A-7: Downstream Lake 1 – Outlet stream, August 2011

Photo A-8: Downstream Lake 2 – Outlet stream, August 2011

Photo A-9: Lac Capot Blanc – Inlet stream, August 2011

Photo A-10: Lake 13 - shoreline view, July 2012

Photo A-11: Lac Capot Blanc – Outlet stream, August 2011

Photo A-12: Lake 13 – aerial view, July 2012

APPENDIX B

Supporting Information for Water Quality Component Design Changes

December 2013
Report No. 12-1337-0002

Golder Associates

1.0 COMPARISON OF AEMP DESIGN PLANS AND WATER LICENCE REQUIREMENTS

Table B-1 Summary of 2005 and 2013 AEMP Design Plans and Recent Water Licence Requirements

Parameter, Station or Sample Depth	Parameter	Diffuser			Snap Lake							Reference Lake/Downstream Stations			Inland Lake Stations	Watercourse Station
					2005 Design Plan		2013 Design Plan		Water Licence Requirements			2005 Design Plan	2013 Design Plan		2013 Design Plan (No Changes)	2013 Design Plan
		2005 Design Plan	2013 Design Plan	Water Licence Requirement	AEMP Stations	TDS Stations	AEMP Stations	TDS Stations	AEMP Stations (SNP 02-18)	SNP 02-21	SNP 02-24					
Stations:		SNP 02-20d; SNP 02-20e; SNP 02-20f (3 stations)	SNP 02-20d; SNP 02-20e; SNP 02-20f (3 stations)	SNP02-20 (SNP02-20d; SNP02-20e; SNP02-20f) (3 stations)	main: SNAP03; SNAP05; SNAP06; SNAP07; SNAP08; SNAP09; SNAP11A; SNAP26; NWA: SNAP02A; SNAP23; SNAP20B; (11 stations - 8 in main basin; 3 in NWA)	main: SNAP04; SNAP10; SNAP12; SNAP28; NWA: SNAP29 (5 stations)	main: SNAP03; SNAP05; SNAP06; ~~SNAP07~~; SNAP08; SNAP09; SNAP11A; ~~SNAP26~~ NWA: SNAP02A; SNAP23; SNAP20B; (9 station - 6 in main basin, 3 in NWA)	main: ~~SNAP04;~~ ~~SNAP10~~; ~~SNAP12;~~ ~~SNAP28;~~ NWA: SNAP29 (1 station)	Diffusers: SNP 02-20d, SNP 02-20e, SNP 02-20f SNAP03; *SNAP04*; SNAP05; SNAP06; SNAP07; SNAP08; SNAP09; *SNAP10*; SNAP11A; *SNAP12*; *SNAP26; SNAP28* (8 stations in main basin)	SNAP08	SNAP05, *SNAP10*, *SNAP12*, *SNAP28*, SNAP29 (5 stations)	NEL01; NEL02; NEL03; NEL04; NEL05 KING01	NEL01; NEL02; NEL03; NEL04; NEL05; **NEL06 LK13-01, LK13-02, LK13-03, LK13-04, LK13-05, LK13-06** [c]	KING01	IL3; IL4; IL5	S1, **S27**
Sample Depth:		surface, mid-depth, bottom	depth of maximum conductivity, or mid-depth if no conductivity gradient is present[a]	-field measurements at one metre intervals from surface to bottom; -samples at *surface, bottom* and at depth of maximum conductivity. If no conductivity peak, mid-depth between surface and bottom	mid-depth if no gradient; surface, mid, bottom if gradient	mid-depth	depth of maximum conductivity, or mid-depth if no conductivity gradient is present [a]	depth of maximum conductivity, or mid-depth if no conductivity gradient is present [a]	not specified	not specified	taken at 1 m depth intervals	mid-depth surface at KING01	mid-depth	surface	mid-depth	0.2 m below surface
Field Measurements/Profiles	Field pH, specific conductivity, dissolved oxygen (DO) and temperature At 1 m intervals from surface to bottom	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	monthly during ice-cover, July, Sept	monthly	May, July, Aug, Sept	May, July, Aug, Sept	quarterly (*early winter*, immediately prior to ice-out, late summer, prior to ice-up) -DO in profiles at deep portions (i.e., >8 m) of Snap Lake with monitoring occurring monthly from Feb through May (i.e., under ice) and in late summer	quarterly[e]	not specified	quarterly	May, July, Aug, Sept	May	monthly during open-water conditions	twice weekly during spring freshet and monthly during open-water conditions
Physical and conventional parameters, TDS and major ions	total suspended solids (TSS); pH; turbidity; conductivity, TDS (calculated and measured); calcium; magnesium; sodium; chloride; sulphate; bicarbonate; carbonate; fluoride; potassium; hydroxide; reactive silica (as SiO_2); hardness; alkalinity; acidity; ion balance	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	quarterly (Jan, Apr, July, Sept)	quarterly (Jan, Apr, July, Sept)	May, July, Aug, Sept	May, July, Aug, Sept	quarterly (*as above*) - TDS, chloride, calcium only	quarterly[e]	TDS only -two times per year during open-water conditions -*four times per year in different months during ice-cover*	quarterly	May, July, Aug, Sept [b]	May	monthly during open-water conditions	twice weekly during spring freshet and monthly during open-water conditions
Nutrients	total and dissolved phosphorus; total organic carbon; ortho-phosphate as P; total ammonia (as nitrogen [N]); nitrate (as N); nitrite (as N); nitrate/nitrite (as N); total Kjeldahl nitrogen (as N); total and dissolved organic phosphorus; total and dissolved inorganic phosphorus	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	quarterly (Jan, Apr, July, Sept)	quarterly (Jan, Apr, July, Sept) for nitrate[a]	May, July, Aug, Sept	May, July, Aug, Sept	quarterly (*as above*) - nitrate total phosphorus, ortho-P and diss-P in *March* and early summer	quarterly[e]	not specified	quarterly	May, July, August, September [b]	May	monthly during open-water conditions for nitrogen nutrients [d]	weekly during spring freshet and monthly during open-water conditions for nitrogen nutrients [d]

Table B-1 Summary of Changes between the 2005 and 2013 AEMP Design Plans and the Water Licence (continued)

Parameter, Station or Sample Depth	Parameter	Diffuser			Snap Lake							Reference Lake/Downstream Stations			Inland Lake Stations	Watercourse Station
					2005 Design Plan		2013 Design Plan		Water Licence Requirements							
		2005 Design Plan	2013 Design Plan	Water Licence Requirement	AEMP Stations	TDS Stations	AEMP Stations	TDS Stations	AEMP Stations (SNP 02-18)	SNP 02-21	SNP 02-24	2005 Design Plan	2013 Design Plan		2013 Design Plan (No Changes)	2013 Design Plan
Stations:		SNP 02-20d; SNP 02-20e; SNP 02-20f (3 stations)	SNP 02-20d; SNP 02-20e; SNP 02-20f (3 stations)	SNP02-20 (SNP02-20d; SNP02-20e; SNP02-20f) (3 stations)	main: SNAP03; SNAP05; SNAP06; SNAP07; SNAP08; SNAP09; SNAP11A; SNAP26; NWA: SNAP02A; SNAP23; SNAP20B; (11 stations - 8 in main basin; 3 in NWA)	main: SNAP04; SNAP10; SNAP12; SNAP28; NWA: SNAP29 (5 stations)	main: SNAP03; SNAP05; SNAP06; ~~SNAP07~~; SNAP08; SNAP09; SNAP11A; ~~SNAP26~~ NWA: SNAP02A; SNAP23; SNAP20B; (9 station - 6 in main basin, 3 in NWA)	main: ~~SNAP04;~~ ~~SNAP10;~~ ~~SNAP12;~~ ~~SNAP28;~~ NWA: SNAP29 (1 station)	Diffusers: SNP 02-20d, SNP 02-20e, SNP 02-20f SNAP03; *SNAP04*; SNAP05; SNAP06; SNAP07; SNAP08; SNAP09; *SNAP10*; SNAP11A; *SNAP12*; *SNAP26; SNAP28* (8 stations in main basin)	SNAP08	SNAP05, *SNAP10*, *SNAP12*, *SNAP28*, SNAP29 (5 stations)	NEL01; NEL02; NEL03; NEL04; NEL05 KING01	NEL01; NEL02; NEL03; NEL04; NEL05; **NEL06 LK13-01, LK13-02, LK13-03, LK13-04, LK13-05, LK13-06** [c]	KING01	IL3; IL4; IL5	S1, **S27**
Metals	total metals (Al; Sb; As; Ba; Be; Bi; B; Cd; Cs; Cr; Cr(VI) (total only); Co; Cu; Fe; Pb; Li; Mn; Hg; Mo; Ni; Se; Ag; Sr; Tl; Ti; U; V; Zn)	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	quarterly (Jan, Apr, July, Sept)	-	May, September	May, September	not specified	*quarterly* [e]	not specified	total metals were analyzed;	May, September [b]	May	-	weekly during spring freshet and monthly during open-water conditions
	dissolved metals (as above)	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	dissolved metals samples were archived and only analyzed if a total metal was above a guideline		dissolved metals samples were archived and only analyzed if a total metal was above a guideline	dissolved metals samples were archived and only analyzed if a total metal was above a guideline	not specified	*quarterly* [e]	not specified	dissolved metals samples were archived and only analyzed if a total metal was above a guideline	dissolved metals samples were archived and only analyzed if a total metal was above a guideline [b]	May	-	dissolved metals samples were archived and only analyzed if a total metal was above a guideline [b]
Other parameters	methyl mercury biochemical oxygen demand (BOD)	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	-BOD -monthly -no requirement for methyl mercury	not applicable; except BOD at SNAP08	-	-	-	not specified		not specified	-	-	-	-	-
Organics	BTEX (benzene; toluene; ethylene; xylene); total oil and grease; total extractable hydrocarbons (TEH); total volatile hydrocarbons (TVH); F1 (without BTEX) and F2 (without BTEX	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	-	-	-	-	not specified		not specified	-	-	-	-	-
Biological	*Escherichia Coli (E. coli)*	monthly (Jan to May, July to Sept)	monthly (Jan to May, July to Sept, Dec)	monthly (Jan, Feb, Mar, Apr, May, *June*, July, Aug, Sept, *Oct, Nov*, Dec)	-	-	-	-	not specified		not specified	-	-	-	-	-
	Microcystin- LR	-	-	-	-	-	-	Jan, May, July, August, September	-		not specified	-	-	-	-	-
Toxicity	*Ceriodaphnia dubia; Pseudokirchneriella subcapitata*	twice per year (Apr, Sept)	twice per year (Apr, Sept)	twice per year (Apr, Sept)	-	-	-	-	-		not specified	-	-	-	-	-
	Early life stage (egg/alevin, fry) with rainbow trout EPS/1/RM/28	-	once per year	once per year	-	-	-	-	-		-	-	-	-	-	-

Notes: ~~strikethrough font~~ = Stations discontinued from the 2005 Design Plan; *italic/underline font* = Proposed deviation from Water Licence; **bold font** = New stations to the 2013 Design Plan.

(a) Criteria for identification of conductivity gradient yet to be finalized as it will depend on review of the most recent water quality data; however, the procedure will likely be similar to that used in the 2005 AEMP study design.

(b) With the exception of NEL06 and LK13-06, where only field parameters are measured.

(c) NEL06 and sites in Reference Lake 13 are new.

(d) Nitrogen nutrients = total ammonia (as nitrogen [N]); nitrate (as N); nitrite (as N); nitrate/nitrite (as N); total Kjeldahl nitrogen (as N).

(e) Samples to be collected quarterly, but the Water Licence does not specify in which months samples should be collected.

2.0 SUPPORTING DATA FOR REDUCING THE NUMBER OF STATIONS IN THE MAIN BASIN OF SNAP LAKE

The number of stations to be sampled in Snap Lake main basin was evaluated using a graphical approach aimed at determining the number of stations above which further sampling yields little additional precision. Total dissolved solids (TDS) results from 14 stations sampled during the ice-covered season and 15 stations during the open water season collected as part of the 2011 AEMP program were used in this evaluation. Depth-averaged TDS results for each station were grouped by month (February, April, July and September). Results were then randomly ordered for each month and the standard error of the mean was calculated as a percentage of the mean (percent Standard Error) for 3 to 14 or 15 stations (as available). This procedure was repeated 10 times (i.e., series 1 to 10). The standard error values were plotted against the number of stations for each month. The number of stations where the Standard Error stabilizes, or converges, was considered to be the appropriate number of stations to sample for calculating whole-lake TDS concentration.

