DE BEERS GROUP

June 3, 2019

Angela Love
Regulatory Officer
Mackenzie Valley Land and Water Board
7th Floor, 4922 48th St.
PO Box 2130, Yellowknife, NT
Canada | X1A 2P6

Dear Ms. Love:

Re: Water License (MV2019L2-0004) Application and Final Closure and Reclamation Plan

On 29 March 2019, De Beers Canada Inc. (De Beers) submitted for review the Final Closure and Reclamation Plan (FCRP) and an application for a renewed Type A Water Licence (Type A) to support the closure and post-closure phases of the Snap Lake Mine (the Mine). On 12 April 2019, the Mackenzie Valley Land and Water Board (MVLWB) invited reviewers to submit comments on the application. On 29 April 2019, De Beers submitted an application for an amendment to Land Use Permit MV2017D032. This package was added to review of the FCRP and Type A renewal. On 17 May 2019, 462 comments and recommendations were received on the combined application of the FCRP, Type A renewal, and Land Use Permit amendment.

On 30 May 2019, De Beers submitted a letter with responses to two recommendations specific to screening of selected activities included in the FCRP and Type A renewal application. De Beers is pleased to provide response to the remaining recommendations. In addition to responses uploaded to the online review system, De Beers is also submitting the following attachments:

- Attachment 1 - Table of Water Quality Detection Limits
    - Response to GNWT-ENR ID 72
- Attachment 2 – Chloride AEMP Benchmark Derivation Method
    - Response to GNWT-ENR ID 97
- Attachment 3 – Precipitation Sensitivities
    - Response to ECCC ID 2, GNWT ID 139, MVLWB ID 45

- Attachment 4 – Schematic Linking Water Models
  - Response to MVLWB ID 43
- Attachment 5 – Updated Figure North Pile Sumps
  - Response to MVLWB ID 57
- Attachment 6 – Updated Figure Mixing Zones
  - Response to MVLWB ID 59
- Attachment 7 – Table of Earthwork Quantities
  - Response to GNWT-ENR ID 129

Items that are currently being worked and that will be submitted prior to the technical sessions include:

- Updated Predictions for Mixing Zone
  - Response to ECCC ID 3 and GNWT-ENR ID 79
- An updated version of Table 5.2 from the FCRP
  - Response to multiple recommendations

We trust this information will meet the needs, but should you require further information or have any questions or concerns, please feel free to contact me by phone at (403)-464-2596 or by email at colleen.prather@debeersgroup.com.

Sincerely,

Colleen Prather, Ph.D., P.Biol.
Regulatory Specialist

Cc: Sarah McLean
Michelle Peters
Sean Whitaker

Encl:
Attachment 1 - Table of Water Quality Detection Limits
Attachment 2 – Chloride AEMP Benchmark Derivation Method

Attachment 3 – Precipitation Sensitivities
Attachment 4 – Schematic Linking Water Models
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Attachment 1 - Table of Water Quality Detection Limits

- Response to GNWT-ENR ID 72

Table 1 - Snap Lake AEMP Water Quality Detection Limits

Parameter	Unit	Detection Limit[a]
Conventional Parameters		
Laboratory pH	-	0.1
Laboratory conductivity	µS/cm	2
Total dissolved solids, calculated	mg/L	1.3
Total dissolved solids, measured	mg/L	10
Total suspended solids	mg/L	3
Turbidity	NTU	0.1
Major Ions		
Bicarbonate, as HCO_3	mg/L	5
Calcium	mg/L	0.02
Carbonate, as CO_3	mg/L	5
Chloride	mg/L	0.5
Fluoride	mg/L	0.02
Hydroxide, as OH	mg/L	5
Magnesium	mg/L	0.005
Potassium	mg/L	0.05
Reactive silica, as SiO_2	mg/L	0.01
Sodium	mg/L	0.05
Sulphate	mg/L	0.05
Total alkalinity, as $CaCO_3$	mg/L	2
Nutrients		
Dissolved organic carbon	mg/L	1
Nitrate, as N	mg-N/L	0.005
Nitrate/Nitrite, as N, calculated	mg-N/L	0.0051
Nitrite, as N	mg-N/L	0.001
ortho-Phosphate, as P	mg-P/L	0.001
Total ammonia, as N	mg-N/L	0.005
Total dissolved phosphorus	mg-P/L	0.001
Total Kjeldahl nitrogen	mg-N/L	0.05
Total nitrogen, measured	mg-N/L	0.03
Total nitrogen, calculated	mg-N/L	0.05
Total phosphorus	mg-P/L	0.001
Total Metals and Metalloids		
Aluminum	µg/L	1
Antimony	µg/L	0.02
Arsenic	µg/L	0.02
Barium	µg/L	0.02
Beryllium	µg/L	0.005
Bismuth	µg/L	0.005
Boron	µg/L	10
Cadmium	µg/L	0.005
Cesium	µg/L	0.005
Chromium	µg/L	0.1
Hexavalent chromium	µg/L	0.5
Cobalt	µg/L	0.005
Copper	µg/L	0.05
Iron	µg/L	1
Lead	µg/L	0.01
Lithium	µg/L	0.5
Manganese	µg/L	0.05
Mercury (ultra-low)	µg/L	0.0005

Table 1 - Snap Lake AEMP Water Quality Detection Limits

Parameter	Unit	Detection Limit[(a)]
Mercury	µg/L	0.02
Molybdenum	µg/L	0.05
Nickel	µg/L	0.05
Rubidium	µg/L	0.005
Selenium	µg/L	0.04
Silver	µg/L	0.005
Strontium	µg/L	0.02
Thallium	µg/L	0.005
Titanium	µg/L	0.05
Uranium	µg/L	0.001
Vanadium	µg/L	0.05
Zinc	µg/L	0.5
Other		
BOD (5-day)	mg/L	2
E. coli	MPN/100mL	1

a) These represent target detection limits. Occasionally, the laboratory may raise the detection limits for a parameter in a specific sample due to the sample matrix (e.g., high suspended solids). Detection limits are subject to change over time based on improvements or changes in analytical procedures.

BOD = biochemical oxygen demand; BTEX = benzene, toluene, ethylbenzene, and xylene; $CaCO_3$ = calcium carbonate; CO_3 = carbonate; *E. coli* = *Escherichia coli*; F1 (C_6-C_{10}) = hydrocarbon fraction 1 encompasses the range of equivalent carbon number from C_6 to C_{10}; F2 (>C_{10}-C_{16}) = hydrocarbon fraction 2 encompasses the range of equivalent carbon number from >C_{10} to C_{16}; HCO_3 = bicarbonate; mg/L = milligrams per litre; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; MPN/100 mL = most probable number per 100 millilitres; N = nitrogen; NTU = nephelometric turbidity units; OH = hydroxide; P = phosphorus; SiO_2 = silica; µg/L = micrograms per litre; µS/cm = microSiemens per centimetre; - = no unit.

Attachment 2 – Chloride AEMP Benchmark Derivation Method

- Response to GNWT-ENR ID 97

TECHNICAL MEMORANDUM

DATE 24-May-2019 **Project No.** 18105918/DCN-011

TO Colleen Prather
De Beers Group

CC Tamara Darwish, Tasha Hall (Golder); Sean Whitaker (De Beers)

FROM Breda Muldoon and Gary Lawrence **EMAIL** breda_muldoon@golder.com; gary_lawrence@golder.com

INFORMATION REQUEST: CHLORIDE AEMP BENCHMARK DERIVATION METHOD

1.0 INTRODUCTION

This technical memo was prepared in response to information request (IR) #97 from the Government of Northwest Territories (GNWT), to provide additional detail on the methodology underlying the chloride AEMP benchmark provided in the *Effluent Quality Criteria Report for Closure and Post Closure* (Golder 2019), which was submitted as part of De Beers Water Licence Renewal Application. In the IR, GNWT requested:

- The specific CCME (2007) method used (Section 2.0).
- The dataset used to estimate the species sensitivity distribution (SSD)-based site-specific water quality objective (SSWQO) (Section 3.1).
- The rationale for inclusion or exclusion of specific studies used to populate the SSD (Section 3.1).
- The standardization method used to adjust SSD data prior to modelling (Section 3.1).
- The choice of SSD model and model diagnostics (Section 3.2).
- The datasets used to estimate hardness dependencies (Section 3.3).
- The hardness-toxicity test endpoint regression models and diagnostics (Section 3.3).

As detailed below, Elphick et al. (2011) has been used to derive SSWQOs at other northern Canadian mine sites (i.e., Con Mine, Ekati Mine; ERM 2015, 2016; Golder 2018), and was therefore reviewed to determine whether it would be considered suitable for deriving the proposed AEMP benchmark for chloride for Snap Lake). During this review, a datum for sensitive mayfly species reported by Streuwing et al. (2015) was identified and added to the Elphick et al. (2011) SSD dataset because this is a sensitive species that was not previously accounted for under the SSD. A discussion detailing the information requested in the IR is provided in the subsequent Sections.

2.0 AEMP BENCHMARK METHODOLOGY

The method used to derive the long-term chloride AEMP benchmark for Snap Lake followed a derivation procedure applied for Con Mine as detailed in Golder (2018). This method was based on federal guidance for water quality guideline derivation from CCME (2007), and incorporated an adjusted hardness-dependent equation derived by Elphick et al. (2011). The latter incorporated recent data for a chloride-sensitive mayfly species (*Centroptilum triangulifer*) reported by Streuwing et al. (2015).

A species sensitivity distribution (SSD) approach was applied to derive the benchmark following CCME (2007) guidance, as follows. Statistical endpoint selections for the chloride benchmark were reviewed according to the CCME (2007) preference ranking for selecting endpoints for a Type A guideline. Effects levels of 10 percent (%) (i.e., EC_{10}) or less were preferentially selected unless a more appropriate no effects threshold was available; the determination of whether a 10% adverse response is the most appropriate effect size depends on considerations of statistical power, test reliability, and acceptable control response for a valid test. If multiple endpoints were available for the same species, then the species mean chronic value (i.e., geometric mean; SMCV) was calculated but only in cases where the exposure duration, endpoint type, and test conditions were broadly comparable. The SSD derivation entails the use of the Hazen plotting position method (CCME 2007), in which SMCV are ranked from lowest to highest and the percent of species affected is calculated using the following equation:

$$\text{Percent Affected} = (x - 0.5) / n$$

Where x is the species rank, with 1 being the most sensitive species, and n is the total number of species in the database. The Hazen plotting position method has been consistently applied in Canadian Council of Ministers of the Environment (CCME) criteria derivation documents, and has the advantage of compatibility with the goodness-of-fit measures such as the Anderson-Darling statistic (Aldenberg et al. 2001).

Species mean chronic values are used to develop an SSD using Environment and Climate Change Canada's (ECCC) SSD Master software (Intrinsik 2013). Four candidate models are fit to the data (normal, logistic, extreme value, and Gumbel). Model fit is assessed using statistical (e.g., Anderson-Darling goodness-of-fit test, mean square error) and graphical techniques (e.g., quantile to quantile plots, probability to probability plots, residual plots). The benchmark is then selected as "the intercept of the 5^{th} percentile of the y-axis with the fitted SSD curve" (i.e., HC_5; the concentration that is protective of 95% of species) for the best model (CCME 2007).

Once the benchmark (i.e., HC_5 value) is derived, the CCME (2007) recommends comparing the value against the toxicity dataset (i.e., used to derive the benchmark) to check that the derived HC_5 value is adequately protective of aquatic life. This check was performed and the benchmark was considered adequately protective as per CCME (2007) guidance.

3.0 AEMP BENCHMARK DERIVIATION AND RESULTS

3.1 Data Review

The dataset used by Elphick et al. (2011) was evaluated to determine if it was acceptable for use in receiving waters of the Snap Lake Mine. The Elphick et al. (2011) approach has been used to derive SSWQOs at other northern Canadian mine sites (i.e., Con Mine, Ekati Mine) and was therefore considered suitable for use in deriving the chloride SSWQO for Snap Lake (ERM 2015, 2016; Golder 2018). The species selected for inclusion in the SSD are considered appropriate surrogate species for biota in receiving waters at northern mine sites. A datum for sensitive mayfly species reported by Streuwing et al. (2015) was added to the Elphick et al. (2011) SSD dataset. As detailed in Golder (2018), the Streuwing et al. (2015) mayfly datum met criteria for inclusion in the SSD as outlined by Elphick et al. (2011) and the study was reviewed as per CCME (2007) guidance and deemed to be of acceptable quality. The mayfly were the most sensitive species included in the dataset.

As per CCME (2007) guidance, accounting for the influence of exposure and toxicity modifying factors (e.g., hardness) is explicitly allowed in derivation of an SSWQO. Because chloride toxicity is dependent on hardness, data collected under hardness conditions ranging between 80 to 100 mg/L (as $CaCO_3$) were preferentially included in the SSD, as detailed by Elphick et al. (2011). Additionally, as discussed by Elphick et al. (2011) select studies included in the U.S. EPA water quality criteria were not included in the SSD because data were not published, available or were reported in terms of chloride tolerance instead of response relative to control. Data for 16 species were retained for use in the SSD: two fish species (one salmon and one non-salmonid), nine invertebrate species (including planktonic crustacean), two algal species, one aquatic plant species, one diatom and one aquatic insect (mayfly; based on CCME 2007 recommendation for the inclusion of a stonefly, mayfly or caddisfly species). A normalization method was not applied directly to data incorporated in the SSD; rather, the results from the SSD were hardness-normalized (as described in Section 3.3).

3.2 Species Sensitivity Distribution Model

The chronic toxicity data in Table 1 were used to develop an SSD as described in Section 2.0. As detailed in Golder (2018) four models were fit to the data. The normal model was selected over the other models after review of Anderson-Darling goodness-of-fit results ($A^2 = 0.154$) and mean squared error of the lower tail (0.0129), relative to the other models. Results for all models and the SSD curves are presented in Golder (2018).

Based on the normal model, an HC_5 of 209 mg/L chloride was calculated. The CCME (2007) protection clause was not invoked. The SMCV for mayfly (14-d IC_{25} = 138 mg/L) fell below the HC_5 but this species is not considered a species at risk and mayflies do not require protection at the level of species (Golder 2018).

3.3 Hardness Normalization Procedure

Following derivation of the HC_5 value, a hardness-dependent equation was derived following the method reported by Elphick et al. (2011) and detailed in Golder (2018). Elphick et al. (2011) exposed the water flea *Ceriodaphnia dubia* for 7 days to chloride under a range of hardness conditions (10 to 320 mg/L as $CaCO_3$) and evaluated effects on survival and reproduction. Elphick et al. (2011) reported a reduction in chloride toxicity to *C. dubia* between hardness of 10 to 160 mg/L (there was not a marked additional reduction in chloride toxicity at further increases in hardness, between 160 and 360 mg/L). Lasier and Harden (2011) have observed a similar relationship between chloride toxicity and hardness in *C. dubia*. The relationship between chloride toxicity and hardness in *C. dubia* was then used to derive the following hardness-dependent SSWQO equation as detailed by Elphick et al. (2011):

$$WQO_{(hardness\ x)} = [WQO_{(hardness\ 80)} / IC25_{(hardness\ 80)}] \times ([161 \times \ln_{(hardness)}] - 281.73)$$

Where:

- $WQO_{(hardness\ x)}$ = the water quality objective derived for a hardness between 10 to 160 mg/L (as $CaCO_3$)
- $WQO_{(hardness\ 80)}$ = HC_5 value derived from the SSD developed from moderately hard test waters (80 to 100 mg/L as $CaCO_3$)

- $IC_{25(hardness\ 80)}$ = the concentration that resulted in 25% reduction in *C. dubia* reproduction at a hardness of 80 mg/L (as $CaCO_3$).

This equation is applicable between a hardness of 10 to 160 mg/L (as $CaCO_3$).

3.4 AEMP Benchmark

Using the HC_5 of 209 mg/L chloride and the equation presented in Section 3.2 the following equation was derived:

$$WQO_{(hardness\ x)} = [79.02 \times \ln_{(hardness\ x)}] - 138.28$$

Using this equation, as detailed in the *Effluent Quality Criteria Report for Closure and Post Closure* (Golder 2019), the hardness-dependent chloride benchmark for Snap Lake was calculated with predicted hardness concentrations as follows:

- at the existing mixing zone boundary in the main basin of Snap Lake (at SNP 02-20e and SNP 02-20f), where hardness predictions ranged from 88 mg/L to 189 mg/L (as $CaCO_3$) during closure (June 2020 to April 2026);
- at the proposed mixing zone boundary in the main basin of Snap Lake (at SNP 02-20h and SNP 02-20i), where hardness predictions ranged from 25 mg/L to 114 mg/L (as $CaCO_3$) during post-closure (May 2026 to December 2049); and,
- At the proposed mixing zone boundary in the northwest arm of Snap Lake (at SNP 02-20j and SNP 02-20k), where hardness predictions ranged from 29 to 101 mg/L (as $CaCO_3$) during post-closure (May 2026 to December 2049).

In these calculations, hardness was capped to the upper validated range for the equation of 160 mg/L. Applying this equation under the specified hardness conditions, the resulting benchmark is 216 to 263 mg/L at SNP 02-20e and SNP 02-20f, 120[1] to 236 mg/L at SNP 02-20h and SNP 02-20i and 127 to 227 mg/L at SNP 02-20j and SNP 02-20k.

Inclusion of the mayfly datum in the SSD-approach detailed herein resulted in a more conservative hardness-dependent equation than developed by Elphick et al. (2011), and results in an AEMP benchmark that is more stringent than the inferred value (i.e., 450 mg/L) calculated as the proportion of chloride in TDS and based on the Snap Lake SSWQO for TDS that was previously used. As discussed in Golder (2018), hardness above 160 mg/L may ameliorate chloride toxicity but currently there is insufficient data to extrapolate beyond this range.

[1] In cases where hardness was less than or equal to 27 mg/L the CCME WQG of 120 mg/L was used. The CCME guideline for aquatic life is intended to be protective under all conditions, therefore the CCME WQG of 120 mg/L (CCME 1999) should be applied when the calculated hardness-dependent SSWQO is lower than the CCME WQG.

Table 1. Chronic Aquatic Toxicity Data for Chloride used in the Species Sensitivity Distribution Models

Test Species	Species Common Name	Endpoint Type	Statistical Endpoint	Threshold Value (mg/L)	SMCV used in SSD	Reference
Centroptilum triangulifer	Mayfly	Weight	14-d IC_{25}	138	138	Streuwing et al. 2015
Daphnia pulex	Cladoceran	Reproduction	21-d IC_{10}[(a)]	368	368	Birge et al. 1985
Daphnia magna	Cladoceran	Reproduction	21-d IC_{25}	421	421	Elphick et al. 2011
Ceriodaphnia dubia	Cladoceran	Reproduction	7-d IC_{25}	454	454	Elphick et al. 2011
Tubifex tubifex	Oligochaete worm	Reproduction	28-d IC_{10}	519	519	Elphick et al. 2011
Pimephales promelas	Fathead minnow	Survival	33-d LC_{10}[(b)]	598	—	Birge et al. 1985
		Biomass	32-d IC_{25}	704	—	Elphick et al. 2011
		Geometric mean	—	649	649	—
Lumbriculus variegatus	Oligochaete worm	Reproduction	28-d IC_{25}	825	825	Elphick et al. 2011
Lemna minor	Duckweed	Growth	96-h MATC	1,172	1,172	Taraldsen et al. 1990
Oncorhynchus mykiss	Rainbow trout	Biomass	56-d IC_{25}	1,174	1,174	Elphick et al. 2011
Nitzschia linearis	Diatom	Growth	5-d EC_{50}	1,482	1,482	Patrick et al. 2011
Brachionus calyciflorus	Rotifer	Reproduction	48-h IC_{10}	1,241	1,241	Elphick et al. 2011
Hyalella azteca	Amphipod	Growth	28-d IC_{25}	1,705	1,705	Elphick et al. 2011
Chironomus dilutus	Midge	Growth	20-d IC_{10}	2,316	2,316	Elphick et al. 2011
Chlamydomonas reinhardtii	Algae	Growth	6-d EC_{50}	3,014	3,014	Reynoso et al. 1982
Stenonema modestum	Mayfly	Survival	14-d MATC	3,074	3,074	Diamond et al. 1992
Chlorella emersonii	Algae	Growth	8-14 d MATC	7,000	7,000	Setter et al. 1982

SMCV = species mean chronic value; MATC = maximum acceptable toxicant concentration (calculated as the geometric mean of the no observed effect concentration and lowest observed effect concentration); LC_X = concentration causing X% mortality in the test population; IC_X/EC_X = inhibitory/effective concentration causing X% reduction in sublethal endpoint in the test population; mg/L = milligram per litre; — = not applicable.

a) Point estimates were calculated by Elphick et al. (2011) using linear interpolation of original data provided in Birge et al. (1985).

b) Point estimates were calculated by Elphick et al. (2011) using multiple estimation of original data provided in Birge et al. (1985).

4.0 CLOSURE

We trust that this memorandum provides sufficient information for your present needs. If you have any questions, please contact the undersigned at 604-296-4000.

Golder Associates Ltd.

ORIGINAL SIGNED

Breda Muldoon
Toxicologist, MSc

ORIGINAL SIGNED

Gary Lawrence
Environmental Scientist, Associate MRM, RPBio

BMM/GSL

5.0 REFERENCES

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Attachment 3 – Precipitation Sensitivities

- Response to ECCC ID 2, GNWT ID 139, MVLWB ID 45

TECHNICAL MEMORANDUM

DATE 30 May 2019

Reference No. 19115886-022-TM-Rev0-7000

TO Sean Whitaker
De Beers Canada Inc.

FROM Alison Snow, Steve Mitchell, Ken De Vos, and Jeffrey Kwok

EMAIL **Alison_Snow@golder.com; Steve_Mitchell@golder.com; Ken_DeVos@golder.com; Jeffrey_Kwok@golder.com**

EFFECTS OF VARYING PRECIPITATION AND NORTH PILE INPUT CONCENTRATIONS ON PREDICTED NORTH PILE SUMP CONCENTRATIONS

1.0 INTRODUCTION

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Mine (Mine) in the Northwest Territories. The Mine is located approximately 220 kilometres (km) northeast of Yellowknife. The existing Type A Water Licence #MV2011L2 0004 for the Mine expires in June 2020 (MVLWB 2016). De Beers submitted a Water Licence renewal application for the Closure and Post-closure periods of the Mine in March 2019. As part of the Water Licence renewal application, De Beers retained Golder Associates Ltd. (Golder) to update predictions of concentrations of total dissolved solids (TDS), nutrients, major ions, and total metals and metalloids in discharges from the Mine site to Snap Lake, given the anticipated conditions at the Mine for the Closure and Post-closure periods.

This technical memorandum provides additional model sensitivity run results to supplement the Snap Lake Mine - Site Water Quality Model Report submitted in March 2019 (Golder 2019a). The objectives of this memorandum are:

- to present how three precipitation scenarios (10th percentile, average, and 90th percentile) affect predicted parameter concentrations in Sump 3 and Sump 5
- to present how three North Pile input concentration scenarios (median, 75th percentile, and 95th percentile) affect predicted parameter concentrations in Sump 3 and Sump 5

2.0 METHODS

A complete description of the overall site water quality model, and input conditions is provided in Golder (2019a). The model scenarios described in this technical memorandum are based on varying the annual precipitation inputs (Section 2.1) and the North Pile input concentrations (Section 2.2).

2.1 Precipitation Scenarios

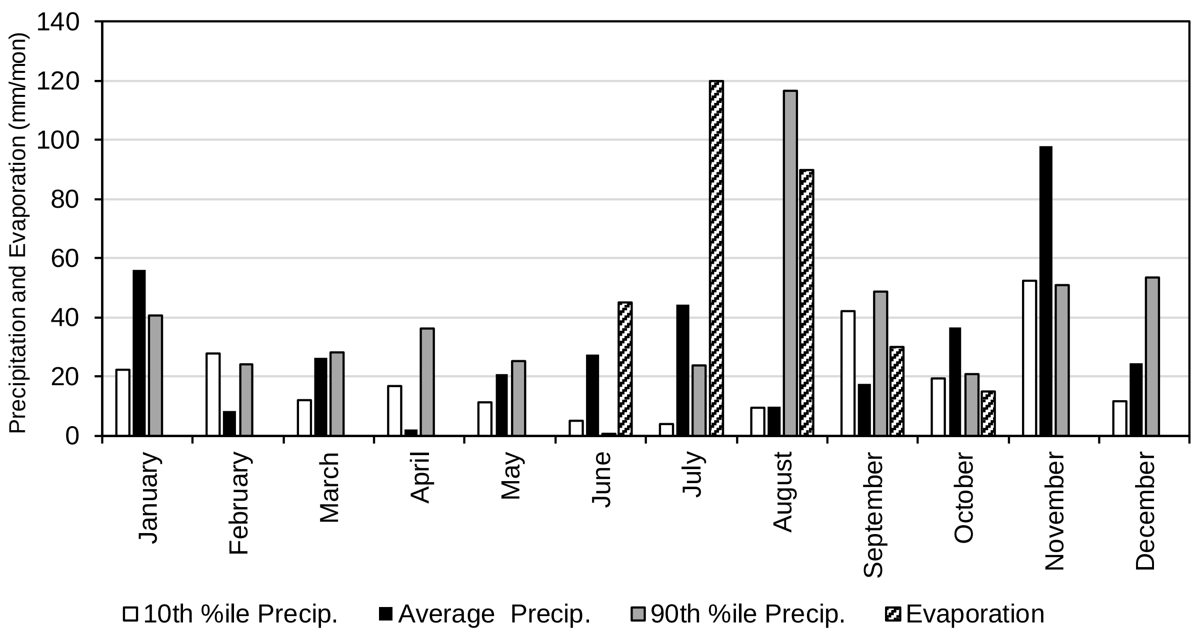
Water quality of the North Pile sumps is influenced by precipitation. Runoff and seepage from the North Pile is collected in the North Pile sumps. The site water quality model results in Golder (2019a) were based on monthly precipitation inputs from an annual average precipitation year, repeated annually from 2018 to 2050. Precipitation data were obtained from the Snap Lake meteorological stations and from Environment Canada Climate Station 2204101 (Yellowknife A) (Government of Canada 2018). To determine how precipitation would affect predicted parameter concentrations in Sump 3 and Sump 5, three precipitation scenarios were modelled as described in this technical memorandum (Table 2-1).

Table 2-1: Annual Precipitation Scenarios for the Snap Lake Site Water Quality Model

Scenario Description	Annual Precipitation Statistic	Precipitation Year	Annual Precipitation (mm)
Dry	10th percentile	1970–1971	235
Average	Average	1995–1996	372
Wet	90th percentile	1964–1965	470

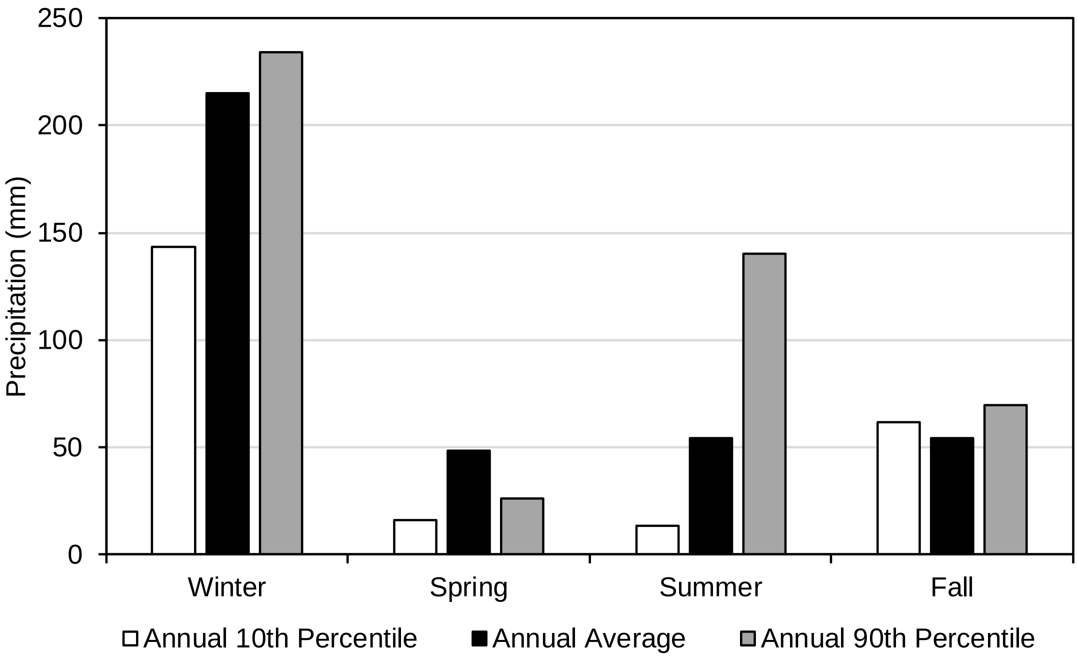
mm = millimetre.

For each scenario, the monthly precipitation rates (Figure 2-1) are repeated each year from 2018 to 2050. The monthly distribution of the total annual precipitation is based on the rainfall and snowfall observed in each month for the dry scenario (i.e., 1970 to 1971), the average scenario (i.e., 1995 to 1996) and the wet scenario (i.e., 1964 to 1965). Therefore, precipitation was not always highest each month in the wet year scenario or lowest in the dry year scenario. For example, spring rainfall was observed to be higher in the average precipitation year than in the dry and wet years (Figure 2-2). Monthly 75th percentile North Pile input concentrations (Section 2.2) were used for all three of the precipitation model sensitivity runs.



mm/mon = millimetres per month; Precip. = precipitation; %ile = percentile.

Figure 2-1: Monthly Distribution of Annual Precipitation for 10th Percentile, Average, and 90th Percentile Precipitation Scenarios



mm = millimetre; Winter = November to April; Spring = May and June; Summer = July and August; Fall = September and October.

Figure 2-2: Seasonal Distribution of Annual Precipitation for 10th Percentile, Average, and 90th Percentile Precipitation Scenarios

2.2 North Pile Input Concentration Scenarios

The site water quality model applies monthly input concentrations to the North Pile runoff and seepage that enters the North Pile sumps. Three North Pile input concentration scenarios were modelled to determine how varying these inputs would affect concentrations in Sump 3 and Sump 5. The three concentration inputs were calculated based on monitoring data from SNP 02-02. The three North Pile input concentration scenarios were:

1) Monthly median SNP 02-02 concentrations (Table 2-2).

2) Monthly 75th percentile SNP 02-02 concentrations (Table 2-3). The site water quality model results in Golder (2019a) were based on monthly 75th percentile SNP 02-02 concentrations.

3) Monthly 95th percentile SNP 02-02 concentrations (Table 2-4).

An average precipitation year input (Table 2-1) was used for all three of the North Pile input concentration scenarios.