Figure B-1 Relationship Between Number of Samples and Standard Error for Total Dissolved Solids in Snap Lake in 2011

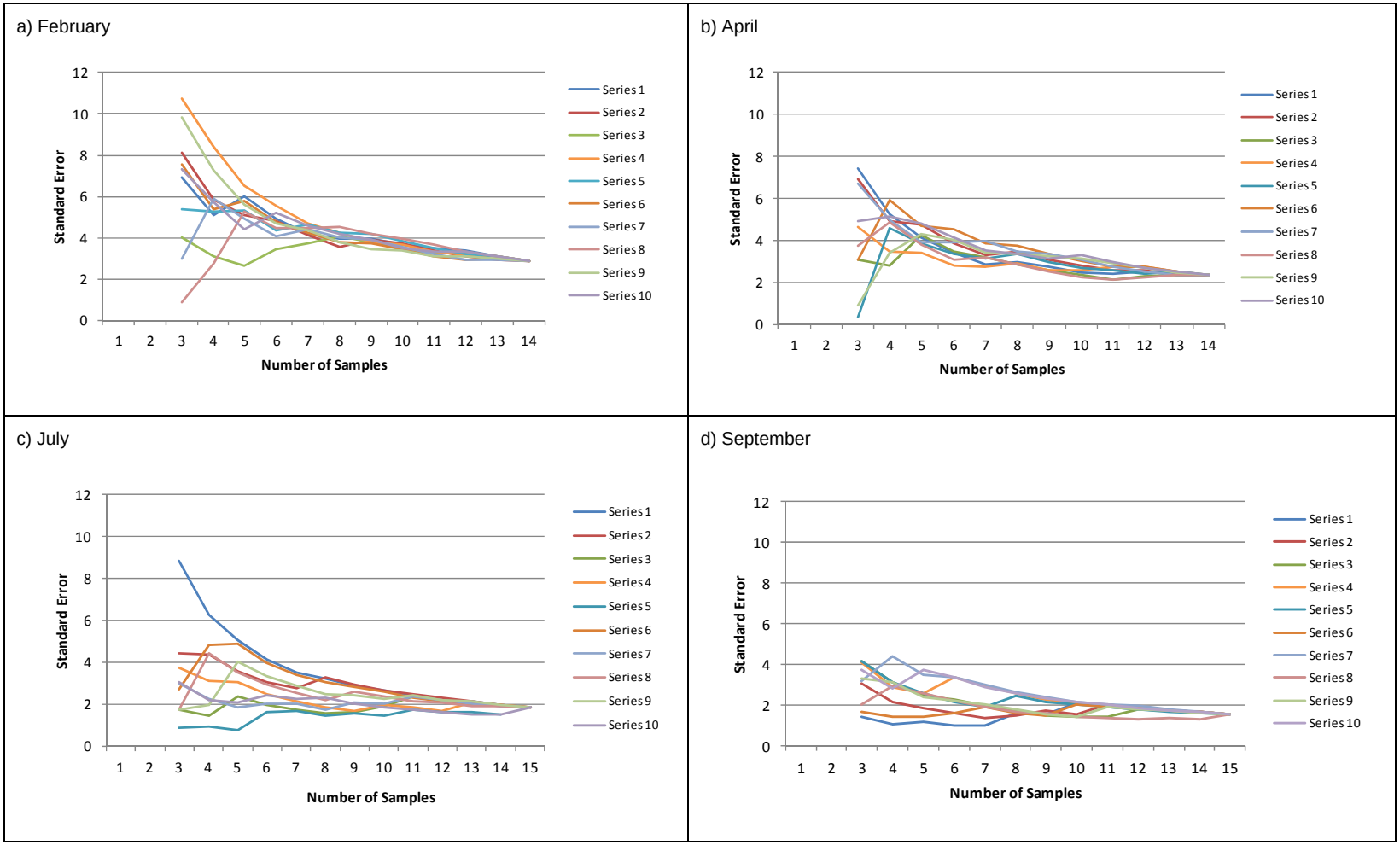
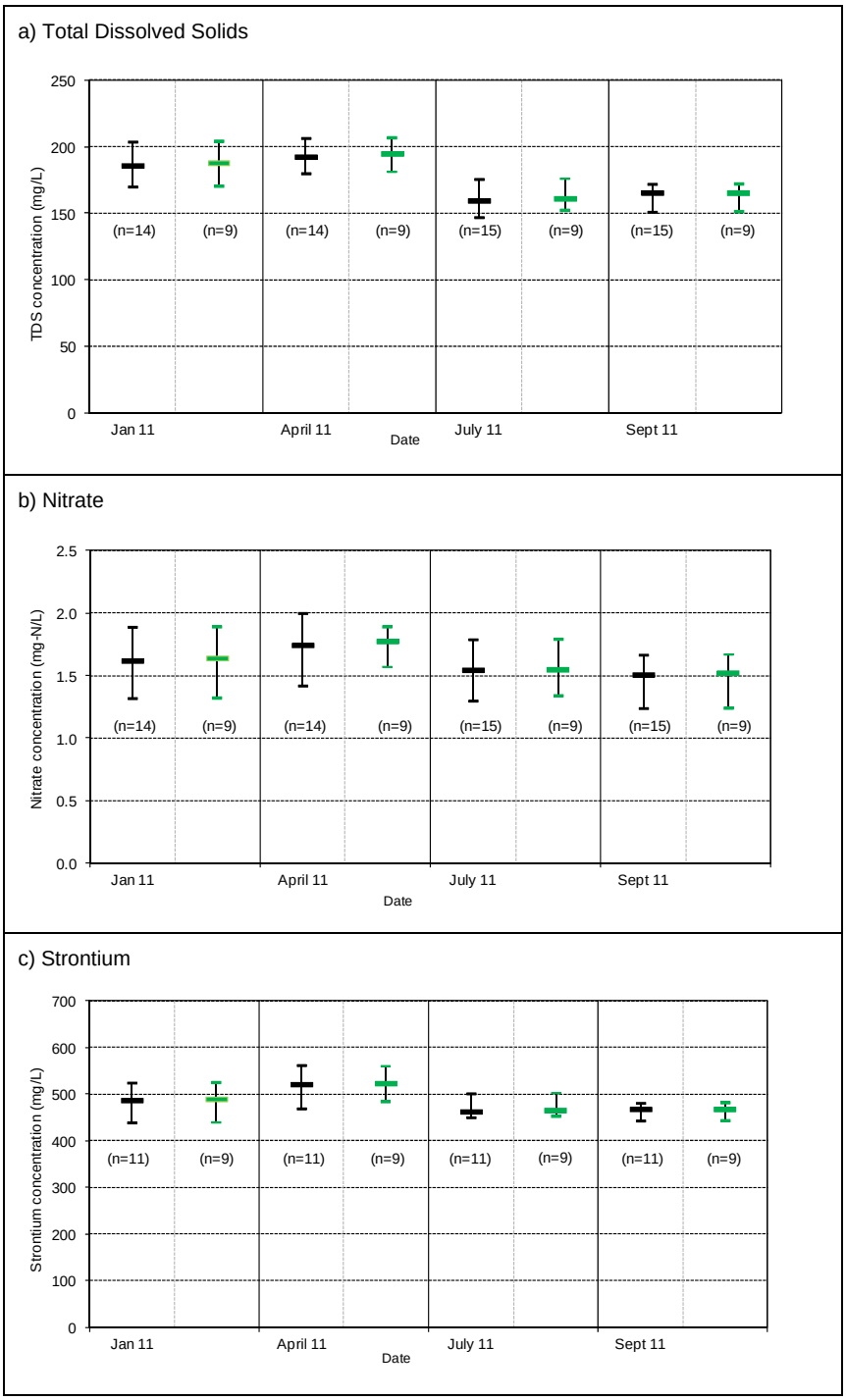


Figure B-2 Comparison of Calculated Whole-lake Average Values for Total Dissolved Solids, Nitrate and Strontium Using Different Sample Sizes



Note: Fifteen stations sampled during the open-water season and 14 stations sampled during the ice-covered season were used. Data from station SNAP28 were not available during ice-cover due to unsafe ice conditions in this area. Number of samples for strontium is lower because metals are not analyzed at the TDS stations. mg/L = milligrams per litre; N = nitrogen; n = number of samples.

3.0 SUPPORTING DATA FOR DISCONTINUING SAMPLING AT SELECTED TDS STATIONS

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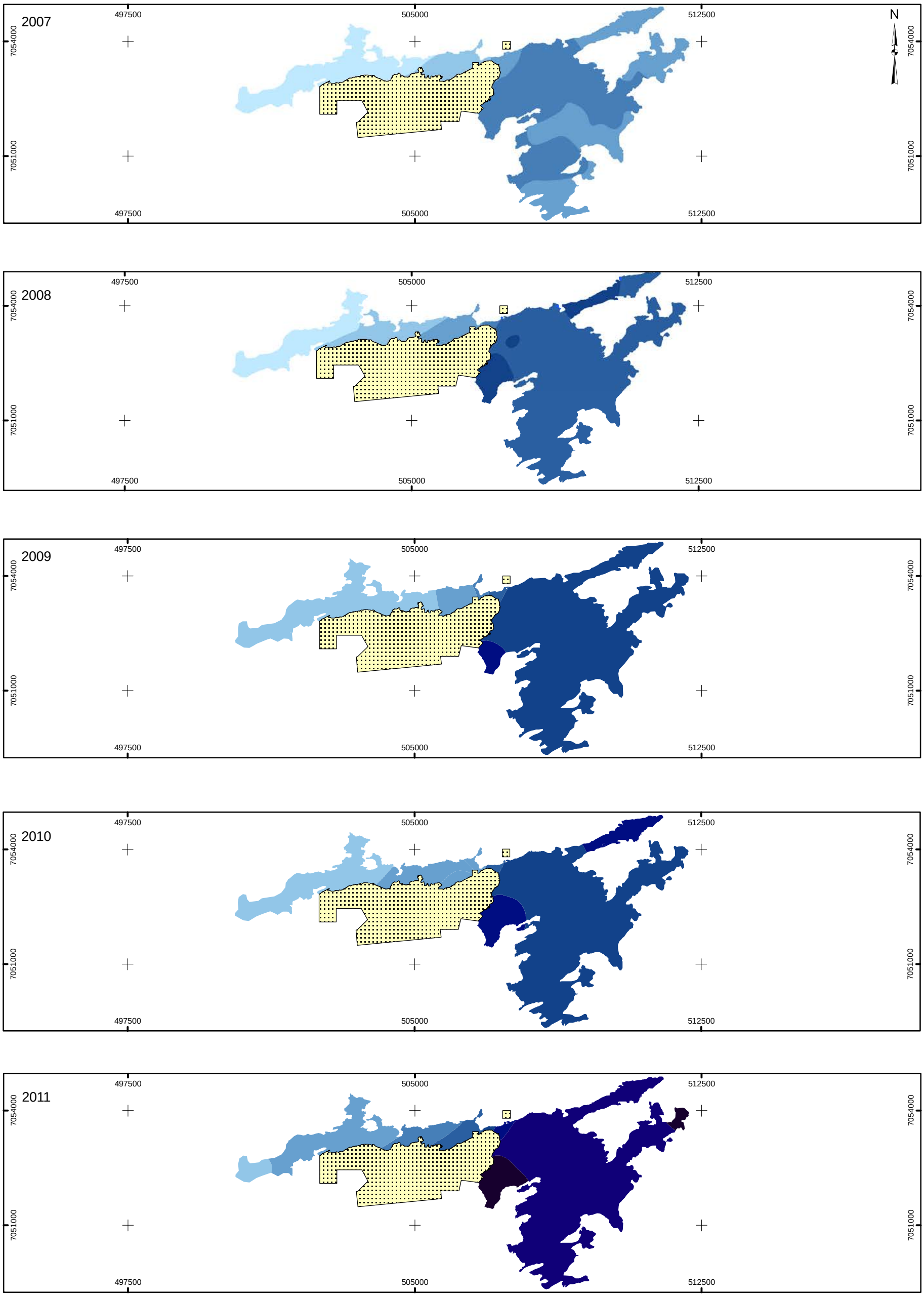


LEGEND

SPECIFIC CONDUCTIVITY

- < 50 µS/cm
- 50 - 100 µS/cm
- 100 - 150 µS/cm
- 150 - 200 µS/cm
- 200 - 250 µS/cm
- 250 - 300 µS/cm
- 300 - 350 µS/cm
- 350 - 400 µS/cm
- 400 - 450 µS/cm

SNAP LAKE MINE FOOTPRINT

REFERENCE

DATUM: NAD83, PROJECTION: UTM ZONE 12N

3 1.5 0 3

SCALE 1:100,000 KILOMETRES

PROJECT

De Beers Canada – Snap Lake Mine

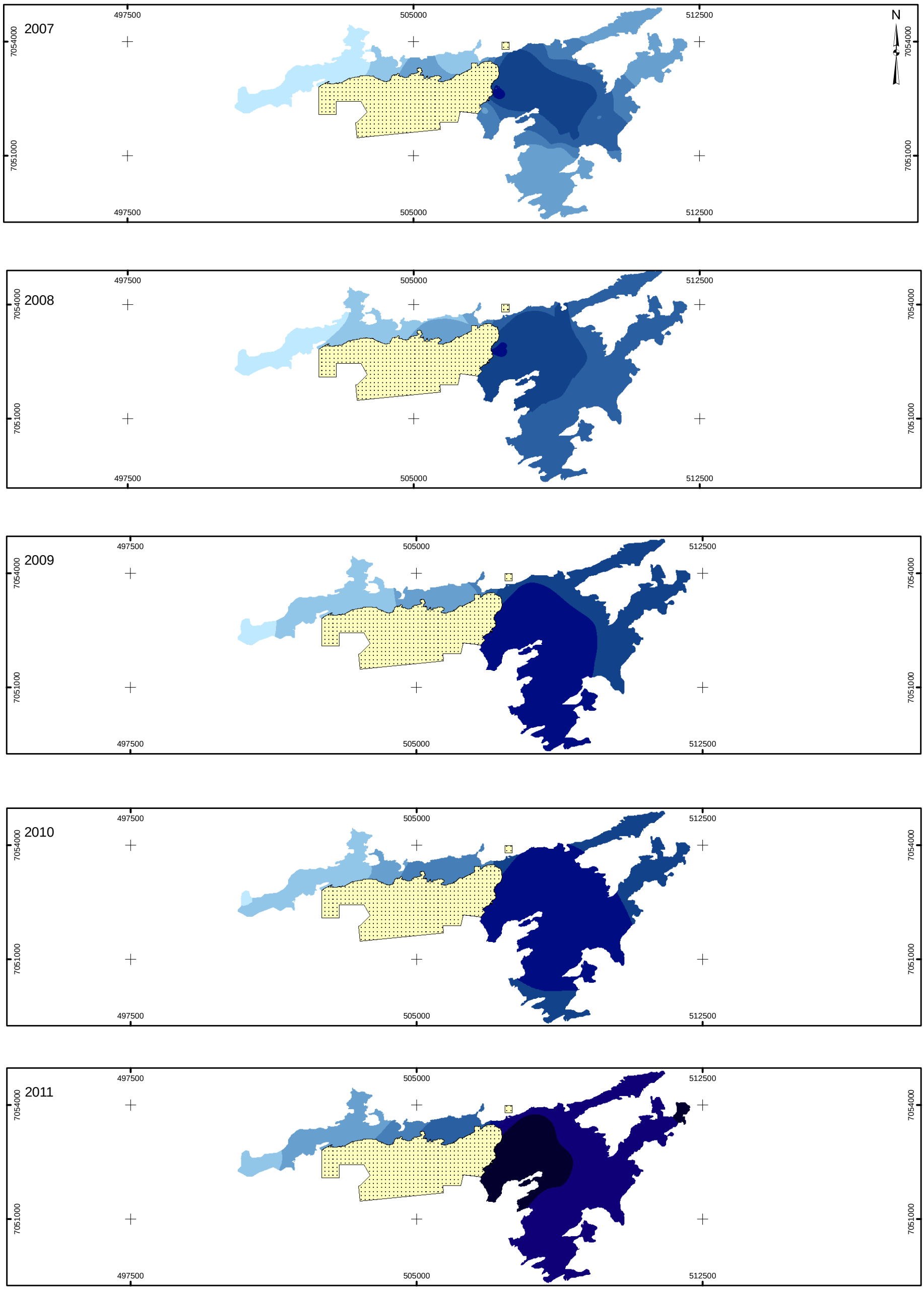
TITLE

SURFACE CONDUCTIVITY LEVELS IN SNAP LAKE DURING ICE-COVERED CONDITIONS, 2007 TO 2011

Golder Associates

PROJECT 12.1337.0002.1100			FILE No.	
DESIGN	CW	5 Jul. 2012	SCALE AS SHOWN	REV. 0
GIS	HP	13 Sep. 2012	FIGURE: B-3	
CHECK	LMB	20 Sep. 2012		
REVIEW	PMC	20 Sep. 2012		

I:\CLIENTS\DE_BEERS\Snap_Lake\Mapping\MXD\AEMP2012\Fig3.1-33_BottomConductivity2007-2011_20120913.mxd



LEGEND

SPECIFIC CONDUCTIVITY

- < 50 µS/cm
- 50 - 100 µS/cm
- 100 - 150 µS/cm
- 150 - 200 µS/cm
- 200 - 250 µS/cm
- 250 - 300 µS/cm
- 300 - 350 µS/cm
- 350 - 400 µS/cm
- 400 - 450 µS/cm

SNAP LAKE MINE FOOTPRINT

REFERENCE

DATUM: NAD83, PROJECTION: UTM ZONE 12N

3 1.5 0 3

SCALE 1:100,000 KILOMETRES

PROJECT

De Beers Canada
Snap Lake Mine

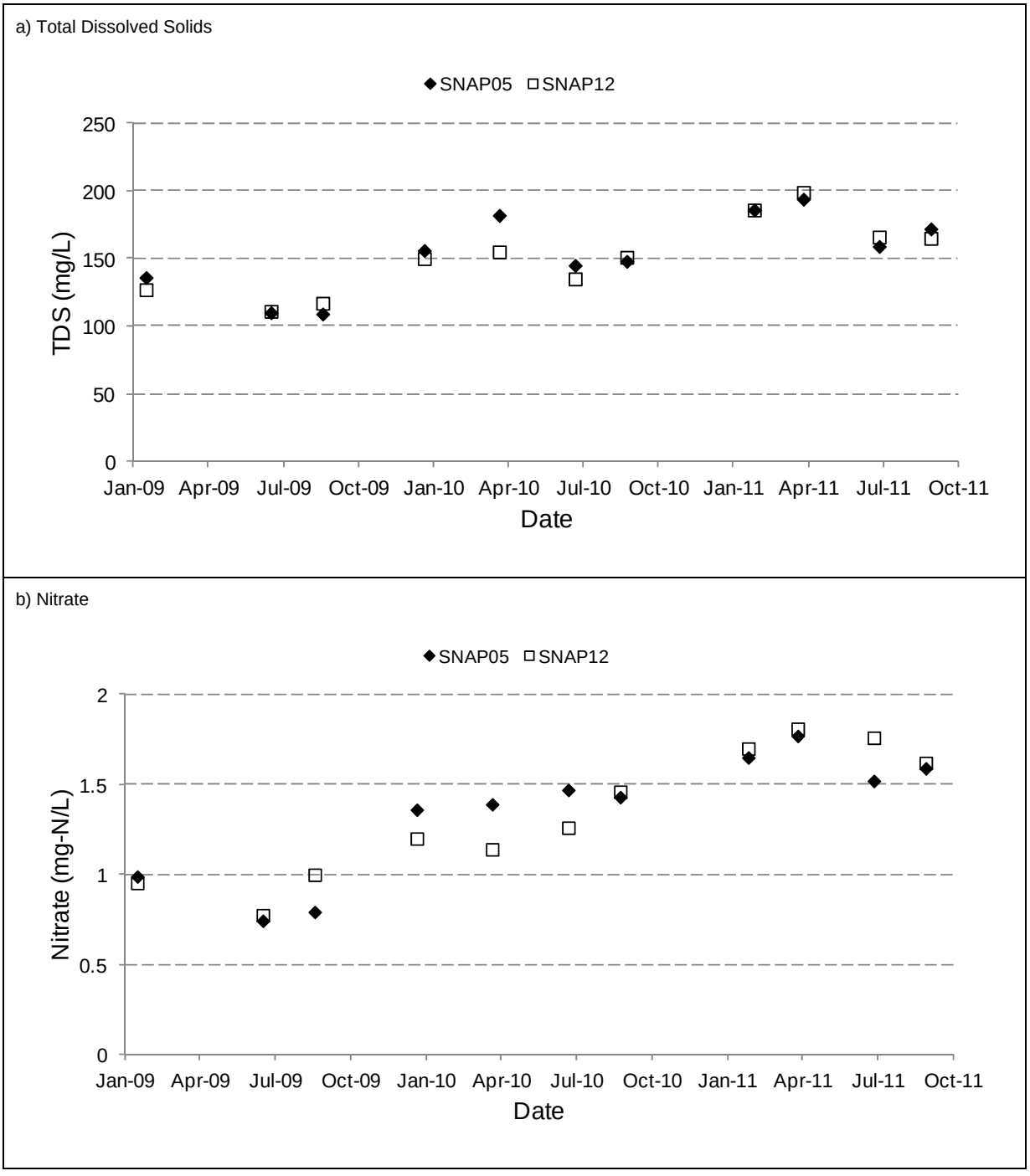
TITLE

BOTTOM CONDUCTIVITY LEVELS IN SNAP LAKE DURING ICE-COVERED CONDITIONS, 2007 TO 2011

Golder Associates

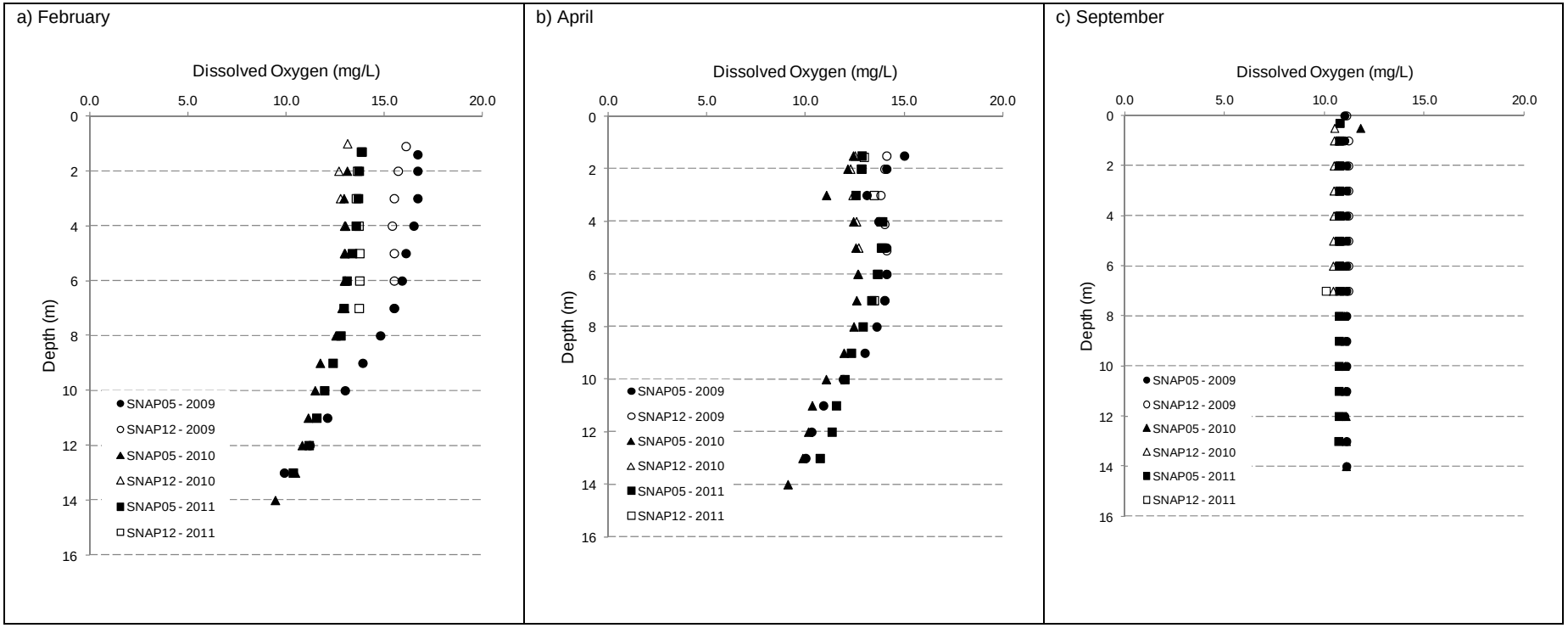
PROJECT 12.1337.0002.1100			FILE No.	
DESIGN	CW	5 Jul. 2012	SCALE AS SHOWN	REV. 0
GIS	HP	13 Sep. 2012	FIGURE: B-4	
CHECK	LMB	20 Sep. 2012		
REVIEW	PMC	20 Sep. 2012		