Table 2-2: Monthly Median Parameter Concentrations at SNP 02-02, 2012 to 2017

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Conventional Parameters												
Total dissolved solids, calculated (mg/L)	2,650	2,235	2,060	2,400	1,140	522	1,805	1,170	1,020	1,960	1,940	2,000
Major Ions												
Calcium (mg/L)	301	255	228	292	139	61	213	136	122	233	232	238
Chloride (mg/L)	590	497	515	510	221	86	381	173	174	298	262	393
Fluoride (mg/L)	0.8	0.81	0.83	0.56	0.36	0.38	0.53	0.45	0.51	0.58	0.63	0.73
Magnesium (mg/L)	166	145	122	149	66	32	116	71	67	134	133	138
Potassium (mg/L)	38	34	37	34	18	9.7	33	17	17	27	24	31
Sodium (mg/L)	206	179	184	181	87	39	163	70	75	139	133	154
Sulphate (mg/L)	567	468	371	525	203	156	360	374	365	439	518	526
Nutrients												
Nitrate, as N (mg/L)	153	130	119	168	67	55	106	93	78	108	107	103
Nitrite, as N (mg/L)	0.36	0.23	0.31	1.2	0.58	0.5	0.58	0.74	0.55	0.18	0.2	0.38
Total ammonia, as N (mg/L)	9.4	10	14	11	4.4	2.3	6.1	0.26	4.2	1.7	3.1	4.8
Total phosphorus, as P (mg/L)	0.02	0.045	0.009	0.016	0.044	0.044	0.029	0.012	0.025	0.0067	0.0041	0.0076
Dissolved Metals												
Aluminum (mg/L)	0.017	0.01	0.012	0.01	0.065	0.032	0.0079	0.011	0.017	0.024	0.018	0.024
Antimony (mg/L)	0.00063	0.00043	0.0005	0.00025	0.00016	0.00024	0.00062	0.00014	0.00022	0.00021	0.0001	0.00025
Arsenic (mg/L)	0.00025	0.00025	0.00025	0.00025	0.00021	0.00019	0.00021	0.00014	0.00016	0.00014	0.0001	0.00025
Barium (mg/L)	0.085	0.068	0.081	0.068	0.047	0.025	0.074	0.068	0.047	0.069	0.071	0.066
Beryllium (mg/L)	0.000025	0.000025	0.00005	0.00005	0.00005	0.00005	0.000031	0.000031	0.00005	0.00005	0.00005	0.000025
Bismuth (mg/L)	0.00013	0.00013	0.00013	0.00013	0.00005	0.000038	0.00005	0.000075	0.00005	0.000075	0.00013	0.00013
Boron (mg/L)	2.1	1.6	1.5	1.6	0.85	0.57	1.2	0.98	0.75	1.4	1.2	1.2
Cadmium (mg/L)	0.000073	0.000057	0.000048	0.000066	0.000025	0.000029	0.000043	0.000033	0.000045	0.000067	0.000064	0.000056

Table 2-2: Monthly Median Parameter Concentrations at SNP 02-02, 2012 to 2017

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Dissolved Metals (cont'd)												
Cesium (mg/L)	0.0002	0.0002	0.00044	0.00007	0.00022	0.000064	0.00028	0.000083	0.00016	0.00015	0.00022	0.0002
Chromium (mg/L)	0.00025	0.00025	0.00025	0.00025	0.00059	0.00029	0.0001	0.0001	0.0001	0.00005	0.00025	0.00025
Cobalt (mg/L)	0.0054	0.0038	0.0032	0.0044	0.0023	0.0016	0.004	0.0013	0.0036	0.0053	0.0058	0.005
Copper (mg/L)	0.0007	0.002	0.00038	0.00069	0.0013	0.0017	0.00072	0.0013	0.0015	0.0012	0.0005	0.0027
Iron (mg/L)	0.05	0.045	0.025	0.025	0.11	0.021	0.01	0.01	0.01	0.046	0.018	0.044
Lead (mg/L)	0.00013	0.00013	0.00013	0.00013	0.00008	0.000025	0.00016	0.00005	0.00005	0.000025	0.000088	0.00013
Lithium (mg/L)	0.017	0.013	0.027	0.021	0.02	0.0058	0.02	0.011	0.01	0.015	0.013	0.017
Manganese (mg/L)	0.44	0.37	0.34	0.63	0.12	0.11	0.32	0.093	0.2	0.37	0.4	0.42
Mercury (mg/L)	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Molybdenum (mg/L)	0.056	0.045	0.042	0.039	0.032	0.018	0.044	0.023	0.026	0.028	0.024	0.022
Nickel (mg/L)	0.12	0.12	0.084	0.058	0.075	0.022	0.089	0.015	0.035	0.087	0.1	0.11
Rubidium (mg/L)	0.066	0.05	0.065	0.041	0.021	0.012	0.05	0.021	0.023	0.034	0.027	0.029
Selenium (mg/L)	0.0006	0.00055	0.00032	0.00043	0.00019	0.00017	0.0004	0.00024	0.00042	0.00058	0.00054	0.00046
Silver (mg/L)	0.000025	0.000025	0.000025	0.000025	0.00001	0.0000075	0.00001	0.000015	0.00001	0.000015	0.000025	0.000025
Strontium (mg/L)	3.4	2.8	2.8	2.9	1.7	0.64	2.3	1.2	1.1	2.4	2.5	2.8
Thallium (mg/L)	0.00006	0.000075	0.00007	0.000021	0.000031	0.000024	0.000059	0.000031	0.000038	0.000025	0.000036	0.000039
Titanium (mg/L)	0.00075	0.00075	0.00075	0.00075	0.0023	0.00025	0.0003	0.0003	0.0003	0.00015	0.00075	0.00075
Uranium (mg/L)	0.013	0.015	0.01	0.017	0.012	0.0023	0.0081	0.0031	0.0049	0.008	0.0085	0.008
Vanadium (mg/L)	0.0005	0.00075	0.00075	0.0013	0.0005	0.00025	0.0005	0.0005	0.0005	0.00025	0.0013	0.0013
Zinc (mg/L)	0.0025	0.0025	0.0025	0.0032	0.0079	0.0043	0.0045	0.0025	0.0089	0.0025	0.0097	0.0085

mg/L = milligrams per litre; N = nitrogen; P = phosphorus; SNP = Surveillance Network Program.

Table 2-3: Monthly 75th Percentile Parameter Concentrations at SNP 02-02, 2012 to 2017

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Conventional Parameters												
Total dissolved solids, calculated (mg/L)	2,660	2,238	2,185	2,490	1,215	845	1,918	1,180	1,405	1,995	2,080	2,045
Major Ions												
Calcium (mg/L)	307	257	247	298	155	96	217	144	170	251	246	239
Chloride (mg/L)	591	499	518	575	247	212	427	174	206	347	364	427
Fluoride (mg/L)	0.8	0.93	0.94	0.8	0.49	0.75	0.63	0.45	0.54	0.59	0.79	0.83
Magnesium (mg/L)	172	148	133	151	74	55	119	73	90	138	138	139
Potassium (mg/L)	41	34	37	42	20	18	35	20	21	30	31	35
Sodium (mg/L)	220	179	185	208	97	77	182	76	98	156	160	163
Sulphate (mg/L)	582	478	441	586	291	160	378	377	461	535	623	562
Nutrients												
Nitrate, as N (mg/L)	155	133	122	186	70	55	119	108	90	111	116	111
Nitrite, as N (mg/L)	0.41	0.24	0.32	1.7	0.69	0.56	0.58	0.8	0.61	0.21	0.25	0.49
Total ammonia, as N (mg/L)	9.4	12	16	16	8.3	4.3	6.7	3.2	4.4	2.2	3.9	6.6
Total phosphorus, as P (mg/L)	0.066	0.066	0.012	0.036	0.049	0.051	0.04	0.012	0.039	0.011	0.025	0.010
Dissolved Metals												
Aluminum (mg/L)	0.021	0.014	0.014	0.012	0.091	0.045	0.008	0.012	0.02	0.034	0.025	0.027
Antimony (mg/L)	0.00064	0.00052	0.00063	0.00069	0.00037	0.00049	0.00064	0.00023	0.00024	0.00023	0.00018	0.00025
Arsenic (mg/L)	0.00025	0.00025	0.00025	0.00025	0.00023	0.00026	0.00021	0.00018	0.00018	0.0002	0.00018	0.00025
Barium (mg/L)	0.093	0.071	0.083	0.081	0.059	0.05	0.08	0.068	0.055	0.07	0.077	0.07
Beryllium (mg/L)	0.000025	0.000025	0.00005	0.00005	0.00005	0.00005	0.00005	0.000041	0.00005	0.00005	0.00005	0.000025
Bismuth (mg/L)	0.00013	0.00013	0.00013	0.00013	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001	0.00013	0.00013
Boron (mg/L)	2.2	1.6	1.5	1.7	0.85	0.61	1.3	1.2	0.81	1.5	1.5	1.3
Cadmium (mg/L)	0.000073	0.00006	0.000054	0.000081	0.000033	0.000031	0.000044	0.000041	0.000049	0.000068	0.000065	0.000056

Table 2-3: Monthly 75th Percentile Parameter Concentrations at SNP 02-02, 2012 to 2017

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Dissolved Metals (cont'd)												
Cesium (mg/L)	0.00056	0.00022	0.00055	0.00012	0.00029	0.00027	0.00034	0.0002	0.00016	0.00019	0.00028	0.00025
Chromium (mg/L)	0.00025	0.00025	0.00025	0.00025	0.00084	0.00036	0.0001	0.0001	0.0001	0.00015	0.00025	0.00025
Cobalt (mg/L)	0.0059	0.0043	0.0033	0.0045	0.0026	0.0018	0.0047	0.0032	0.0038	0.0053	0.0059	0.0053
Copper (mg/L)	0.0029	0.0029	0.00044	0.00078	0.0016	0.0023	0.00086	0.0026	0.0028	0.0013	0.0005	0.0038
Iron (mg/L)	0.059	0.055	0.025	0.043	0.17	0.03	0.01	0.017	0.01	0.067	0.021	0.054
Lead (mg/L)	0.00013	0.00013	0.00013	0.00013	0.000095	0.000041	0.00022	0.00006	0.00005	0.000075	0.00011	0.00013
Lithium (mg/L)	0.017	0.014	0.032	0.028	0.025	0.017	0.023	0.012	0.011	0.016	0.017	0.017
Manganese (mg/L)	0.44	0.39	0.4	0.69	0.21	0.11	0.36	0.23	0.26	0.4	0.47	0.44
Mercury (mg/L)	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Molybdenum (mg/L)	0.059	0.05	0.042	0.056	0.037	0.036	0.051	0.024	0.028	0.039	0.042	0.022
Nickel (mg/L)	0.16	0.15	0.088	0.094	0.078	0.046	0.099	0.02	0.053	0.11	0.13	0.11
Rubidium (mg/L)	0.071	0.053	0.073	0.061	0.033	0.034	0.056	0.025	0.028	0.039	0.044	0.029
Selenium (mg/L)	0.00062	0.00059	0.00035	0.00048	0.00029	0.00019	0.00042	0.00027	0.00048	0.00061	0.00057	0.00046
Silver (mg/L)	0.000025	0.000025	0.000025	0.000025	0.00001	0.00001	0.00001	0.00002	0.00001	0.00002	0.000025	0.000025
Strontium (mg/L)	3.6	2.9	2.9	3.0	1.8	1.2	2.5	1.3	1.7	2.6	2.9	2.8
Thallium (mg/L)	0.00013	0.0001	0.000093	0.000023	0.000042	0.000059	0.000073	0.000047	0.000039	0.000044	0.000057	0.000046
Titanium (mg/L)	0.00075	0.00075	0.00075	0.00075	0.0033	0.00036	0.0003	0.0003	0.0003	0.00098	0.00075	0.00075
Uranium (mg/L)	0.013	0.016	0.012	0.017	0.015	0.0044	0.0081	0.0032	0.0058	0.0084	0.0092	0.0086
Vanadium (mg/L)	0.0013	0.001	0.001	0.0013	0.0005	0.00044	0.0005	0.0005	0.0005	0.00075	0.0013	0.0013
Zinc (mg/L)	0.007	0.0025	0.0025	0.0036	0.01	0.0048	0.0054	0.0038	0.0097	0.0042	0.0097	0.0088

mg/L = milligrams per litre; N = nitrogen; P = phosphorus; SNP = Surveillance Network Program.

Table 2-4: Monthly 95th Percentile Parameter Concentrations at SNP 02-02, 2012 to 2017

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Conventional Parameters												
Total dissolved solids, calculated (mg/L)	2,692	2,240	2,285	2,562	1,347	961	2,008	1,868	1,713	2,023	2,192	2,081
Major Ions												
Calcium (mg/L)	309	259	262	303	173	109	220	211	208	265	256	239
Chloride (mg/L)	596	501	521	627	286	242	465	420	231	385	446	454
Fluoride (mg/L)	1.0	1.0	1.0	0.98	0.77	0.78	0.71	0.8	0.57	0.6	0.91	0.91
Magnesium (mg/L)	181	150	142	152	87	55	121	111	109	140	142	141
Potassium (mg/L)	44	34	38	48	23	21	38	33	25	33	38	38
Sodium (mg/L)	235	180	185	230	109	91	196	155	116	169	182	170
Sulphate (mg/L)	702	486	497	635	403	161	392	387	537	612	707	590
Nutrients												
Nitrate, as N (mg/L)	158	135	124	200	72	56	130	120	100	114	123	117
Nitrite, as N (mg/L)	0.41	0.24	0.32	2.1	0.79	0.61	0.59	0.84	0.65	0.24	0.28	0.59
Total ammonia, as N (mg/L)	9.8	14	17	20	12	4.8	7.1	6.6	4.5	2.5	4.6	8.1
Total phosphorus, as P (mg/L)	0.083	0.083	0.014	0.052	0.051	0.06	0.048	0.013	0.049	0.014	0.042	0.012
Dissolved Metals												
Aluminum (mg/L)	0.025	0.018	0.015	0.013	0.11	0.053	0.0081	0.015	0.022	0.042	0.031	0.03
Antimony (mg/L)	0.00068	0.00059	0.00073	0.001	0.00054	0.00052	0.00066	0.00025	0.00026	0.00025	0.00024	0.00025
Arsenic (mg/L)	0.00025	0.00025	0.00025	0.00025	0.00025	0.00027	0.00021	0.00024	0.0002	0.00024	0.00024	0.00025
Barium (mg/L)	0.098	0.073	0.084	0.091	0.068	0.053	0.085	0.077	0.062	0.07	0.082	0.072
Beryllium (mg/L)	0.000025	0.000025	0.00005	0.00005	0.00005	0.00005	0.00005	0.000048	0.00005	0.00005	0.00005	0.000025
Bismuth (mg/L)	0.00013	0.00013	0.00013	0.00013	0.00005	0.00005	0.00005	0.00012	0.00005	0.00012	0.00013	0.00013
Boron (mg/L)	2.3	1.6	1.6	1.7	0.85	0.65	1.3	1.4	0.86	1.6	1.7	1.4
Cadmium (mg/L)	0.000088	0.000062	0.000059	0.000092	0.000046	0.000037	0.000045	0.000058	0.000051	0.000068	0.000066	0.000057

Table 2-4: Monthly 95th Percentile Parameter Concentrations at SNP 02-02, 2012 to 2017

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Dissolved Metals (cont'd)												
Cesium (mg/L)	0.00056	0.00024	0.00064	0.00016	0.00033	0.00029	0.00039	0.00029	0.00017	0.00022	0.00032	0.00029
Chromium (mg/L)	0.00025	0.00025	0.00025	0.00025	0.001	0.00043	0.0001	0.00022	0.0001	0.00023	0.00025	0.00025
Cobalt (mg/L)	0.0059	0.0048	0.0033	0.0046	0.0028	0.002	0.0052	0.0035	0.004	0.0054	0.0059	0.0055
Copper (mg/L)	0.0034	0.0036	0.00049	0.00085	0.0018	0.0025	0.00096	0.0056	0.0039	0.0015	0.0005	0.0047
Iron (mg/L)	0.093	0.063	0.025	0.057	0.21	0.037	0.01	0.023	0.01	0.083	0.024	0.061
Lead (mg/L)	0.00013	0.00013	0.00013	0.00013	0.00011	0.00005	0.00026	0.00011	0.00005	0.00012	0.00012	0.00013
Lithium (mg/L)	0.02	0.014	0.036	0.034	0.029	0.019	0.026	0.016	0.012	0.017	0.02	0.017
Manganese (mg/L)	0.46	0.42	0.45	0.75	0.28	0.11	0.39	0.28	0.31	0.42	0.52	0.45
Mercury (mg/L)	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Molybdenum (mg/L)	0.064	0.054	0.042	0.069	0.04	0.037	0.056	0.04	0.03	0.047	0.056	0.022
Nickel (mg/L)	0.17	0.17	0.091	0.12	0.081	0.048	0.11	0.11	0.068	0.13	0.15	0.11
Rubidium (mg/L)	0.074	0.056	0.08	0.078	0.042	0.035	0.061	0.05	0.033	0.044	0.058	0.029
Selenium (mg/L)	0.0007	0.00062	0.00037	0.00052	0.00036	0.0002	0.00043	0.00037	0.00053	0.00063	0.00059	0.00046
Silver (mg/L)	0.000025	0.000025	0.000025	0.000025	0.00001	0.00001	0.00001	0.000024	0.00001	0.000024	0.000025	0.000025
Strontium (mg/L)	3.9	3.0	3.0	3.1	1.8	1.3	2.7	2.4	2.1	2.8	3.3	2.9
Thallium (mg/L)	0.00013	0.00012	0.00011	0.000025	0.00005	0.000065	0.000084	0.000076	0.00004	0.000059	0.000074	0.000052
Titanium (mg/L)	0.0012	0.00075	0.00075	0.00075	0.0041	0.00065	0.0003	0.00066	0.0003	0.0016	0.00075	0.00075
Uranium (mg/L)	0.014	0.017	0.013	0.017	0.017	0.0046	0.0082	0.0065	0.0065	0.0087	0.0098	0.009
Vanadium (mg/L)	0.0013	0.0012	0.0012	0.0013	0.0005	0.0005	0.0005	0.0011	0.0005	0.0012	0.0013	0.0013
Zinc (mg/L)	0.009	0.0025	0.0025	0.0038	0.012	0.0076	0.0061	0.0064	0.01	0.0056	0.0097	0.0091

mg/L = milligrams per litre; N = nitrogen; P = phosphorus; SNP = Surveillance Network Program.