Figure B-5 Total Dissolved Solids and Nitrate Concentrations at SNAP05 and SNAP12



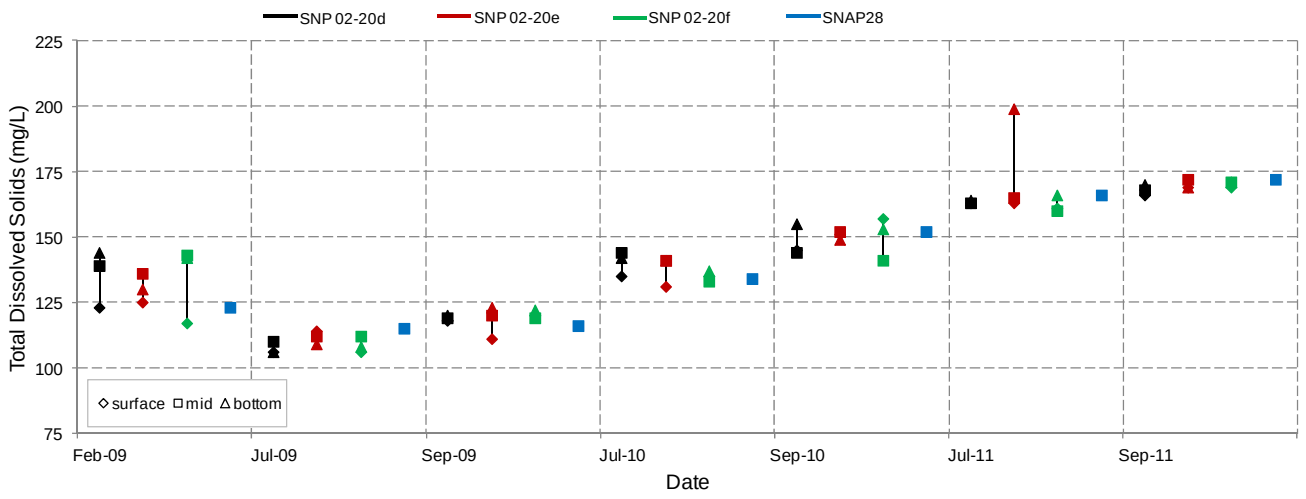
Note: SNAP12 will be discontinued as part of the 2013 AEMP Design Plan.
mg/L = milligrams per litre; N = nitrogen; TDS = total dissolved solids.

Figure B-6 Dissolved Oxygen Profiles at SNAP05 and SNAP12



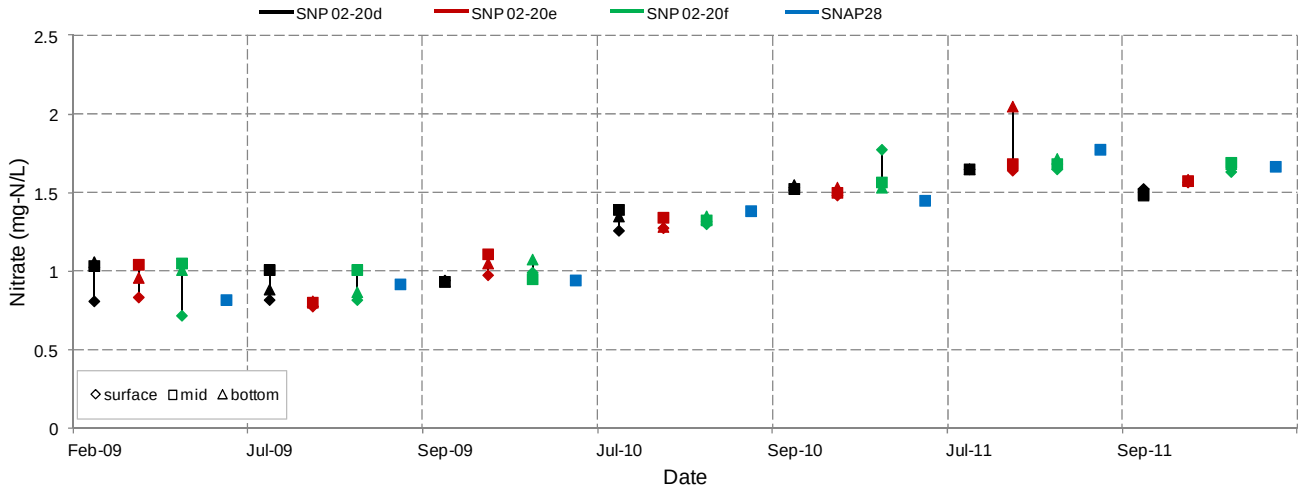
Note: SNAP12 will be discontinued as part of the 2013 AEMP Design Plan.
m = metre; mg/L = milligrams per litre.

Figure B-7 Total Dissolved Solids Concentrations at the Diffuser Stations and SNAP28 (Discontinued Station)



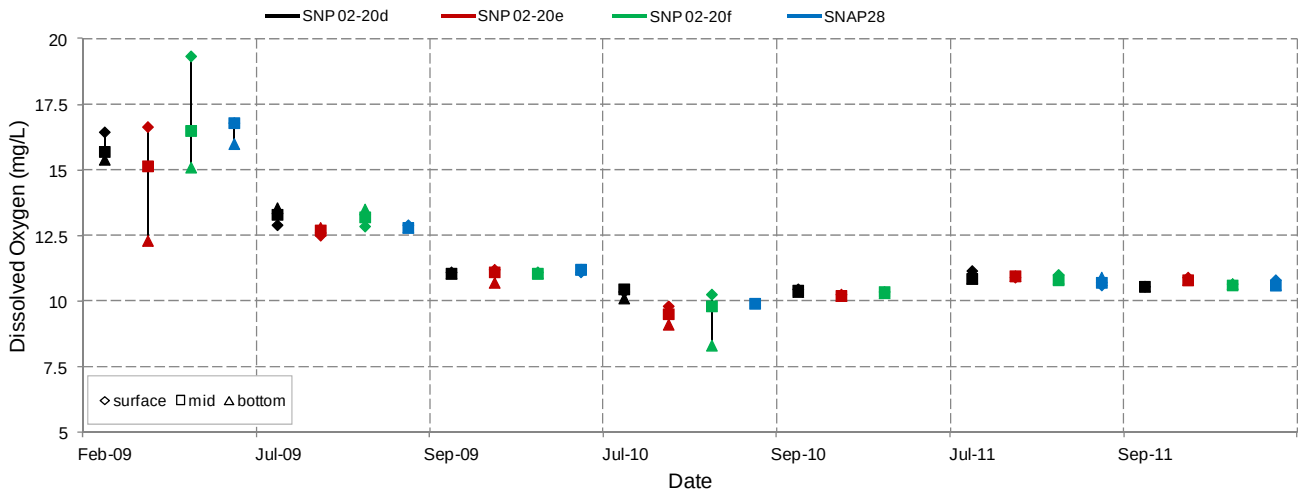
mg/L = milligrams per litre

Figure B-8 Nitrate Concentrations at the Diffuser Stations and SNAP28 (Discontinued Station)



mg-N/L = milligrams nitrogen per litre.

Figure B-9 Strontium Concentrations at the Diffuser Stations and SNAP28 (Discontinued Station)

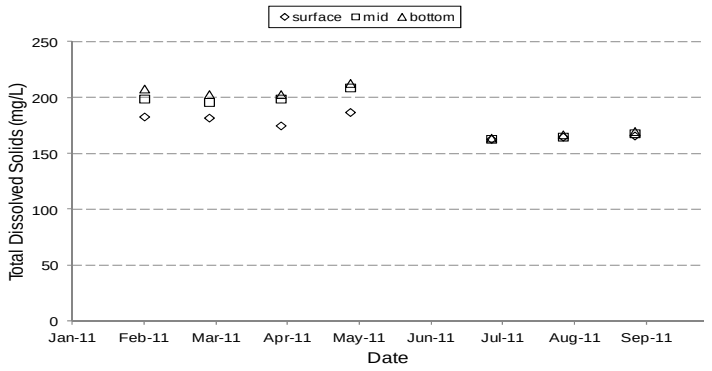


mg /L = milligrams per litre.

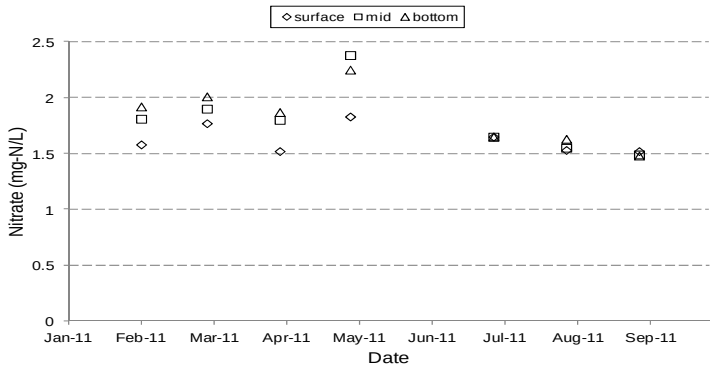
4.0 SUPPORTING DATA FOR REDUCING MULTIPLE DEPTH SAMPLES AT DIFFUSER STATIONS

Figure B-10 Parameter Concentrations at Varying Depths at Diffuser Station SNP02-20d in 2011

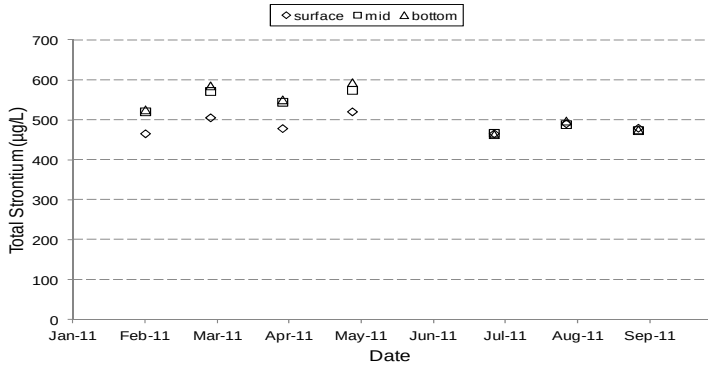
a) Total Dissolved Solids



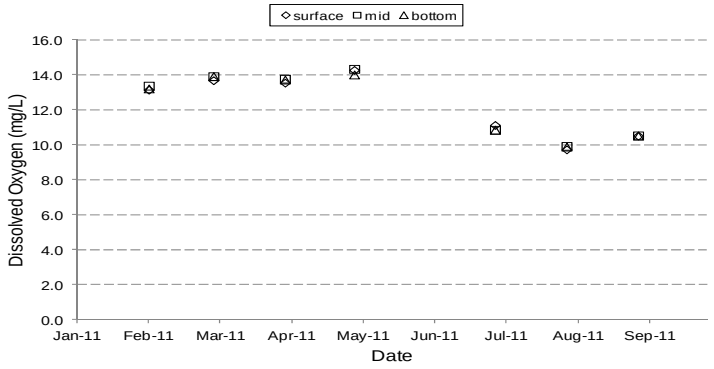
b) Nitrate



c) Strontium



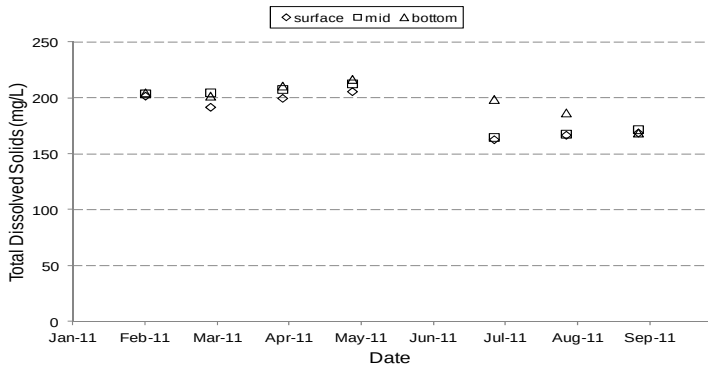
d) Dissolved Oxygen



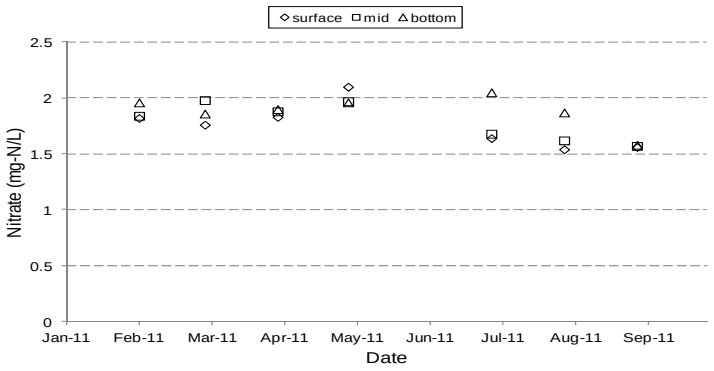
µg/L = micrograms per litre; mg/L = milligrams per litre; m = metre; N = nitrogen.