3.0 RESULTS AND DISCUSSION

Predicted parameter concentrations in Sump 3 and Sump 5 for the precipitation scenarios and the North Pile input concentration scenarios are presented in Sections 3.1 and 3.2, respectively.

3.1 Results of the Precipitation Scenarios

During the open-water season, predicted concentrations of TDS, fluoride, nitrate, nitrite, total ammonia, total aluminium, arsenic, chromium, copper, lead, nickel and zinc in Sump 3 and Sump 5 in each of the precipitation scenarios is shown in Figures 3-1 to 3-6.

Extended Care and Maintenance and Closure

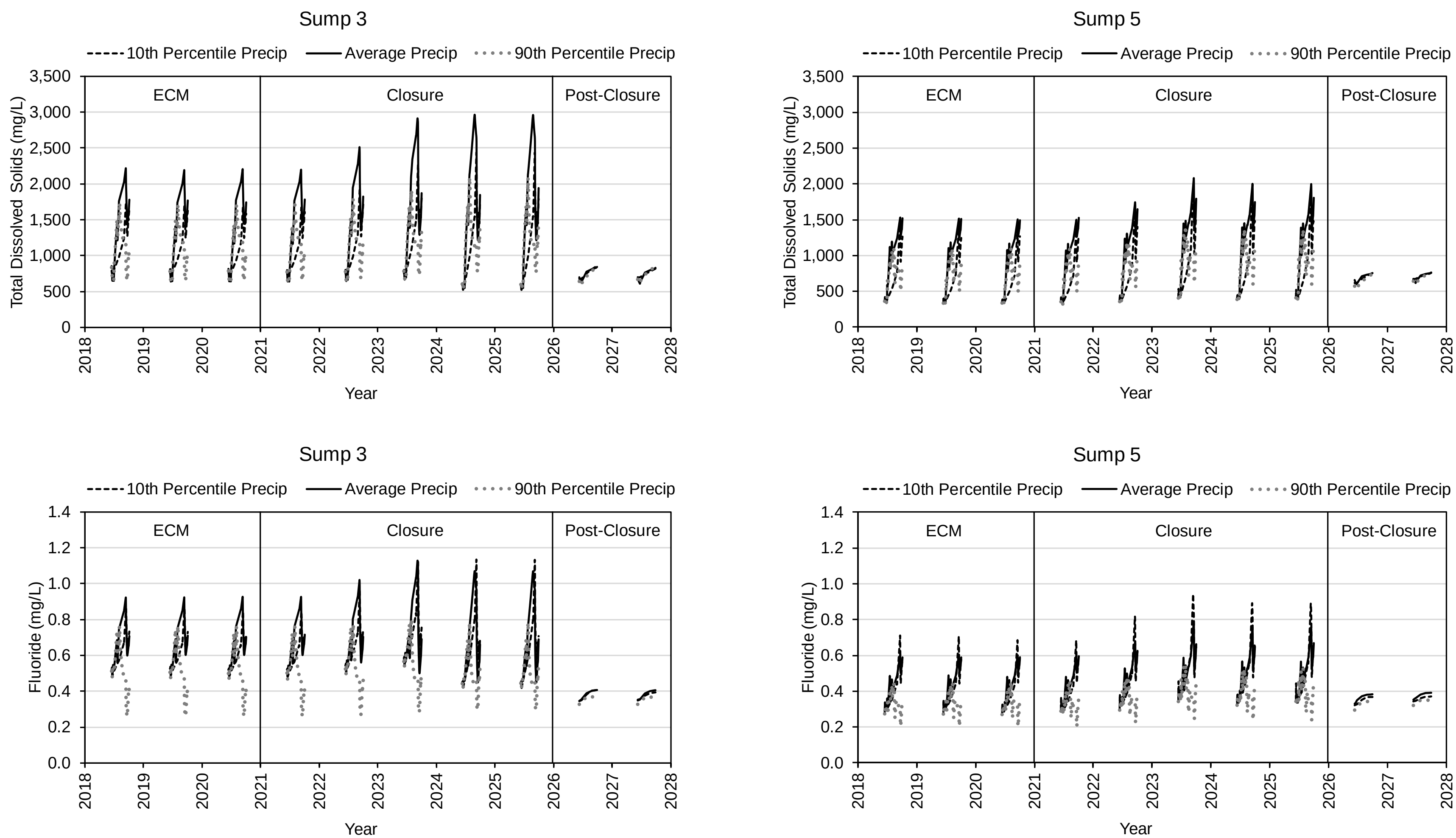
Results for the Extended Care and Maintenance and Closure periods indicate:

- Yearly peaks in parameter concentrations for the dry and average precipitation scenarios occur in September. Total rainfall in August and September is lower in the dry and average scenarios compared to the wet scenario (Figure 2-1). As a result, there is less dilution of parameter concentrations in the sumps by precipitation in the dry and average scenarios compared to the wet scenario.
- Yearly peaks in parameter concentrations for the wet scenario occur in early August. Evapo-concentration of parameters occurs in this scenario until August. In August, higher rainfall rates in the wet scenario cause dilution of parameter concentrations in the sumps (Figure 2-1).
- The wet scenario results in the lowest maximum predicted parameter concentrations in Sump 3 and Sump 5 compared to the dry and average scenarios. This is likely due to the higher precipitation rates during August and September in the wet scenario. Higher precipitation rates mean that there was more dilution of parameter concentrations in the sumps.
- The average precipitation scenario resulted in the highest parameter concentrations in Sump 3 and Sump 5. This is likely due to the low precipitation rates during August and September in the average scenario. Lower precipitation rates mean that there was less dilution of parameter concentrations in the sumps. Since evaporation rates were assumed to be constant in the three precipitation scenarios, evapo-concentration of parameter concentrations in the sumps in August and September would be highest in the average precipitation scenario.

Post-Closure

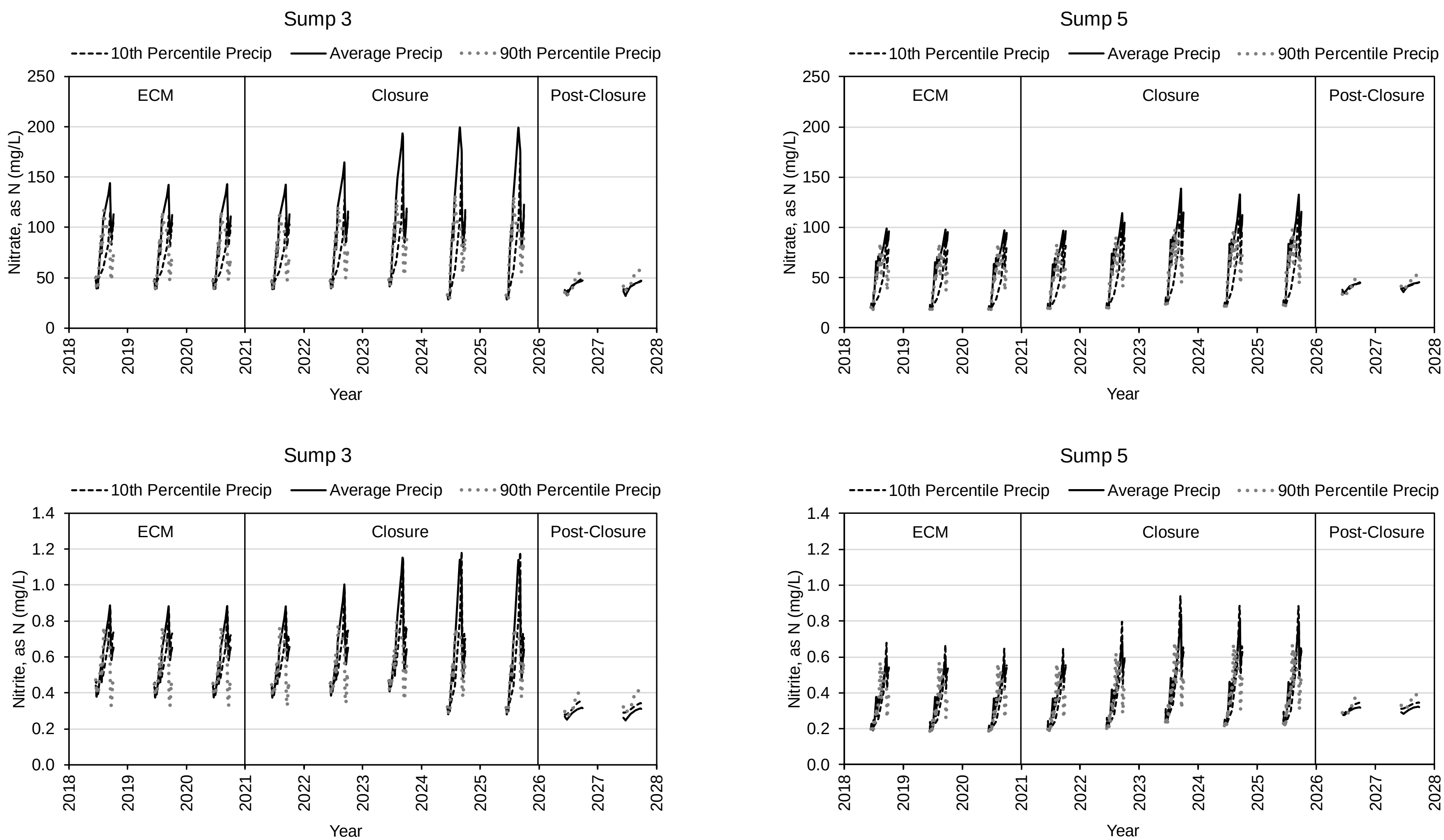
Results for the Post-closure period indicate that:

- Predicted parameter concentrations in the sumps are similar for the three precipitation scenarios during the Post-closure period. This is likely due to the higher volumes of water in Sump 3 and Sump 5 in Post-closure when the sumps are predicted to fill to their maximum volumes (Golder 2019a). The increased volume makes changes to parameter concentrations in the sumps less sensitive to precipitation.



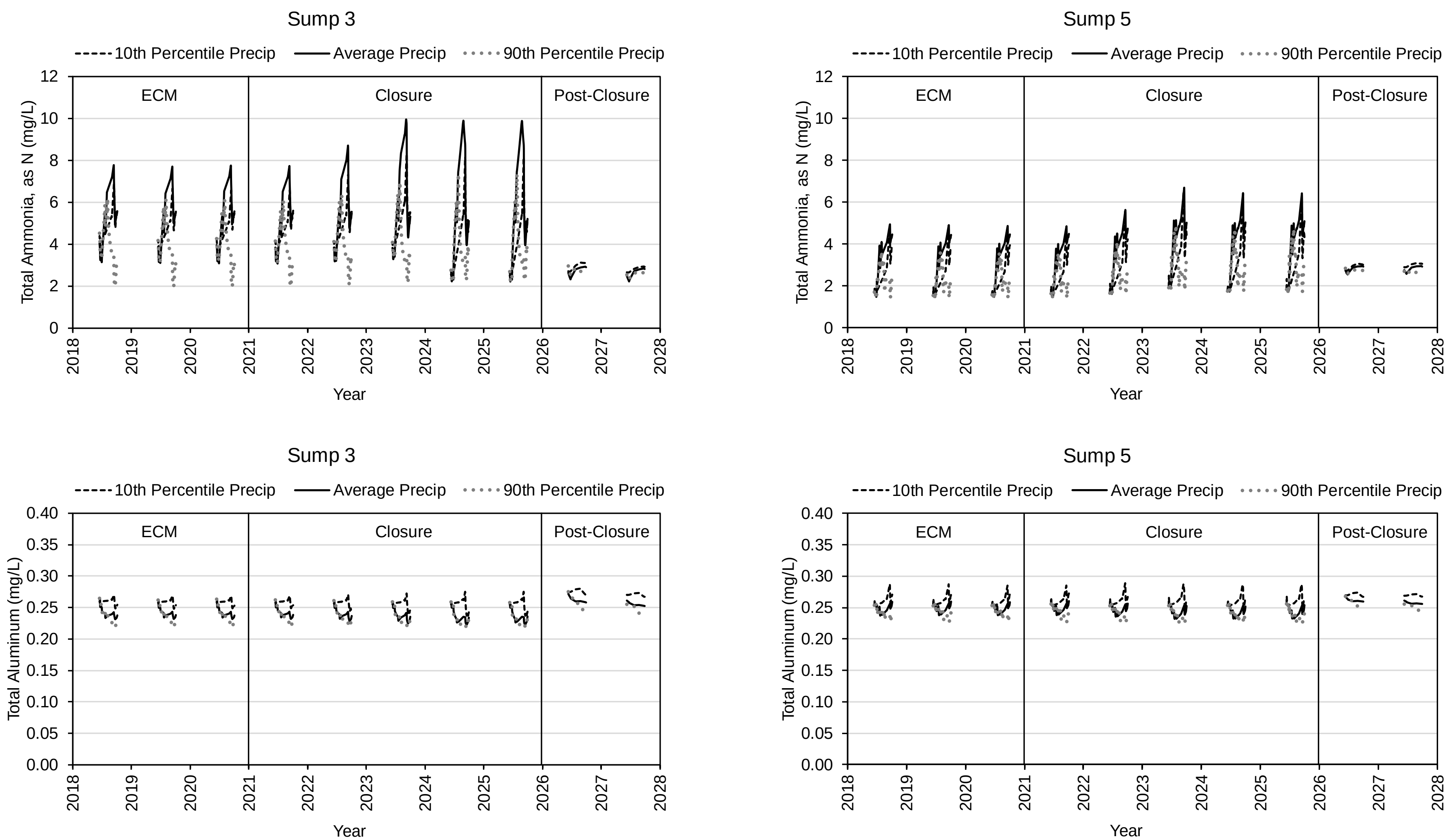
mg/L = milligrams per litre; precip = precipitation; ECM = Extended Care and Maintenance.