Figure B-11 Parameter Concentrations at Varying Depths at Diffuser Station SNP02-20e in 2011

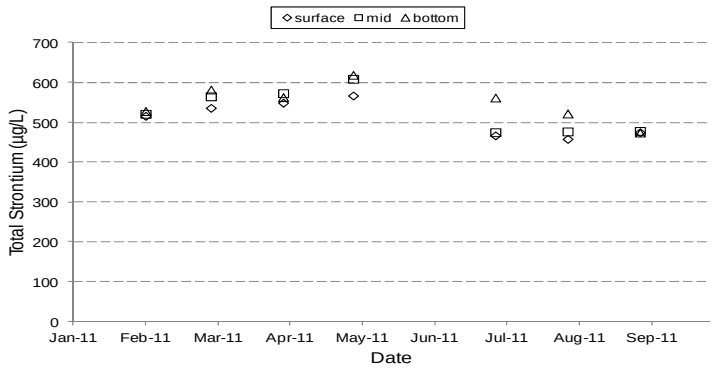
a) TDS



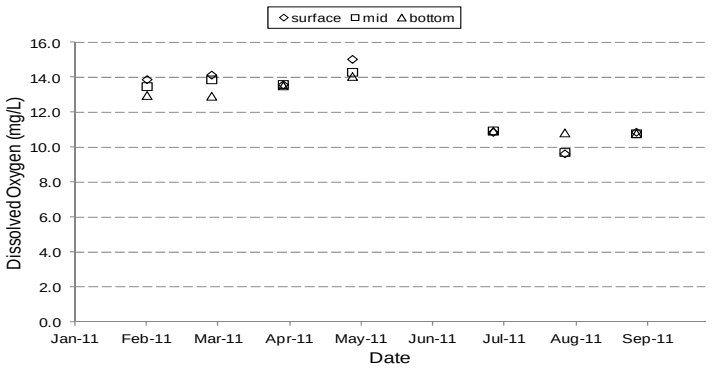
b) Nitrate



c) Strontium



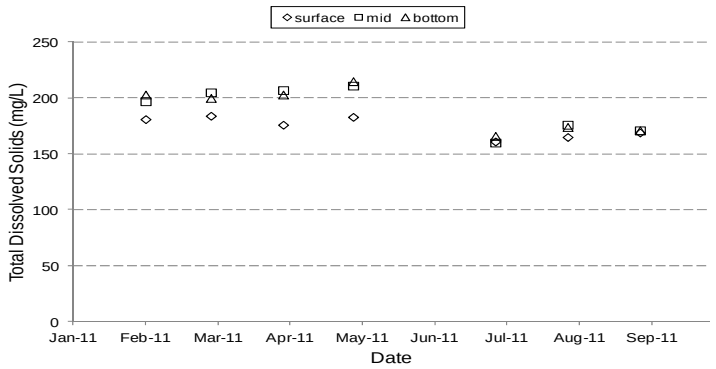
d) Dissolved Oxygen



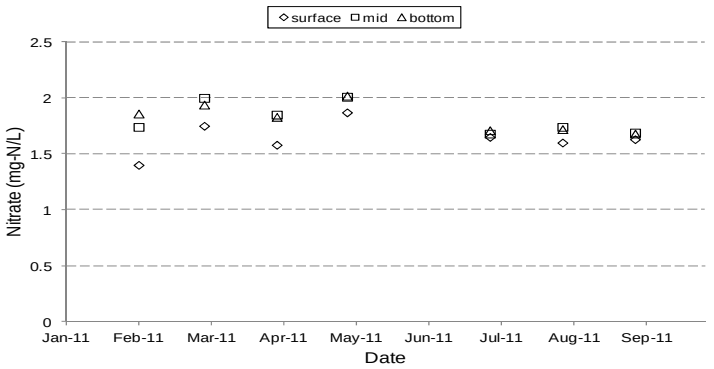
TDS = total dissolved solids; µg/L = micrograms per litre; mg/L = milligrams per litre; m = metre; N = nitrogen.

Figure B-12 Parameter Concentrations at Varying Depths at Diffuser Station SNP02-20f in 2011

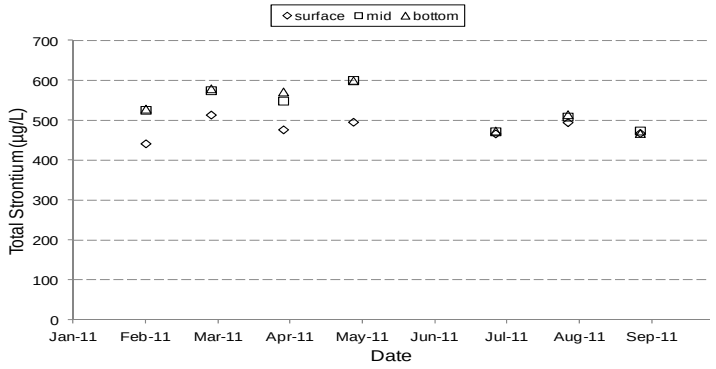
a) TDS



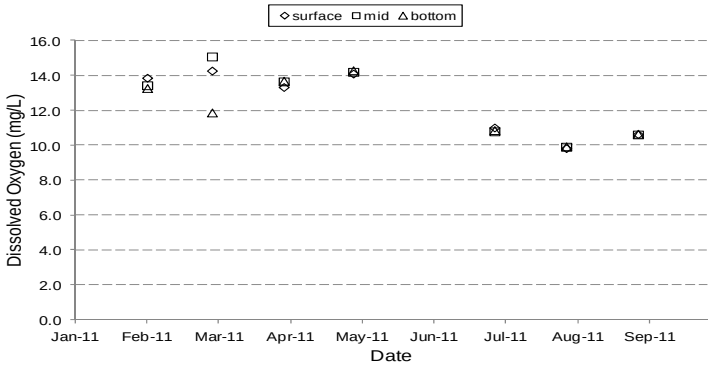
b) Nitrate



c) Strontium



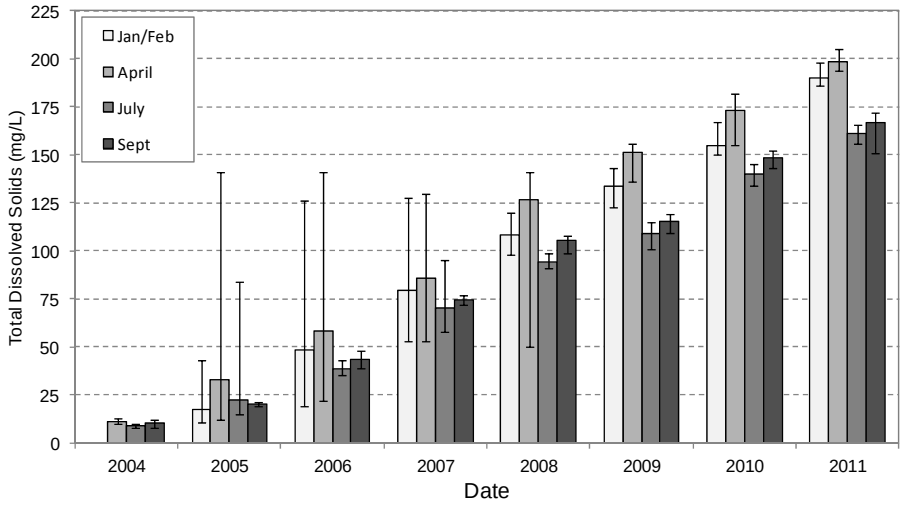
d) Dissolved Oxygen



TDS = total dissolved solids; µg/L = micrograms per litre; mg/L = milligrams per litre; m = metre; N = nitrogen.

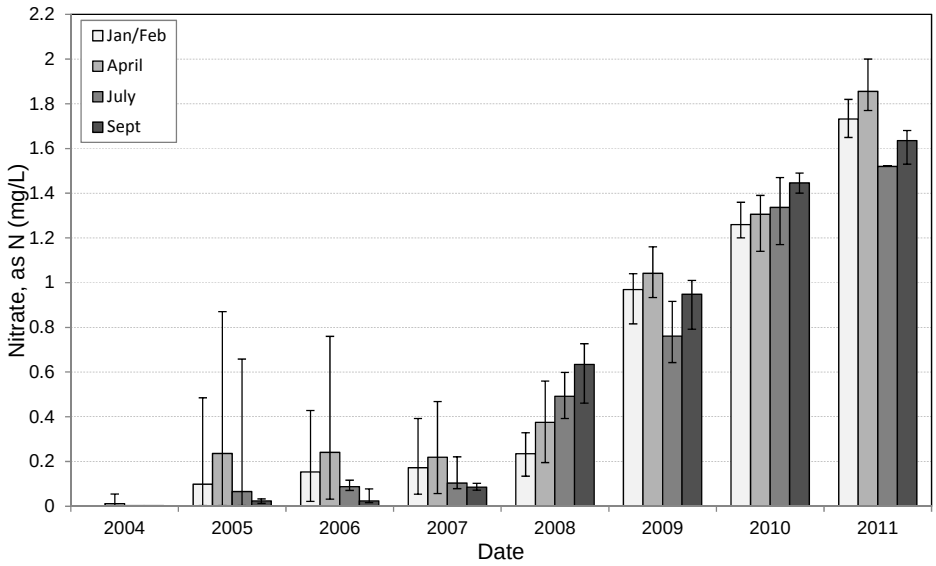
5.0 SUPPORTING DATA FOR ELIMINATING THE JANUARY ICE-COVERED PROGRAM

Figure B-13 Calculated Total Dissolved Solids Concentrations in the Near-Field of Snap Lake, 2004 to 2011



mg/L = milligrams per litre; Jan/Feb = January/February; Sept = September. Upper and lower error bars are equal to the maximum and minimum of all depths sampled during the season.

Figure B-14 Nitrate, as N, Concentrations in the Near-Field of Snap Lake, 2004 to 2011



mg/L = milligrams per litre; N= nitrogen; Jan/Feb = January/February; Sept = September. Upper and lower error bars are equal to the maximum and minimum of all depths sampled during the season.