Figure 3-1: Predicted Open-Water Concentrations of Total Dissolved Solids and Fluoride in Sump 3 and Sump 5 for 10th Percentile, Average, and 90th Percentile Precipitation Years



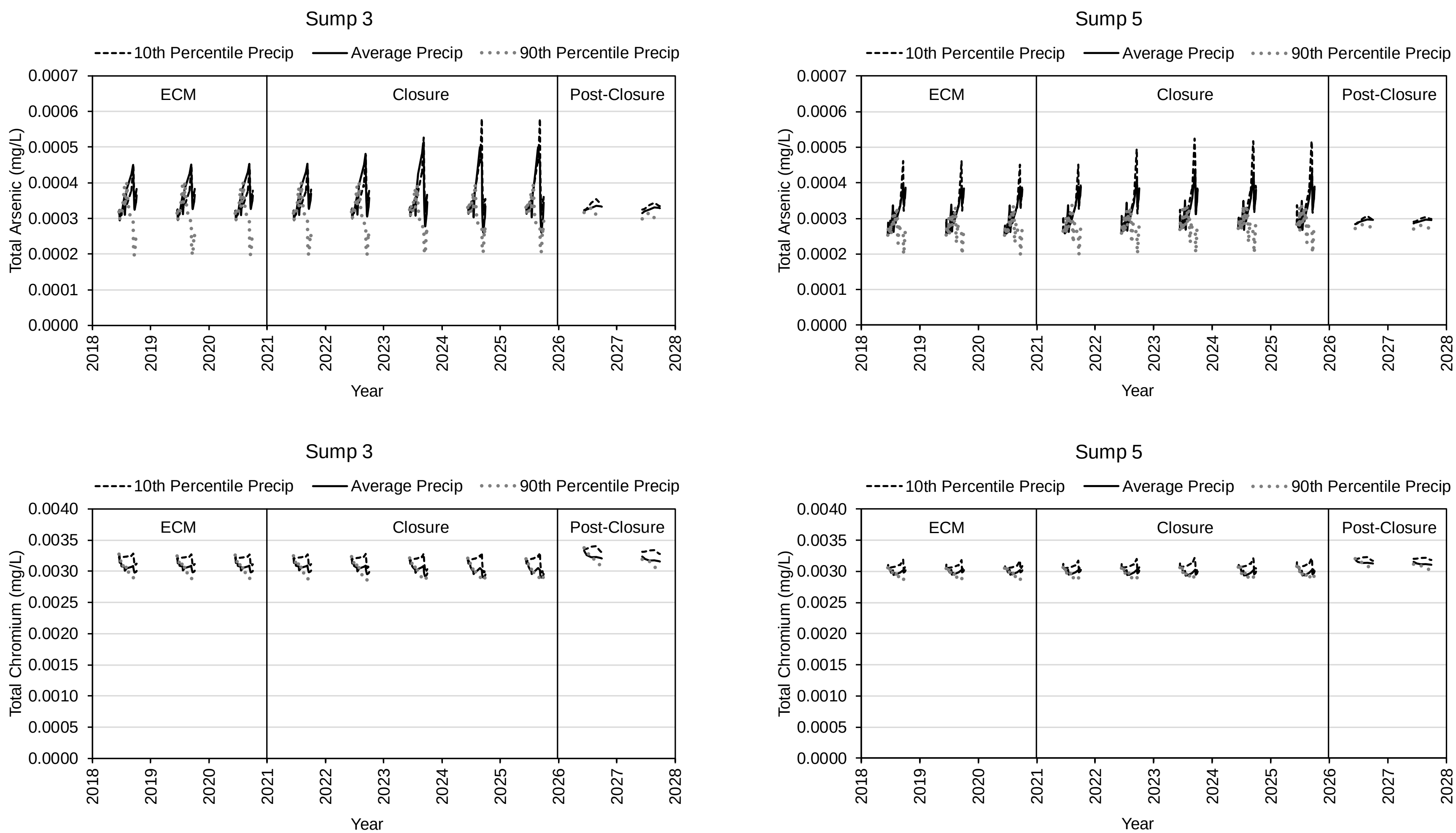
mg/L = milligrams per litre; N = nitrogen; precip = precipitation; ECM = Extended Care and Maintenance.

Figure 3-2: Predicted Open-Water Concentrations of Nitrate and Nitrite in Sump 3 and Sump 5 for 10th Percentile, Average, and 90th Percentile Precipitation Years



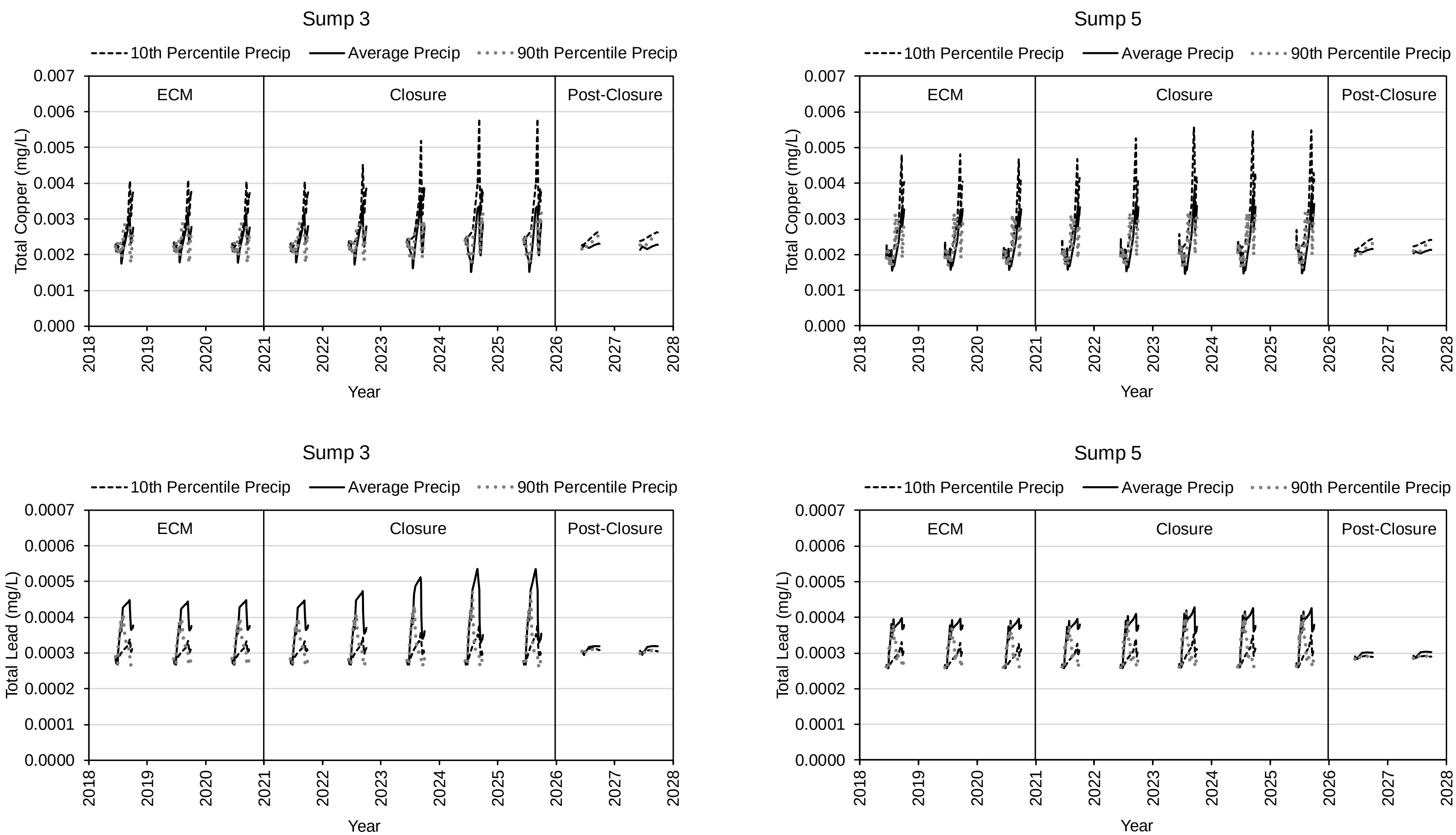
mg/L = milligrams per litre; N = nitrogen; precip = precipitation; ECM = Extended Care and Maintenance.

Figure 3-3: Predicted Open-Water Concentrations of Total Ammonia and Total Aluminum in Sump 3 and Sump 5 for 10th Percentile, Average, and 90th Percentile Precipitation Years



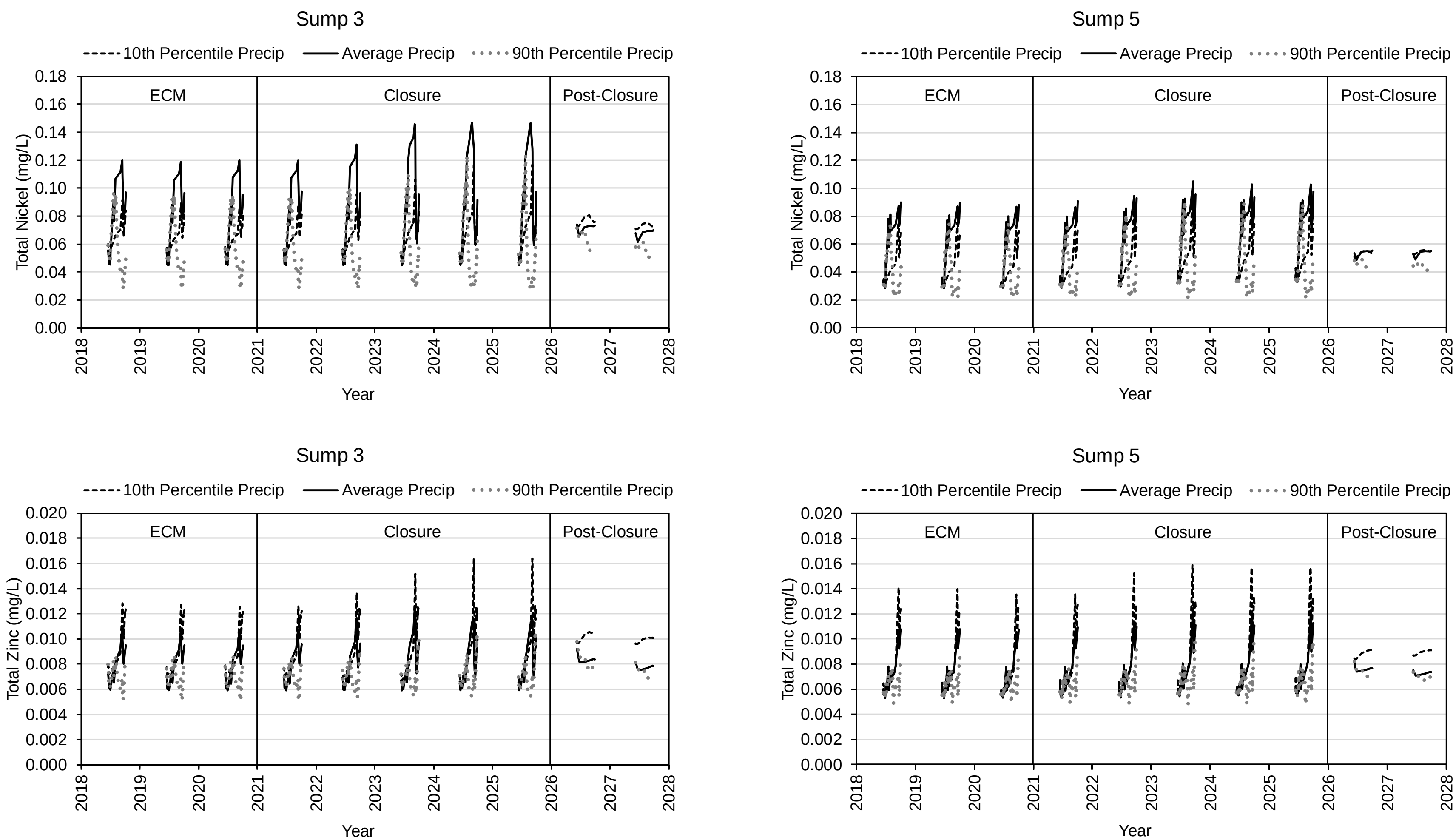
mg/L = milligrams per litre; precip = precipitation; ECM = Extended Care and Maintenance.

Figure 3-4: Predicted Open-Water Concentrations of Total Arsenic and Total Chromium in Sump 3 and Sump 5 for 10th Percentile, Average, and 90th Percentile Precipitation Years



mg/L = milligrams per litre; precip = precipitation; ECM = Extended Care and Maintenance.

Figure 3-5: Predicted Open-Water Concentrations of Total Copper and Total Lead in Sump 3 and Sump 5 for 10th Percentile, Average, and 90th Percentile Precipitation Years



mg/L = milligrams per litre; precip = precipitation; ECM = Extended Care and Maintenance.

Figure 3-6: Predicted Open-Water Concentrations of Total Nickel and Total Zinc in Sump 3 and Sump 5 for 10th Percentile, Average, and 90th Percentile Precipitation Years

3.2 Results of the North Pile Input Concentration Scenarios

During the open-water season, predicted concentrations of TDS, fluoride, nitrate, nitrite, total ammonia, total aluminium, arsenic, chromium, copper, lead, nickel and zinc in Sump 3 and Sump 5 in each of the input concentration scenarios are shown in Tables 3-1 and 3-2 and Figures 3-7 to 3-12.

Key results are:

- The monthly 95th percentile SNP 02-02 parameter concentration scenario resulted in the highest predicted concentrations in Sump 3 and Sump 5 (Tables 3-1 and 3-2 and Figures 3-7 to 3-12).
- The monthly median SNP 02-02 parameter concentration scenario resulted in the lowest predicted concentrations in Sump 3 and Sump 5 (Tables 3-1 and 3-2 and Figures 3-7 to 3-12).

The monthly 75th percentile SNP 02-02 parameter concentration scenario results were used to identify parameters of potential concern (POPC) that may require effluent quality criteria (EQC) in the Water Licence in Post-closure (Golder 2019b). This scenario resulted in predicted parameter concentrations that matched monitoring data in the water management pond and the North Pile sumps in 2016, 2017 and 2018 (Golder 2019a).

If the results of the monthly 95th percentile SNP 02-02 parameter concentration scenario were used to identify POPC that require EQC in Post-closure:

- The results from Step 1 of the screening process would be identical to the results presented in the EQC Report (i.e., all of the predicted Sump 3 and Sump 5 overflow concentrations were greater than the normal range in Snap Lake; Golder [2019b]).
- The results from Step 2 of the screening process would be identical to the results presented in the EQC Report (i.e., parameters with predicted Sump 3 and Sump 5 overflow concentrations that were greater than AEMP benchmarks were chloride, sulphate, nitrate, nitrite, total ammonia, total phosphorus, and total aluminum, cobalt, copper, iron, nickel and zinc; Golder [2019b]).

Table 3-1: Predicted 95th Percentile Sump 3 Open-Water Parameter Concentrations during Extended Care and Maintenance, Closure and Post-closure

Parameter	Extended Care and Maintenance and Closure			Post-closure		
	Median North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile North Pile Input Concentration	Median North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile North Pile Input Concentration
Conventional Parameters						
Total Dissolved Solids	2,474	2,671	3,054	934	1,072	1,161
Major Ions						
Calcium	292	310	344	114	130	140
Chloride	483	556	685	156	201	230
Fluoride	0.82	1.0	1.2	0.39	0.5	0.56
Magnesium	158	168	186	62	71	75
Potassium	43	49	56	15	19	21
Sodium	206	234	281	67	83	94
Sulphate	584	633	671	257	288	311
Nutrients						
Nitrate, as N	157	178	194	55	60	63
Nitrite, as N	1.0	1.0	1.1	0.34	0.37	0.4
Total Ammonia, as N	7.2	9.0	11	2.4	3.4	4.1
Total Phosphorus, as P	0.05	0.064	0.076	0.045	0.055	0.062
Total Metals						
Total Aluminum	0.26	0.28	0.29	0.25	0.27	0.28
Total Antimony	0.00082	0.0009	0.001	0.00037	0.00057	0.00063
Total Arsenic	0.00043	0.00047	0.0005	0.00033	0.00039	0.00041
Total Barium	0.12	0.14	0.15	0.064	0.083	0.088
Total Beryllium	0.00013	0.00015	0.00015	0.000119	0.00012	0.00012
Total Bismuth	0.0001	0.00012	0.00013	0.000067	0.000079	0.000081
Total Boron	1.9	2.1	2.2	1.08	1.2	1.2
Total Cadmium	0.000073	0.000079	0.000087	0.000046	0.000051	0.000057
Total Cesium	0.00039	0.00055	0.00065	0.00021	0.00037	0.00041

Table 3-1: Predicted 95th Percentile Sump 3 Open-Water Parameter Concentrations during Extended Care and Maintenance, Closure and Post-closure

Parameter	Extended Care and Maintenance and Closure			Post-closure		
	Median North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile North Pile Input Concentration	Median North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile North Pile Input Concentration
Total Metals (cont'd)						
Total Chromium	0.0032	0.0034	0.0035	0.0031	0.0033	0.0034
Total Cobalt	0.0061	0.0075	0.0082	0.0037	0.0042	0.0045
Total Copper	0.0022	0.0032	0.0045	0.0021	0.0027	0.0032
Total Iron	0.46	0.49	0.52	0.43	0.46	0.47
Total Lead	0.00044	0.0005	0.00057	0.00031	0.00034	0.00037
Total Lithium	0.03	0.036	0.04	0.016	0.025	0.027
Total Manganese	0.42	0.51	0.57	0.18	0.21	0.23
Total Mercury	0.000018	0.000018	0.000018	0.0000126	0.000013	0.000013
Total Molybdenum	0.064	0.076	0.088	0.035	0.049	0.054
Total Nickel	0.12	0.14	0.18	0.069	0.09	0.10
Total Rubidium	0.068	0.082	0.1	0.031	0.049	0.055
Total Selenium	0.00063	0.00067	0.00074	0.00035	0.0004	0.00044
Total Silver	0.000028	0.00003	0.000032	0.00002	0.000022	0.000023
Total Strontium	3.3	3.7	4.4	1.8	2.2	2.4
Total Thallium	0.00009	0.00012	0.00014	0.000047	0.000075	0.000086
Total Titanium	0.014	0.015	0.016	0.014	0.014	0.015
Total Uranium	0.011	0.013	0.014	0.0076	0.0097	0.0107
Total Vanadium	0.0014	0.0014	0.0017	0.00099	0.0012	0.00125
Total Zinc	0.009	0.011	0.014	0.008	0.0095	0.0119

mg/L = milligrams per litre; N = nitrogen; P = phosphorus; ECM = Extended Care and Maintenance; %ile = percentile.

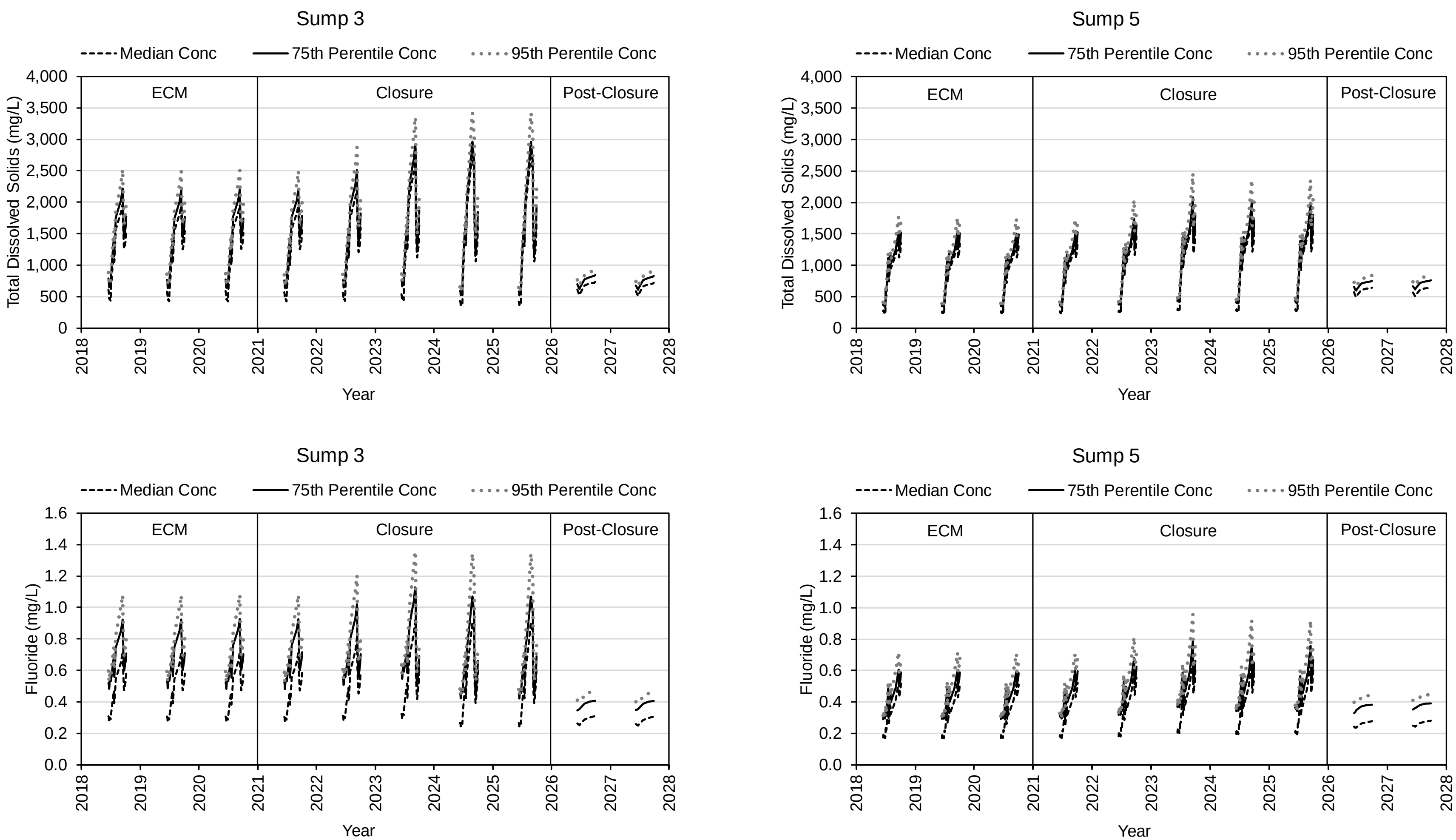
Table 3-2: Predicted 95th Percentile Sump 5 Open-Water Parameter Concentrations during Extended Care and Maintenance, Closure and Post-closure

Parameter	Extended Care and Maintenance and Closure			Post-closure		
	Median North Pile Input Concentration	95th %ile North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile NP Input Conc.
Conventional Parameters						
Total Dissolved Solids	1,639	1,813	2,086	772	904	986
Major Ions						
Calcium	195	216	245	93	109	118
Chloride	294	333	421	134	179	205
Fluoride	0.6	0.67	0.79	0.33	0.45	0.51
Magnesium	107	117	131	50	59	63
Potassium	27	31	36	13	16	18
Sodium	126	146	176	58	73	83
Sulphate	424	478	518	198	225	247
Nutrients						
Nitrate, as N	103	116	127	49	53	55
Nitrite, as N	0.62	0.65	0.68	0.32	0.36	0.38
Total Ammonia, as N	4.3	5.4	6.6	2.2	3.3	4.0
Total Phosphorus, as P	0.034	0.045	0.054	0.034	0.041	0.047
Total Metals						
Total Aluminum	0.26	0.27	0.28	0.25	0.27	0.27
Total Antimony	0.00053	0.00059	0.00061	0.00027	0.00041	0.00046
Total Arsenic	0.00037	0.0004	0.00043	0.00029	0.00033	0.00035
Total Barium	0.09	0.1	0.11	0.049	0.063	0.067
Total Beryllium	0.00012	0.00013	0.00013	0.000104	0.00011	0.00011
Total Bismuth	0.000086	0.0001	0.00011	0.000053	0.000061	0.000063
Total Boron	1.4	1.5	1.6	0.8	0.84	0.88

Table 3-2: Predicted 95th Percentile Sump 5 Open-Water Parameter Concentrations during Extended Care and Maintenance, Closure and Post-closure

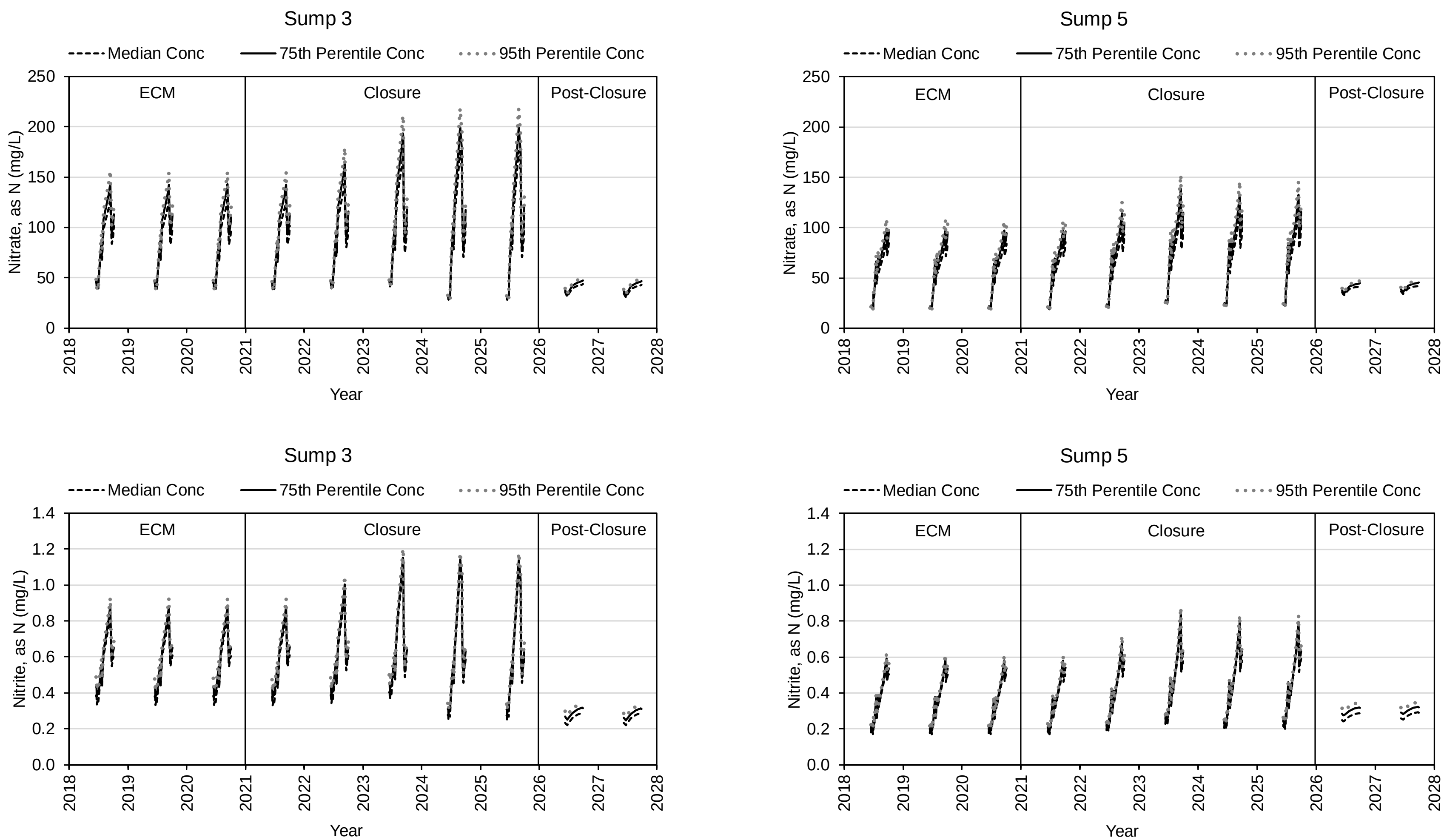
Parameter	Extended Care and Maintenance and Closure			Post-closure		
	Median North Pile Input Concentration	95th %ile North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile North Pile Input Concentration	75th %ile North Pile Input Concentration	95th %ile NP Input Conc.
Total Metals (cont'd)						
Total Cadmium	0.000068	0.000071	0.000077	0.000037	0.000041	0.000046
Total Cesium	0.00027	0.00037	0.00043	0.00017	0.00027	0.0003
Total Chromium	0.0031	0.0032	0.0033	0.0031	0.0032	0.0033
Total Cobalt	0.0052	0.006	0.0064	0.0029	0.0032	0.0034
Total Copper	0.0025	0.0034	0.0046	0.0019	0.0024	0.0028
Total Iron	0.53	0.56	0.57	0.49	0.51	0.52
Total Lead	0.00037	0.00041	0.00046	0.00029	0.00032	0.00033
Total Lithium	0.021	0.024	0.027	0.013	0.019	0.02
Total Manganese	0.29	0.35	0.4	0.15	0.17	0.19
Total Mercury	0.000018	0.000018	0.000018	0.0000118	0.000012	0.0000118
Total Molybdenum	0.043	0.051	0.06	0.026	0.036	0.039
Total Nickel	0.082	0.1	0.13	0.052	0.067	0.075
Total Rubidium	0.046	0.055	0.067	0.023	0.036	0.04
Total Selenium	0.00054	0.00058	0.00063	0.00026	0.00029	0.00032
Total Silver	0.000024	0.000027	0.000029	0.000018	0.000019	0.00002
Total Strontium	2.4	2.8	3.3	1.3	1.6	1.8
Total Thallium	0.000063	0.000081	0.0001	0.000036	0.000056	0.000064
Total Titanium	0.014	0.015	0.015	0.014	0.014	0.014
Total Uranium	0.0082	0.0088	0.01	0.0056	0.0071	0.0079
Total Vanadium	0.0012	0.0013	0.0015	0.00089	0.001	0.00108
Total Zinc	0.01	0.011	0.013	0.0074	0.0085	0.0102

mg/L = milligrams per litre; N = Nitrogen; P = Phosphorus; ECM = Extended Care and Maintenance; %ile = percentile.



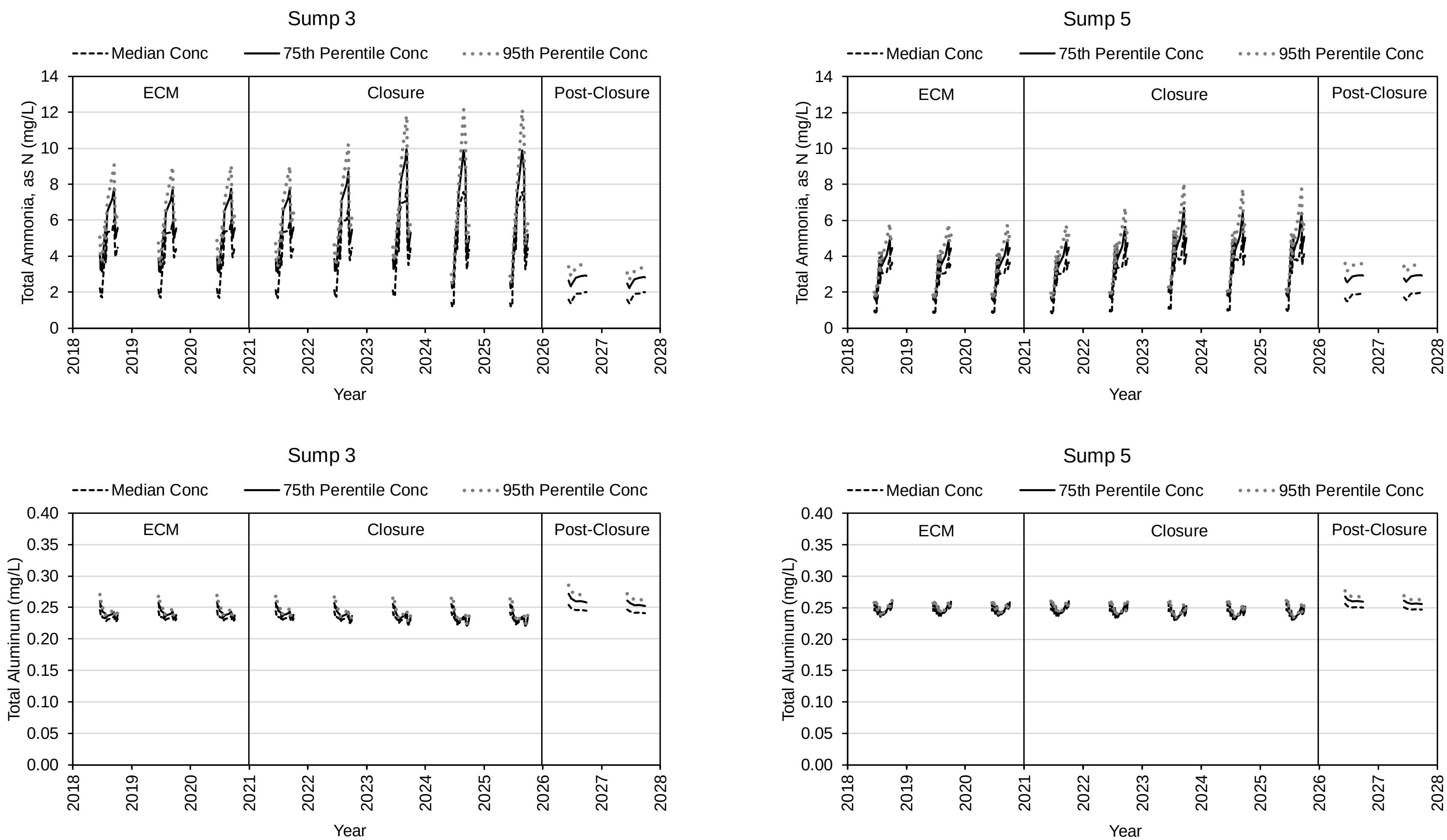
mg/L = milligrams per litre; Conc = concentration; ECM = Extended Care and Maintenance.