6.0 SUPPORTING DATA ANNUAL SAMPLING AT DOWNSTREAM STATION KING01

Figure B-15 Concentrations of Total Dissolved Solids and Conductivity Levels at the Downstream Station KING01

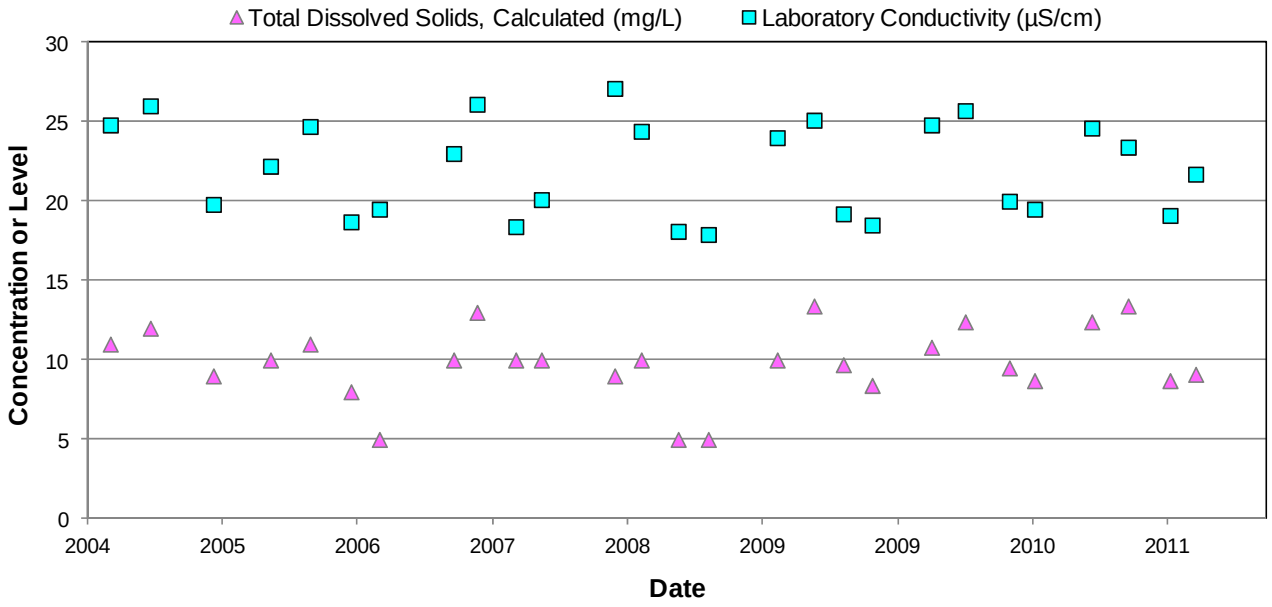


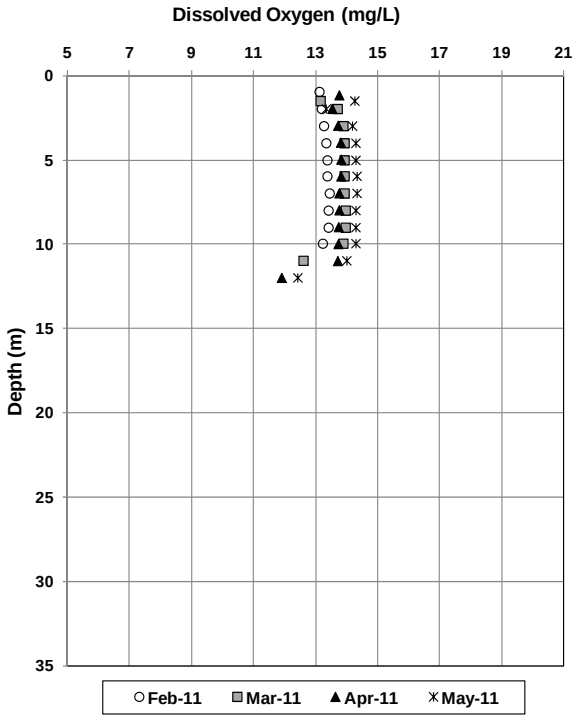
Table B-2 Summary of Month when Maximum Total Dissolved Solids and Conductivity Levels Occur at the Downstream Station (KING01)

Year	Maximum Conductivity Value	Month of Maximum Conductivity Value	Maximum Total Dissolved Solids Value	Month of Maximum Total Dissolved Solids Value
2005	26	April	12	April
2006	25	April	11	April
2007	26	April	13	April
2008	27	February	10	April
2009	25	May	13	May
2010	26	April	12	April
2011	25	January	13	April

7.0 SUPPORTING DATA FOR LESS FREQUENT UNDER-ICE DISSOLVED OXYGEN PROFILING

Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011

a. SNP02-20d



b. SNP02-20e

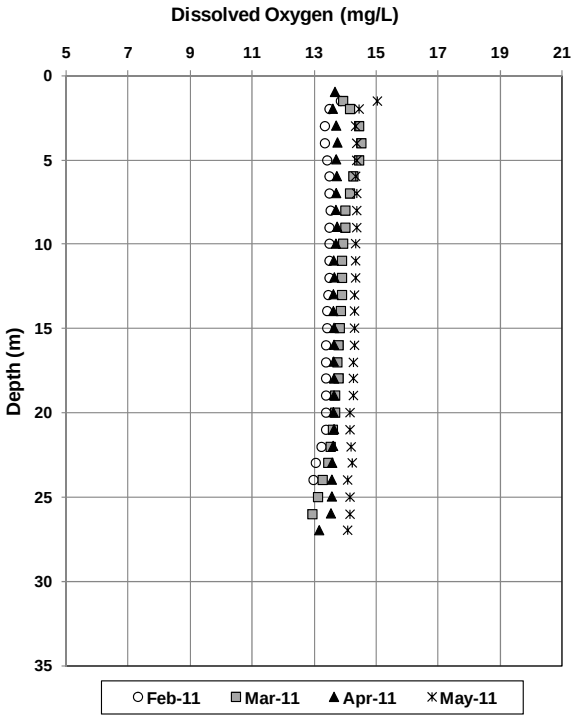
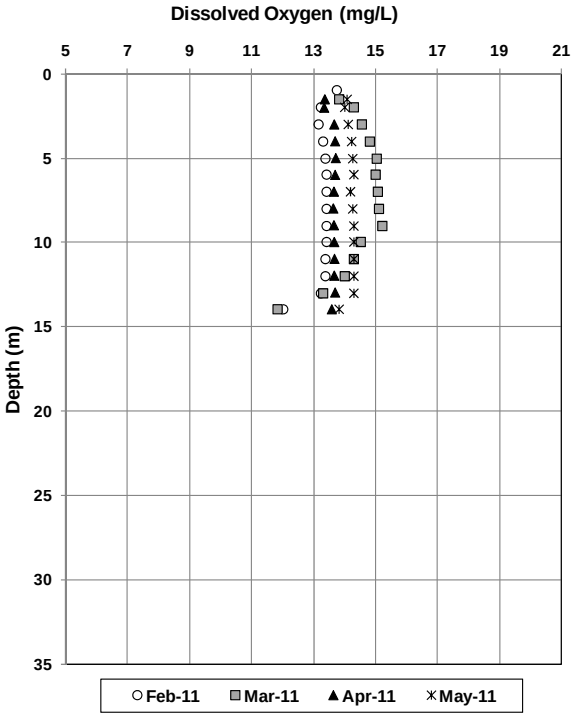


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

c. SNP02-20f



d. SNAP03

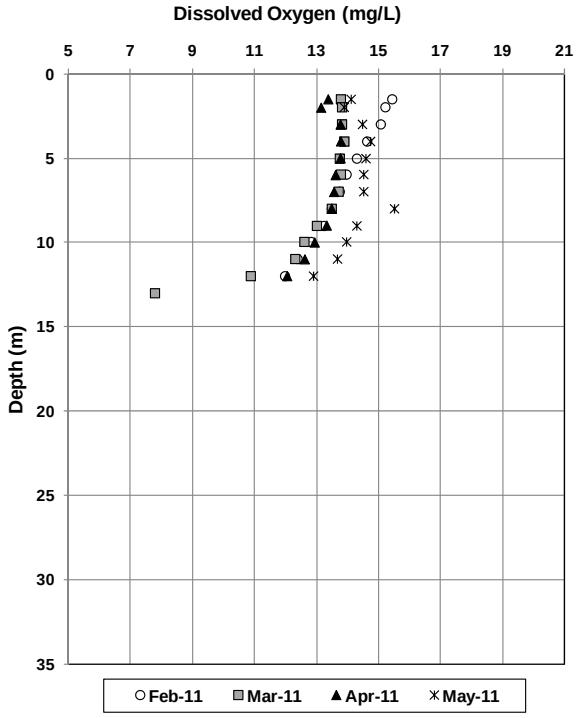
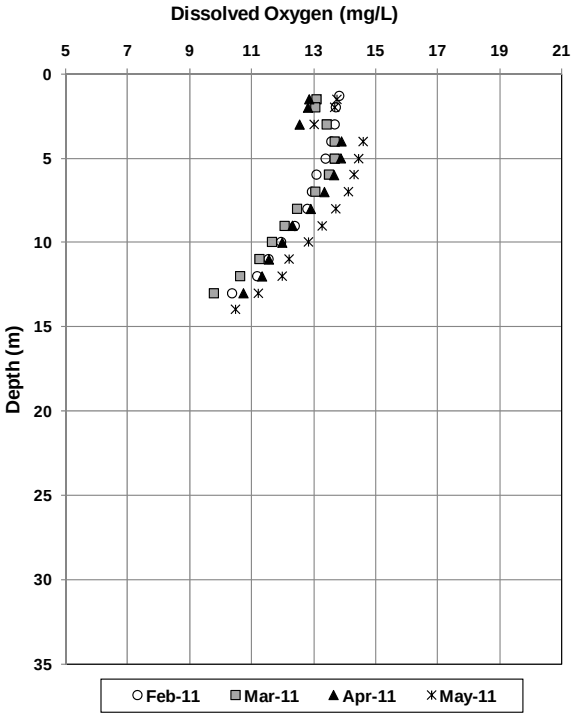


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

e. SNAP05



f. SNAP06

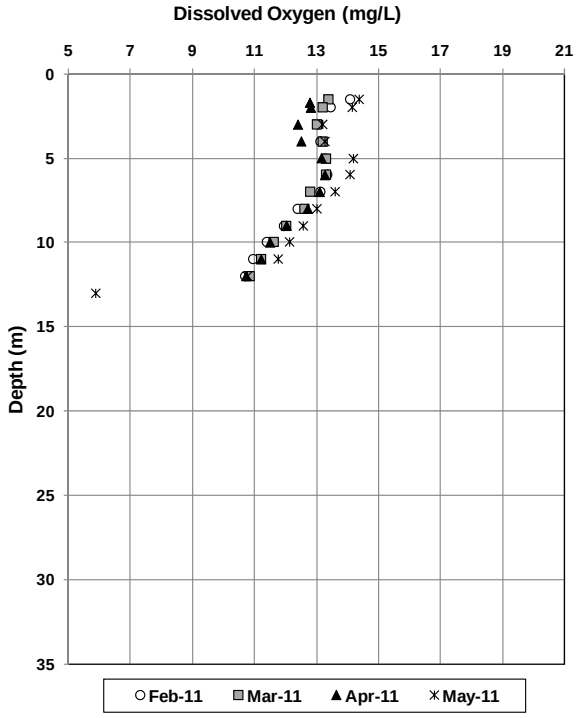
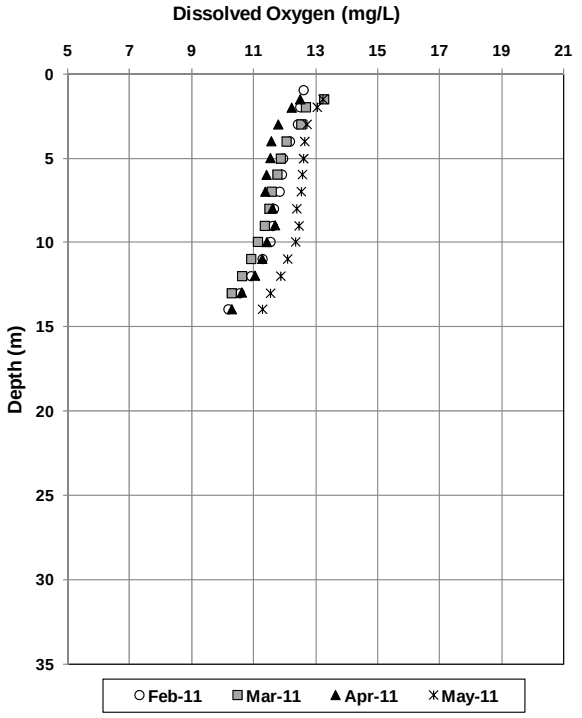


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

g. SNAP09



h. SNAP11A

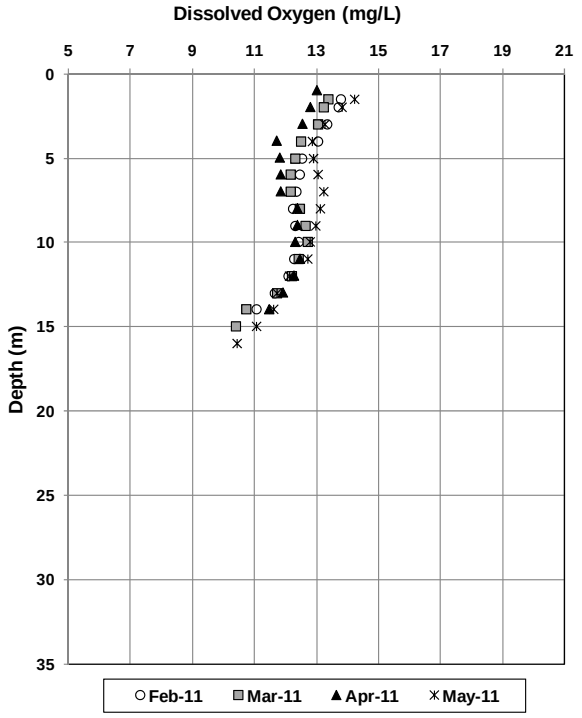
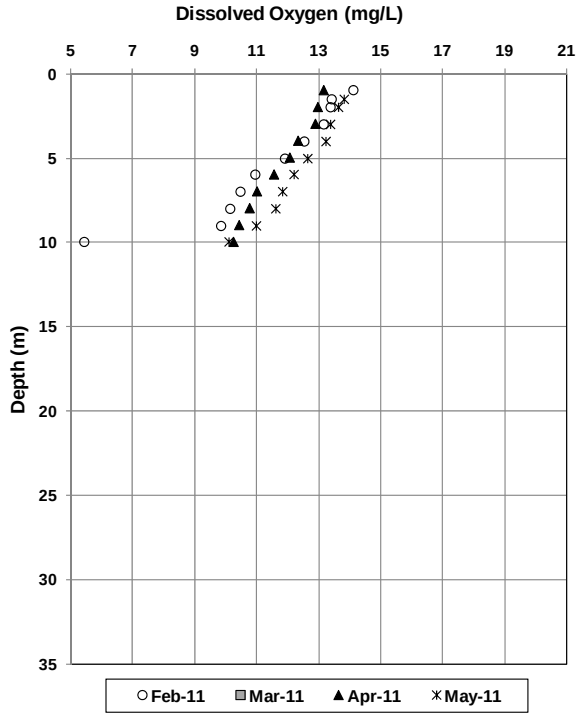


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

i. SNAP07



j. SNAP08

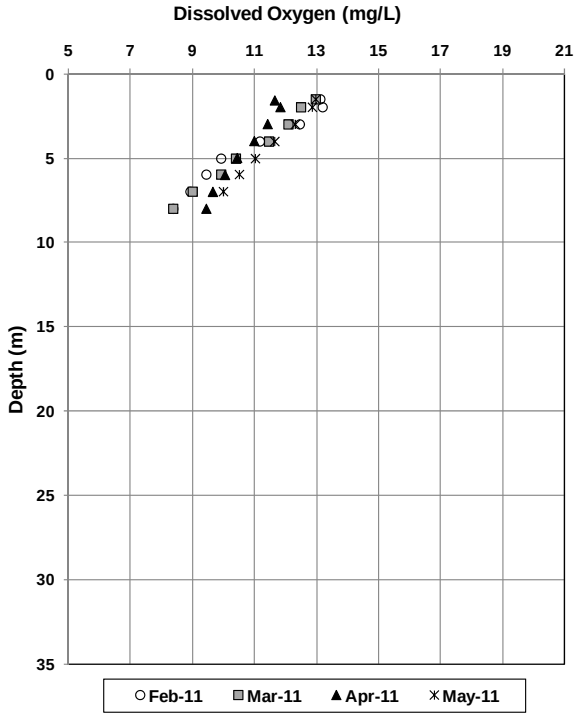
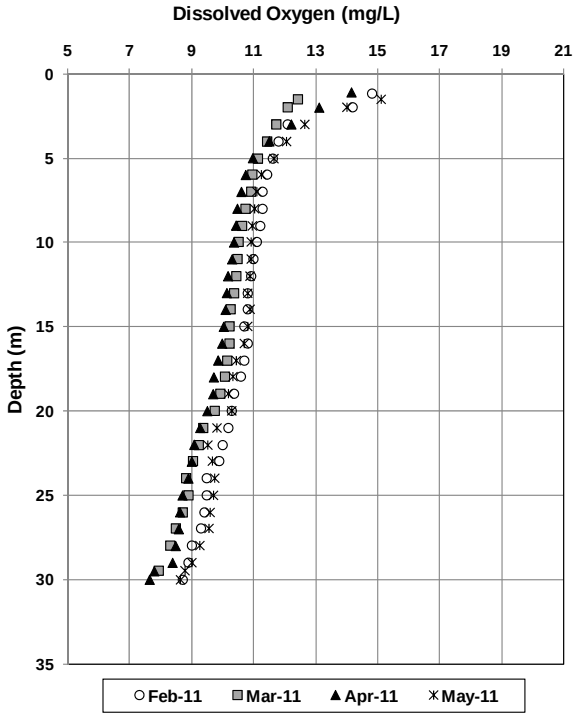


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

k. SNAP20B



l. SNAP02A

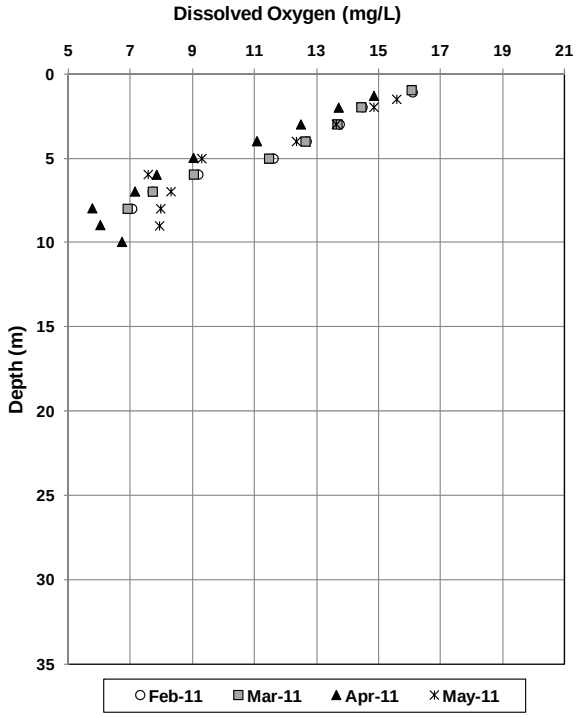
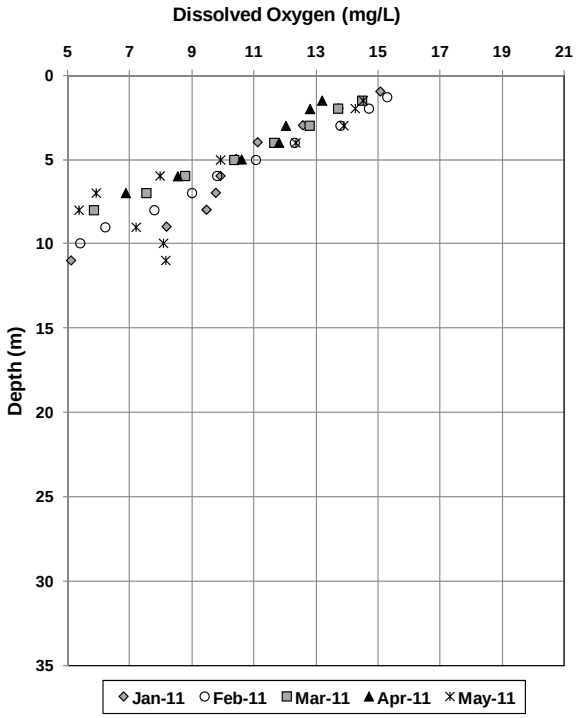


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

m. SNAP23



n. NEL01

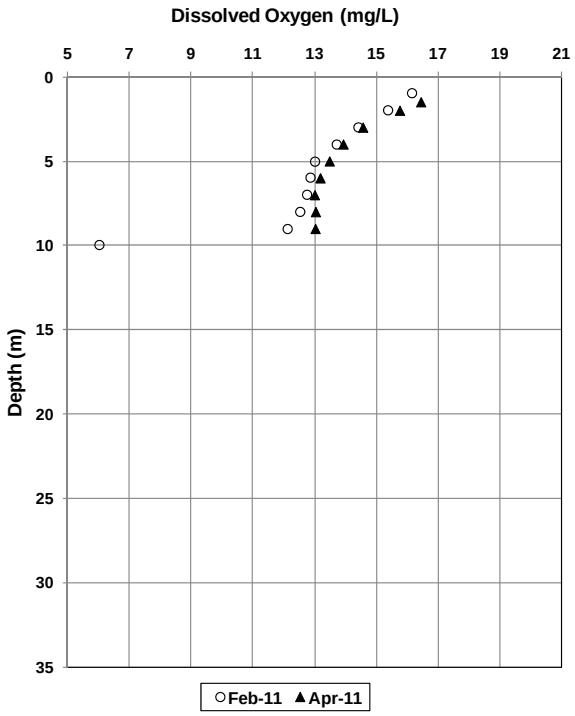
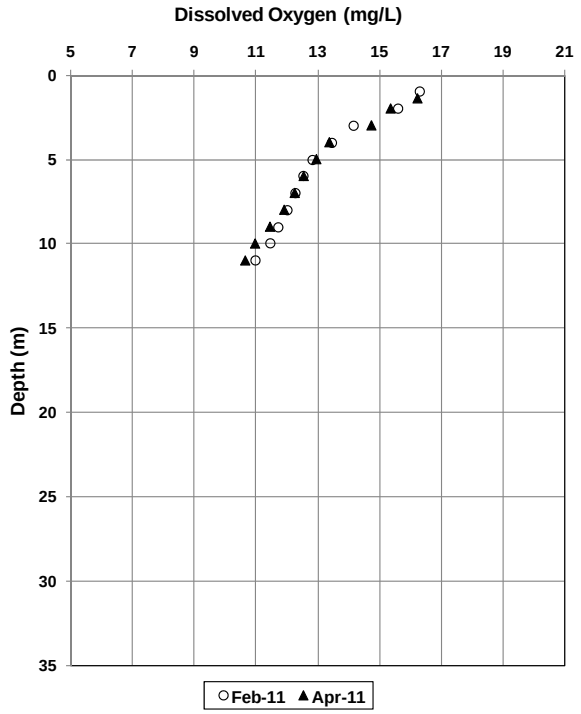


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

o. Northeast Lake (NEL02)



p. Northeast Lake (NEL03)

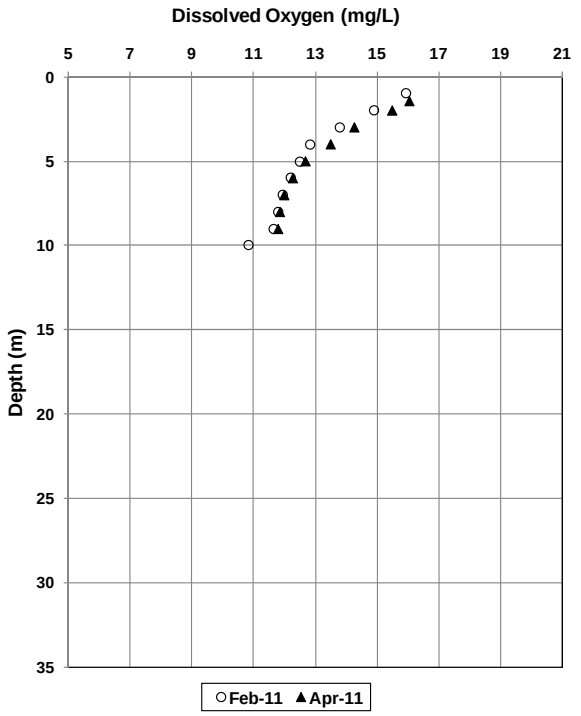
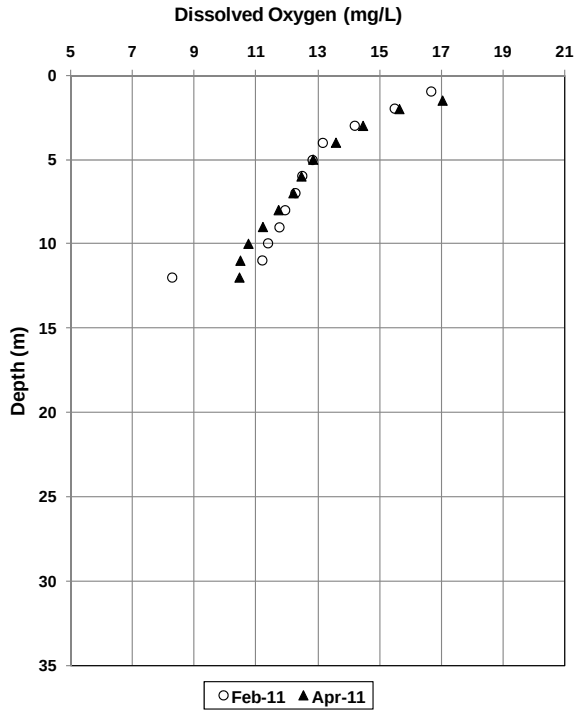
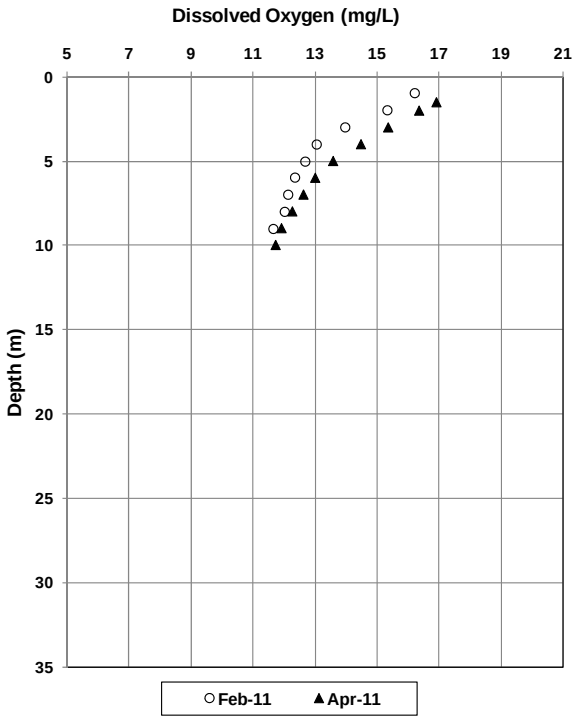