Figure 3-7: Predicted Open-Water Concentrations of Total Dissolved Solids and Fluoride in Sump 3 and Sump 5 for Median, 75th Percentile, and 95th Percentile North Pile Input Concentrations



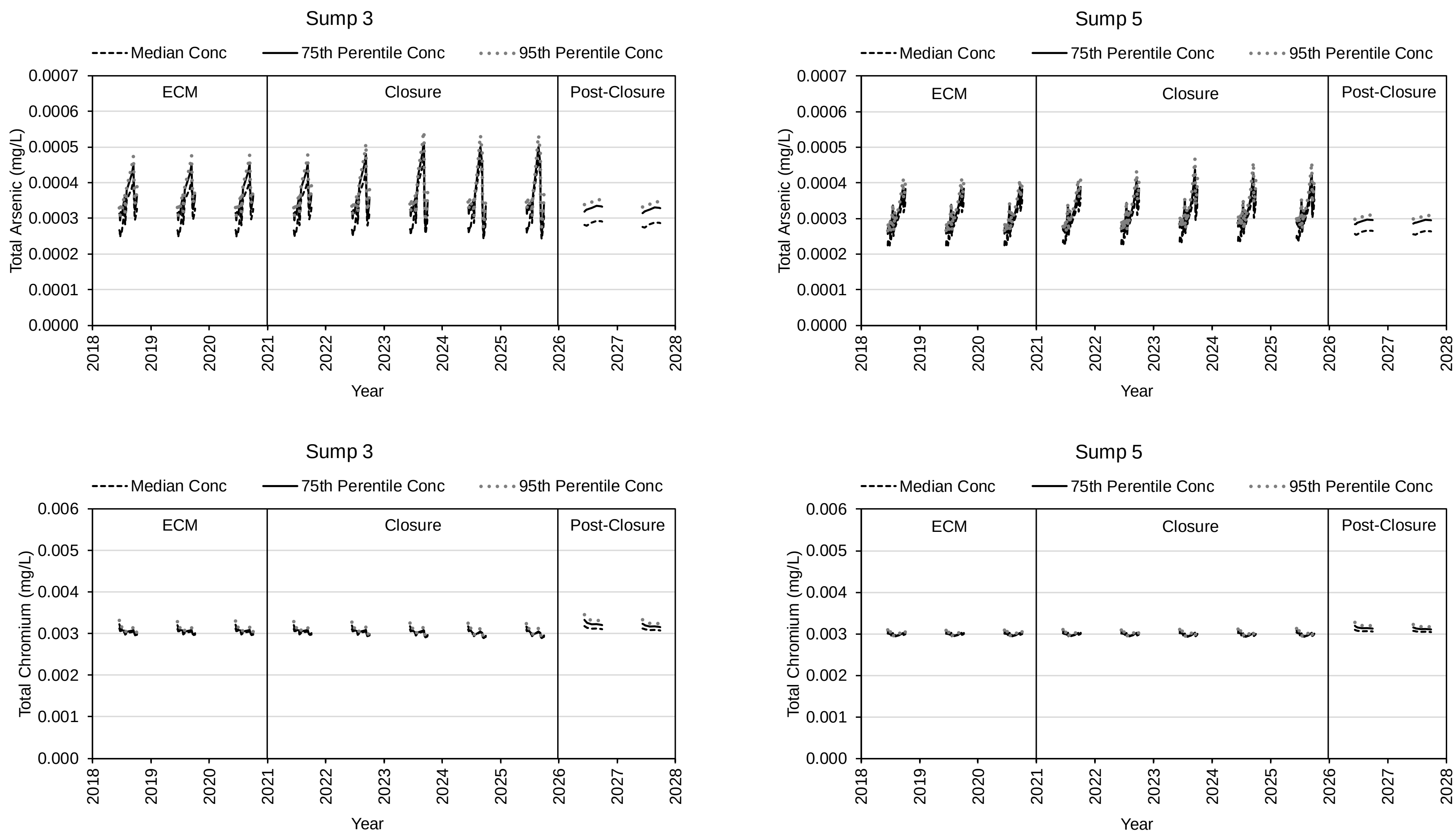
mg/L = milligrams per litre; N = nitrogen; Conc = concentration; ECM = Extended Care and Maintenance.

Figure 3-8: Predicted Open-Water Concentrations of Nitrate and Nitrite in Sump 3 and Sump 5 for Median, 75th Percentile, and 95th Percentile North Pile Input Concentrations



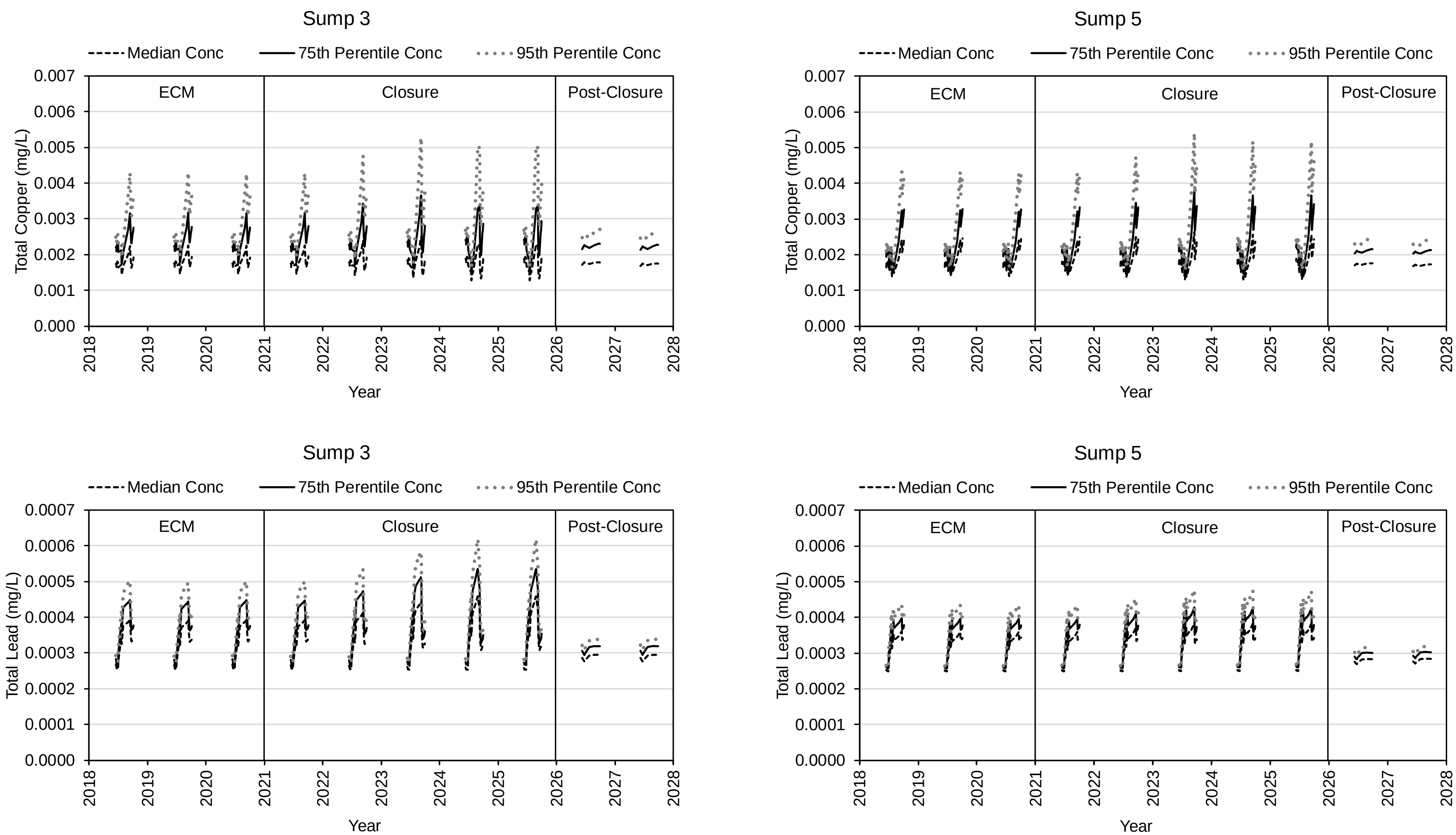
mg/L = milligrams per litre; N = nitrogen; Conc = concentration; ECM = Extended Care and Maintenance.

Figure 3-9: Predicted Open-Water Concentrations of Total Ammonia and Total Aluminum in Sump 3 and Sump 5 for Median, 75th Percentile, and 95th Percentile **North Pile Input Concentrations**



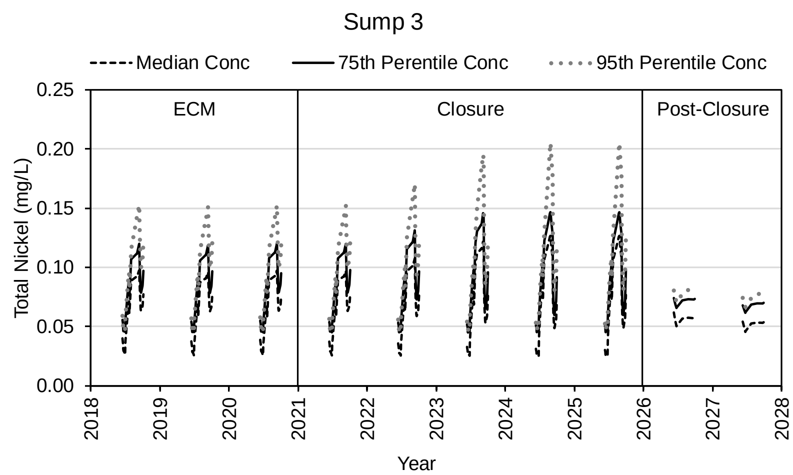
mg/L = milligrams per litre; Conc = concentration; ECM = Extended Care and Maintenance.

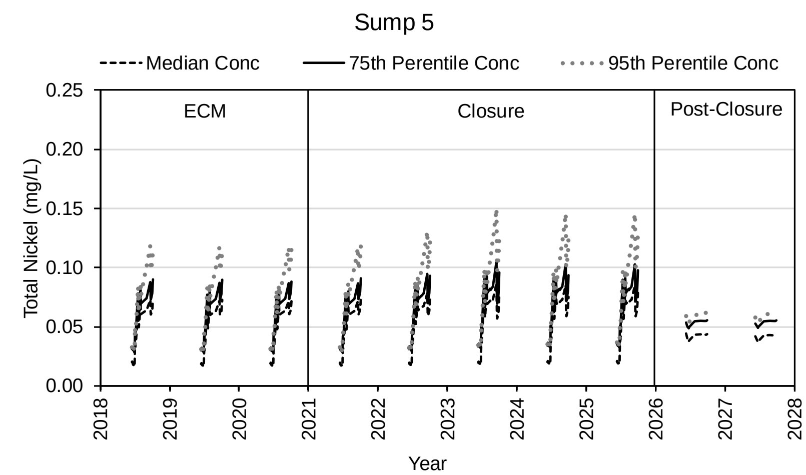
Figure 3-10: Predicted Open-Water Concentrations of Total Arsenic and Total Chromium in Sump 3 and Sump 5 for Median, 75th Percentile, and 95th Percentile North Pile Input Concentrations

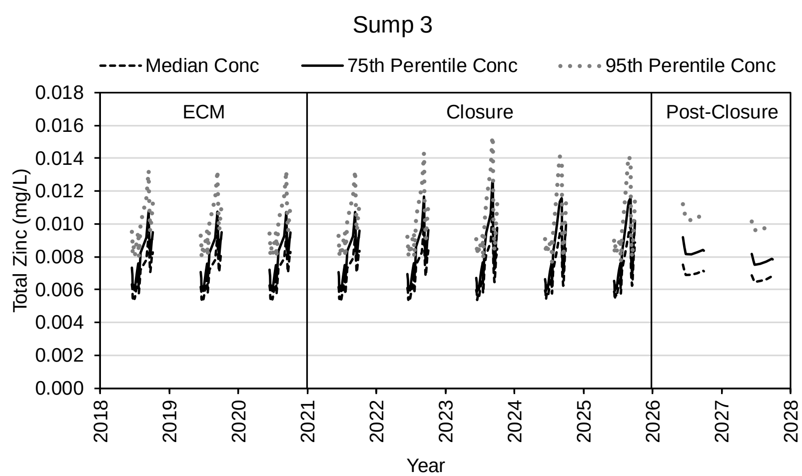


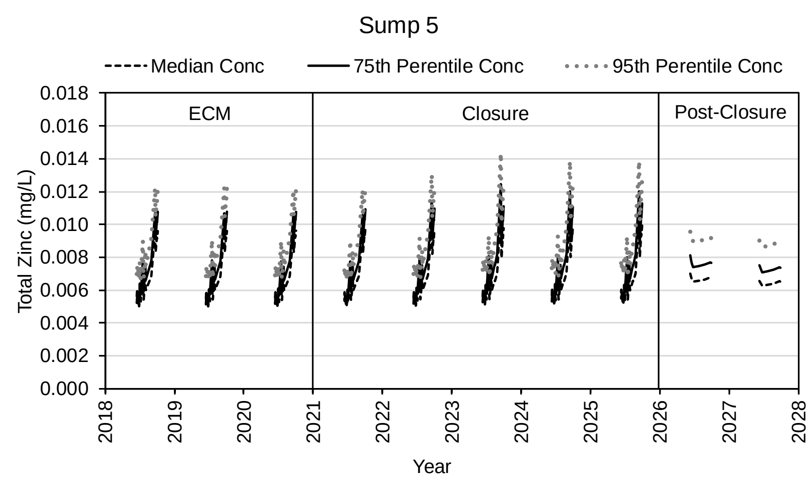
mg/L = milligrams per litre; Conc = concentration; ECM = Extended Care and Maintenance.

Figure 3-11: Predicted Open-Water Concentrations of Total Copper and Total Lead in Sump 3 and Sump 5 for Median, 75th Percentile, and 95th Percentile North Pile Input Concentrations









mg/L = milligrams per litre; Conc = concentration; ECM = Extended Care and Maintenance.

Figure 3-12: Predicted Open-Water Concentrations of Total Nickel and Total Zinc in Sump 3 and Sump 5 for Median, 75th Percentile, and 95th Percentile North Pile Input Concentrations

4.0 LIMITATIONS

Limitations of the sensitivity model run scenarios are the same as those identified in the Snap Lake Mine - Site Water Quality Model Report submitted in March 2019 (Golder 2019a). In addition, the results from the precipitation scenarios and North Pile input concentration scenarios have not been applied to any of the downstream models. Future studies would be required to carry forward these scenarios to Snap Lake and the downstream lakes to determine how these sensitivities could affect predicted parameter concentrations in Snap Lake and other lakes downstream of the Mine site.

5.0 SUMMARY

The results of the precipitation scenarios presented in this technical memorandum show that using monthly rainfall and snowfall rates based on the average precipitation year results in the highest predicted parameter concentrations in Sump 3 and Sump 5 during the Extended Care and Maintenance and Closure periods. Therefore, using an average precipitation year is reasonably conservative for closure planning purposes. The dry, average, and wet precipitation scenarios all resulted in similar predicted parameter concentrations during Post-closure.

The results of the North Pile concentration input scenarios presented in this technical memorandum show that applying the 95th percentile SNP 02-02 parameter concentrations to the North Pile runoff and seepage resulted in the highest predicted parameter concentrations in Sump 3 and Sump 5. However, it also illustrates that the results from this scenario would not change the list of POPC that require EQC in the Water Licence in Post-closure. Therefore, it is considered that the use of the 75th percentile value is reasonable and appropriate for closure planning purposes.

6.0 CLOSING

We trust that the information above addresses your needs. If you have any questions or comments, please contact the undersigned at (403) 299-5600.

Golder Associate Ltd.