Figure B-16 Dissolved Oxygen Concentrations During Ice-Covered Conditions in Snap Lake and Northeast Lake, 2011 (continued)

q. Northeast Lake (NEL04)



r. Northeast Lake (NEL05)



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

APPENDIX C

Fish Community Supplemental Data

Table C-1 Set Durations and UTM Coordinates for Snap Lake Fish Community Monitoring Sites

Small-Mesh Gillnets					Large-Mesh Gillnets				
Depth Strata (m)	Site Number [(a)]	Set Duration (h)	UTM - Easting	UTM - Northing	Depth Strata (m)	Site Number [(a)]	Set Duration (h)	UTM - Easting	UTM - Northing
1-3	FPM-SL-10S	18	502176.68	7052771.61	1-3	FPM-SL-07L	18	508054.93	7051689.75
	FPM-SL-06S	18	507660.26	7050361.81		FPM-SL-09L	18	505779.77	7053013.06
	FPM-SL-11S	18	510209.36	7051011.85	3-6	FPM-SL-12L	18	510899.72	7053175.44
	FPM-SL-08S	18	509345.73	7053872.04		FPM-SL-15L	18	506629.35	7053414.30
3-6	FPM-SL-18S	18	501275.36	7052487.98		FPM-SL-17L	18	501846.30	7053041.44
	FPM-SL-16S	18	503296.94	7054055.14		FPM-SL-19L	18	508639.28	7050157.63
	FPM-SL-13S	18	509618.02	7053361.86	6-12	FPM-SL-26L	18	500966.66	7052526.02
	FPM-SL-14S	18	507002.20	7051608.27		FPM-SL-24L	18	505475.71	7053342.83
6-12	FPM-SL-25S	18	503576.46	7053203.37		FPM-SL-22L	18	508530.45	7053515.49
	FPM-SL-21S	18	510416.42	7052579.14		FPM-SL-20L	18	508238.26	7051231.07
	FPM-SL-23S	18	507467.93	7053621.74	12-20	FPM-SL-27L	18	509084.59	7052649.59
12-20	FPM-SL-30S	18	500623.69	7052252.06		FPM-SL-28L	18	509892.91	7051437.11
	FPM-SL-31S	18	508296.14	7052324.94		FPM-SL-29L	18	500802.58	7052351.44
					20-35	FPM-SL-03L	18	507187.68	7052642.16
						FPM-SL-04L	18	500491.92	7052389.87
						FPM-SL-05L	18	500636.09	7052485.98
					35-50	FPM-SL-01L	18	500503.93	7052530.03
						FPM-SL-02L	18	500483.91	7052477.97

Note: See Figure 4.7-1 for site locations.

(a) For site numbers, FPM = Fish Population Monitoring; SL = Snap Lake; S = small-mesh gillnet; L = large-mesh gillnet.

UTM = Universal Transverse Mercator; h = hours; m = metre.

Table C-2 Set Durations and UTM Coordinates for Northeast Lake Fish Community Monitoring Sites

Small-Mesh Gillnets					Large-Mesh Gillnets				
Depth Strata (m)	Site Number [(a)]	Set Duration (h)	UTM - Easting	UTM - Northing	Depth Strata (m)	Site Number[(a)]	Set Duration (h)	UTM - Easting	UTM - Northing
1-3	FPM-NEL-04S	18	512092.95	7060444.83	1-3	FPM-NEL-01L	18	507756.31	7057885.10
	FPM-NEL-05S	18	510663.97	7060055.49		FPM-NEL-02L	18	509222.57	7059558.45
	FPM-NEL-06S	18	507930.27	7059235.38		FPM-NEL-03L	18	511889.99	7058999.29
	FPM-NEL-07S	18	508327.90	7058021.78	3-6	FPM-NEL-09L	18	507657.84	7058531.01
	FPM-NEL-08S	18	509591.20	7058328.29		FPM-NEL-10L	18	509412.42	7057996.08
3-6	FPM-NEL-14S	18	509685.24	7059638.33		FPM-NEL-11L	18	509524.76	7058514.97
	FPM-NEL-15S	18	510402.05	7060344.44		FPM-NEL-12L	18	512252.91	7060044.87
	FPM-NEL-16S	18	510803.24	7058365.19		FPM-NEL-13L	18	510225.52	7059959.29
	FPM-NEL-17S	18	509043.32	7058006.78	6-12	FPM-NEL-19L	18	509768.21	7058255.69
	FPM-NEL-18S	18	508663.51	7059456.45		FPM-NEL-20L	18	508699.03	7058199.02
6-12	FPM-NEL-24S	18	510134.68	7058557.93		FPM-NEL-21L	18	508415.67	7059154.86
	FPM-NEL-25S	18	510735.39	7059657.34		FPM-NEL-22L	18	511366.32	7058667.50
	FPM-NEL-26S	18	508083.21	7058969.74		FPM-NEL-23L	18	512129.48	7060057.81
	FPM-NEL-27S	18	510508.71	7058372.81	12-20	FPM-NEL-28L	18	509466.09	7059299.18
12-20	FPM-NEL-32S	18	511907.72	7060026.48		FPM-NEL-29L	18	509290.75	7058526.43
	FPM-NEL-33S	18	511050.55	7058831.64		FPM-NEL-30L	18	510732.36	7059039.43
	FPM-NEL-34S	18	509810.25	7059481.01		FPM-NEL-31L	18	511732.39	7059721.27
					35-50	FPM-NEL-35L	18	510031.04	7059448.54
						FPM-NEL-36L	18	510225.85	7059377.11
						FPM-NEL-37L	18	510738.85	7058786.18
						FPM-NEL-38L	18	510862.23	7058890.08

Note: See Figure 4.7-2 for site locations.

(a) For site numbers, FPM = Fish Population Monitoring; NEL = Northeast Lake; S = small-mesh gillnet; L = large-mesh gillnet.

UTM = Universal Transverse Mercator; h = hours; m = metre.

Table C-3 Set Durations and UTM Coordinates for Lake 13 Fish Community Monitoring Sites

Small-Mesh Gillnets					Large-Mesh Gillnets				
Depth Strata (m)	Site Number	Set Duration (h)	UTM - Easting	UTM - Northing	Depth Strata (m)	Site Number	Set Duration (h)	UTM - Easting	UTM - Northing
1-3	FPM-L13-3S	18	487254.7877	7062647.5258	1-3	FPM-L13-1L	18	488434.8734	7063127.2850
	FPM-L13-4S	18	489178.4323	7062798.1066		FPM-L13-2L	18	493433.4711	7060349.1883
	FPM-L13-5S	18	492329.6854	7062501.5784	3-6	FPM-L13-7L	18	489100.1612	7062564.5394
	FPM-L13-6S	18	492485.1304	7060183.0942		FPM-L13-8L	18	488970.5184	7062809.8986
3-6	FPM-L13-11S	18	487256.2228	7064111.3080		FPM-L13-9L	18	489278.8763	7062039.3019
	FPM-L13-12S	18	488408.1965	7062815.0871		FPM-L13-10L	18	492894.3192	7061885.9700
	FPM-L13-13S	18	485567.2781	7062578.7144	6-12	FPM-L13-15L	18	487357.8184	7063037.9934
	FPM-L13-14S	18	491097.5757	7062883.1294		FPM-L13-16L	18	492589.9304	7062126.8240
6-12	FPM-L13-19S	18	486563.3255	7063182.8965		FPM-L13-17L	18	487281.8287	7063357.6250
	FPM-L13-20S	18	490716.9386	7062109.8594		FPM-L13-18L	18	489666.7830	7062043.4083
	FPM-L13-21S	18	493305.3839	7061656.9371	12-20	FPM-L13-22L	18	491434.9400	7061434.1434
12-20	FPM-L13-25S	18	487022.8359	7063576.1331		FPM-L13-23L	18	490357.0675	7062194.0954
	FPM-L13-26S	18	492871.3496	7061427.1379		FPM-L13-24L	18	492796.5360	7061633.0633
					20-35	FPM-L13-27L	18	492434.8061	7061962.5177
						FPM-L13-28L	18	492202.8064	7061114.3326
						FPM-L13-29L	18	492663.5128	7060666.1294

Note: See Figure 4.7-3 for site locations.

(a) For site numbers, FPM = Fish Population Monitoring; L13 = Lake 13; S = small-mesh gillnet; L = large-mesh gillnet.

UTM = Universal Transverse Mercator; h = hours; m = metre.

Table C-4 Summary of Large and Small-Mesh Gillnet Construction

A: Large-Mesh Gillnet								
Stretch measure (in)	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
Stretch measure (mm)	38	51	64	76	89	102	114	127
Mono diameter (mm)	0.28	0.28	0.28	0.33	0.33	0.33	0.40	0.40
Series order	5	3	7	1	4	8	2	6
Panel length (m)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Panel length (ft)	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Panel height (m)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Panel height (ft)	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Mono colour	clear							
Float line	braided 13 mm (1/2 in)							
Lead line	no. 27 (27 lbs/300 ft)							
Mesh labels	yes (mm)							

B: Small-Mesh Gillnet					
Stretch measure (in)	0.50	0.75	1.00	1.25	1.50
Stretch measure (mm)	13	19	25	32	38
Mono diameter (mm)	0.10	0.13	0.13	0.15	0.15
Series order	4	2	5	1	3
Panel length (m)	2.5	2.5	2.5	2.5	2.5
Panel length (ft)	8.2	8.2	8.2	8.2	8.2
Panel height (m)	1.8	1.8	1.8	1.8	1.8
Panel height (ft)	5.9	5.9	5.9	5.9	5.9
Mono colour	clear				
Float line	braided 10 mm (3/8 in)				
Lead line	no. 30 (15 lbs/300 ft)				
Mesh labels	yes (mm)				

in = inches; ft = feet; m = metre; lbs = pounds, mm = millimeter.

APPENDIX D

Fish Preparation and Observation Protocol

FISH PREPARATION & OBSERVATION PROTOCOL

Preparation

The whole fish will be reviewed and assessed for health. This would include taking a photograph, checking the internal organs and general observations when the fish are being prepared for cooking.

1) Preparation of the fish will be only by boiling. Each individual fish will be boiled separately in water that has not been used for the preparation of any prior fish.

2) No cooking medium (oil, butter margarine) spices, seasoning, salt, pepper, etc. will be applied to the fish.

Fish Health Observation

1) Fish appears to be above average in health (“very good”).

2) Fish appears to be of average health (“good”).

3) Fish is below average health (“not good”).

Texture Observation

1) Texture is firm; fish is above average quality (“very good”).

2) Texture is of average firmness; fish is average quality (“good”).

3) Texture is below average firmness; fish is below average quality (“not good”).

Fish Taste Observation

1) Fish taste appears to be above average (“very good”).

2) Fish taste appears to be average (“good”).

3) Fish taste is below average (“not good”).