Alison Snow, M.A.Sc.
Water Quality Modeller

Steve Mitchell, B.Sc.
Water Quality Modeller

REGISTERED PROFESSIONAL GEOLOGIST
K.J. DE VOS
LICENSEE
May 30, 2019
NWT/NU

Ken De Vos, M.Sc., P.Geo.
Principal, Senior Hydrogeochemist

Jeffrey Kwok
Associate, Project Manager

AS/SM/KJD/JEK/cmm/cr

https://golderassociates.sharepoint.com/sites/103085/deliverables/_issued/19115886-022-tm-rev0-7000/19115886-022-tm-rev0-7000-precip_sensitivities_30may_19.docx

PERMIT TO PRACTICE
GOLDER ASSOCIATES LTD.
Signature
Date May 30, 2019
PERMIT NUMBER: P 049
NT/NU Association of Professional Engineers and Geoscientists

REFERENCES

Golder. (Golder Associates Ltd.). 2019a. Site, Snap Lake and Downstream Lakes Water Quantity Model Report. Prepared for De Beers Canada Inc. March 2019.

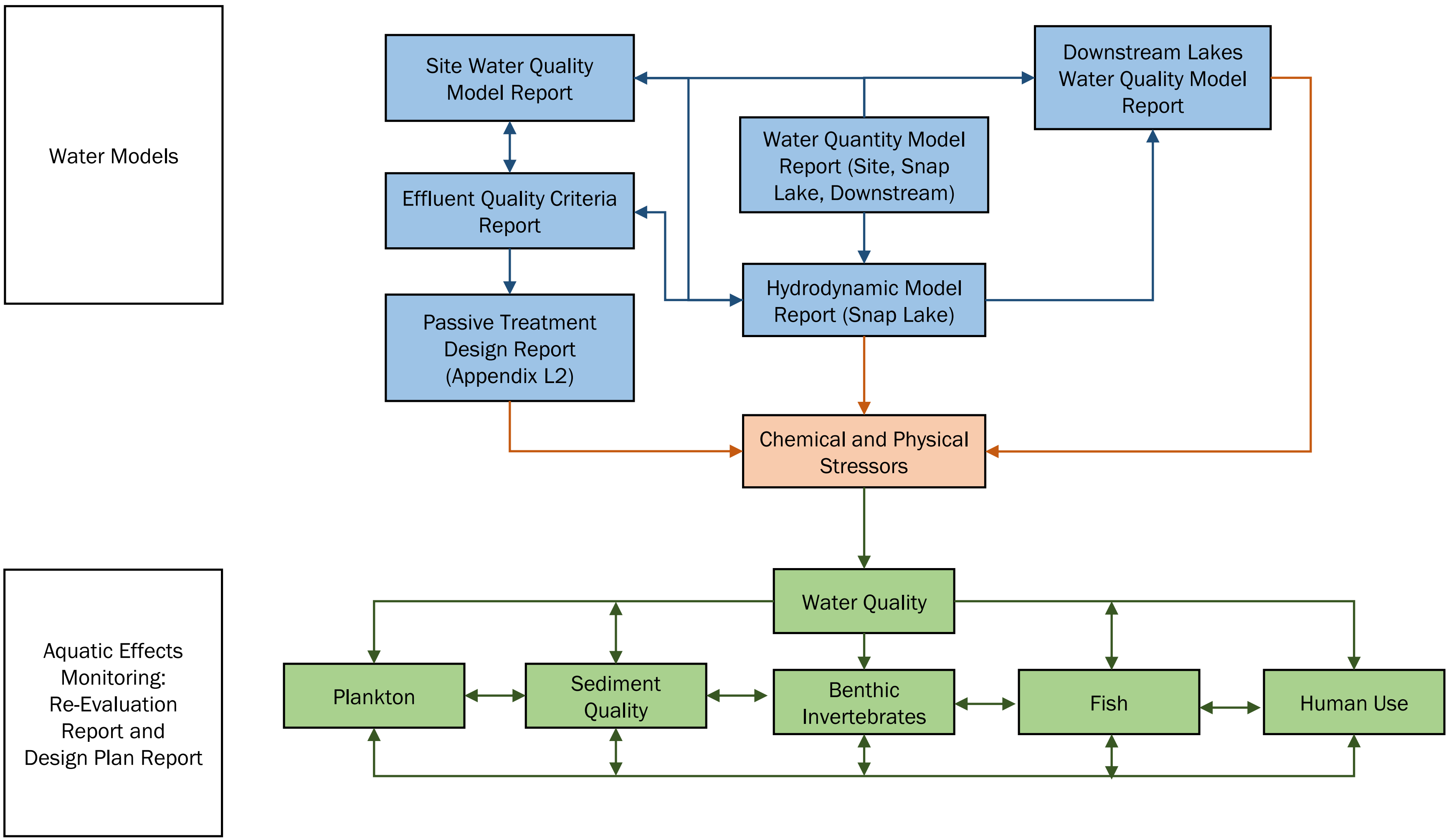
Golder. 2019b. Snap Lake Mine Effluent Quality Criteria Report for Closure and Post-closure. Prepared for De Beers Canada Inc. March 2019.

Government of Canada. 2018. Historical Climate Data. Available at: http://climate.weather.gc.ca. Accessed: June 2018.

Attachment 4 – Schematic Linking Water Models

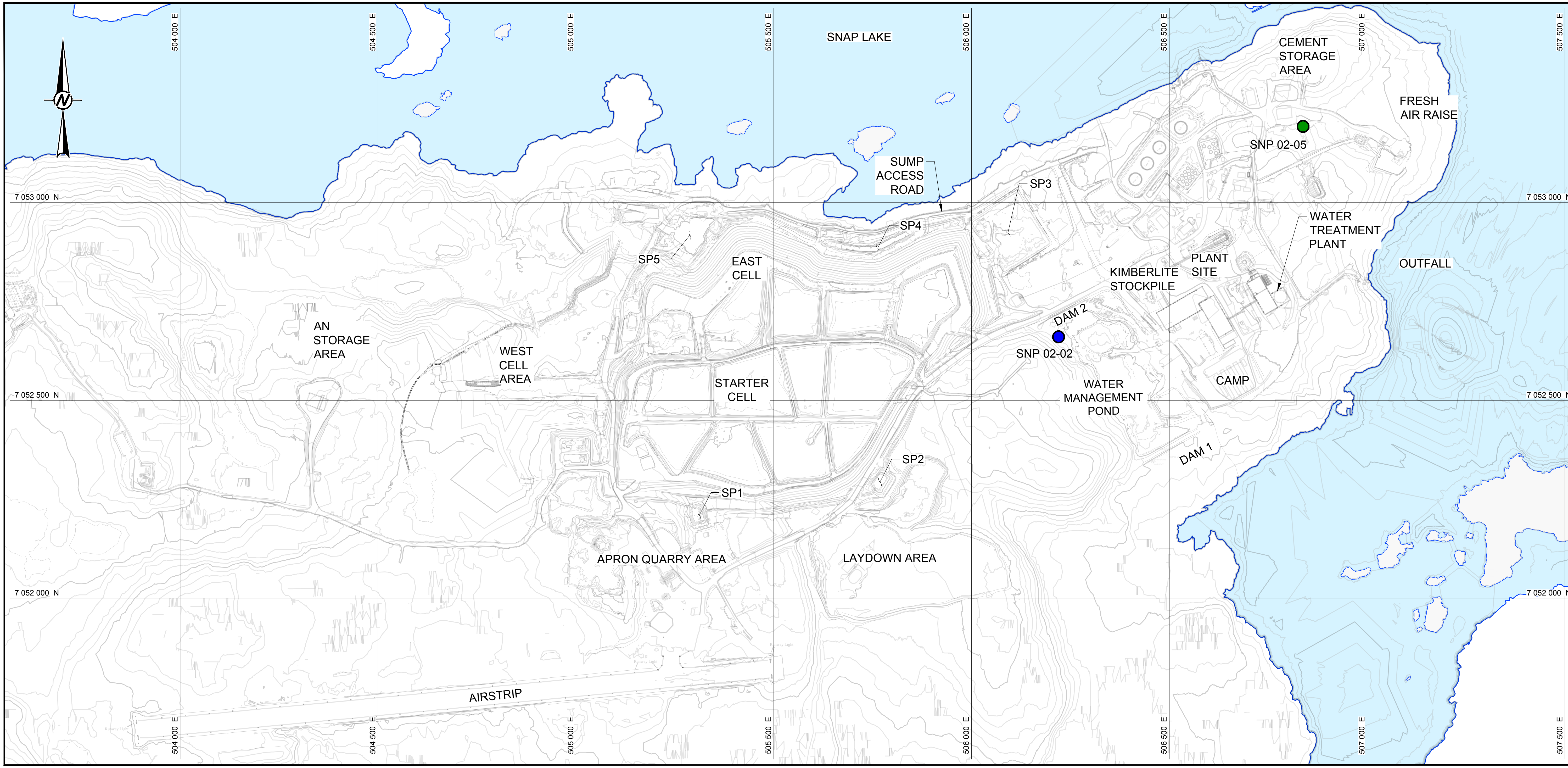
- Response to MVLWB ID 43

Linkage of Snap Lake Water Models



Attachment 5 – Updated Figure North Pile Sumps

- Response to MVLWB ID 57



0 250 500
1:10,000 METRES

LEGEND

- ● NORTH PILE DRAINAGE COLLECTION DITCH STATION (green)
- ● SURFACE RUNOFF, BULK SAMPLE MINE ROCK PAD STATION (blue)

REFERENCE

October 2018 contours and infrastructure provided by De Beers. Received, November 15, 2018, File name: "Statmap Oct22, 2018_Final.dwg"

NOTES

1. Grid is displayed in Transverse Mercator, Datum : NAD83, Coordinate system : UTM zone 12.
2. Plant site information shown for information only.

CLIENT	DE BEERS GROUP
CONSULTANT	GOLDER
YYYY-MM-DD	2019-05-24
PREPARED	R. MARTIN
DESIGN	E. TANIERE
REVIEW	A. SNOW
APPROVED	T. HALL

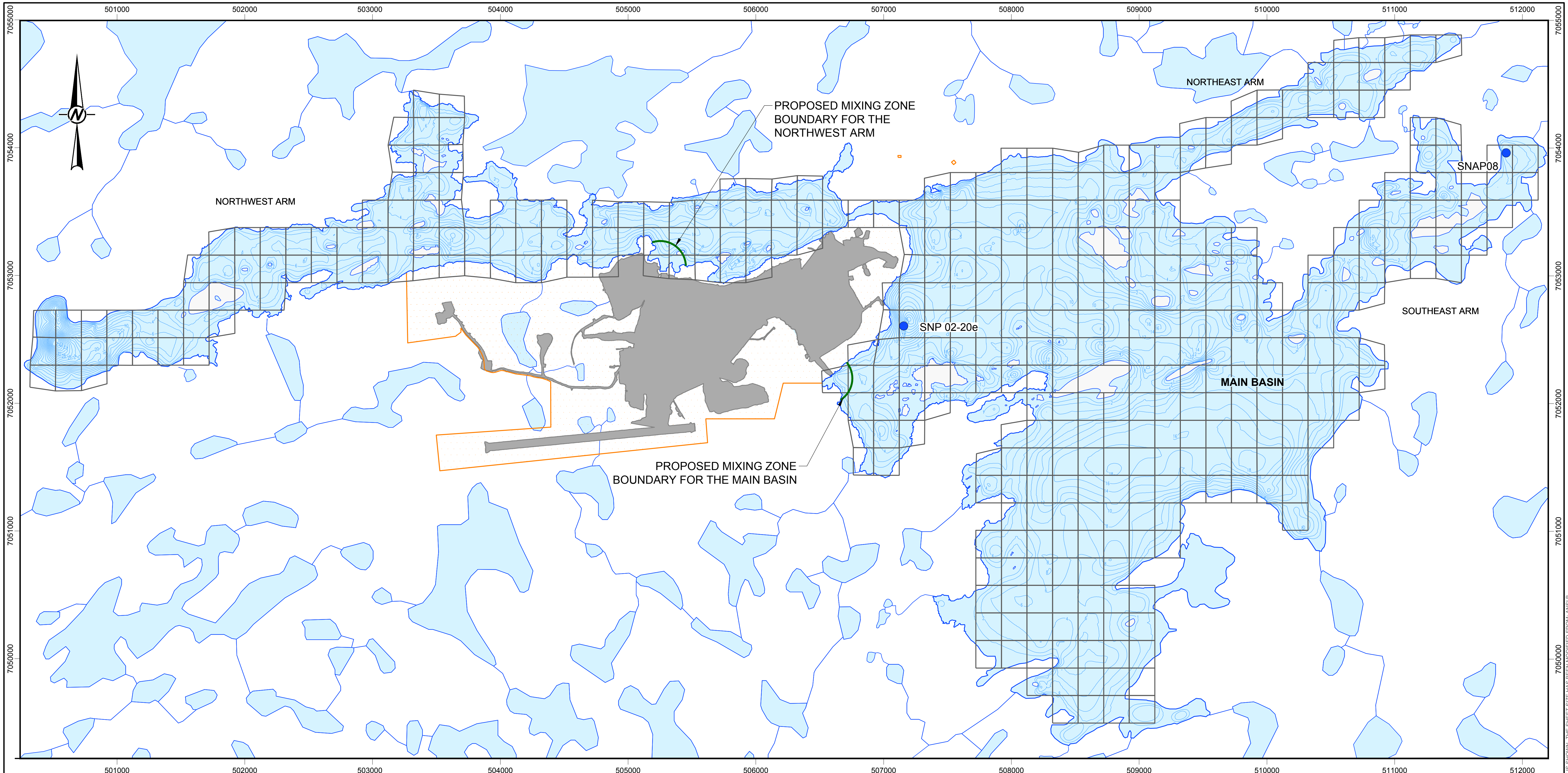
PROJECT
SNAP LAKE MINE

TITLE
NORTH PILE AND NORTH PILE SUMPS AT SNAP LAKE MINE

PROJECT No.	PHASE	Rev.	FIGURE
18105918	9400	1	2-1

Attachment 6 – Updated Figure Mixing Zones

- Response to MVLWB ID 59



LEGEND

- Depth Contour (m)
- Watercourse
- Mixing Zone Boundary
- Waterbody
- Company Managed Land
- Proposed Footprint End of Closure (2028)
- Snap Lake Model Grid
- Sampling and Model Calibration Location

REFERENCE

Digital Map 75M obtained from CANVEC, Original scale 1:250,000, projection : Transverse Mercator, Datum : NAD83, coordinate system : UTM zone 12.

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).

De Beers managed land and mine footprint information provided by De Beers.

0 500 1,000

1:30,000 METRES

CLIENT	DE BEERS GROUP	PROJECT	SNAP LAKE MINE
CONSULTANT	GOLDER	TITLE	PROPOSED MIXING ZONES FOR DISCHARGE TO SNAP LAKE
	YYYY-MM-DD	2019-05-24	
	PREPARED	R. MARTIN	
	DESIGN	E. TANIERE	
	REVIEW	A. SNOW	
	APPROVED	T. HALL	

PROJECT No.	PHASE	Rev.	FIGURE
18105918	9400	1	5-1

Attachment 7 – Table of Earthwork Quantities

- o Response to GNWT-ENR ID 129

Table 1. Material Quantities by Closure Component

Earthworks - Balance				
Available Materials			Required Materials	
Excavation			**Place**	
Cell 5 Outlet Channel	21,000		Cell 5 Outlet Channel	100
South Perimeter Ditch	102,600		South Perimeter Ditch	45,400
North Perimeter Ditch	-		North Perimeter Ditch	75,300
West Cell Initial Divider Dyke Channel	5,500		East Cell	127,000
West ISP	290,700		Starter Cell	139,300
West CW	150,100		West Perimeter	5,800
East ISP	96,500		West ISP	133100
East CW	437,600		West CW	32450
Starter Cell	29,000		East ISP	23500
Culverts	11,700		East CW	37850
Total	**1,144,700**		Access Roads (temp)	3750
			Portal Fill	39500
Cut to fill			Cover	138,556
East Cell	118,300		**Total**	**801,606**
Starter Cell	119,700			
West Perimeter	14,000		**Rip Rap**	
Total	**252,000**		East Cell	2,100
			Starter Cell	4,300
			West Perimeter	800
			Culverts	2,340
			Total	**9,540**
Total Excavation	1,396,700			
Total Place	1,063,146			
Remaining	333,555			
% Extra	24%			