7.0 SUMMARY OF KEY PREDICTIVE STUDIES

A number of the environmental effects assessments detailed in Chapter 8 depend upon predictive studies regarding the release and fate of air contaminants, greenhouse gases (GHG), sound, and effluent from the Project throughout the phases of Construction, Operation, and ultimately Decommissioning, Reclamation and Closure. Emissions, releases and wastes from the Project have been characterized in Sections 3.4.1 to 3.4.3 based on existing information about the Project developed in support of the feasibility study. In this section, summaries of the key predictive studies that were carried out to support the environmental effects assessments are presented. These include:

- air quality modelling of the Project's emissions to the atmosphere and their dispersion in the ambient environment (Section 7.1);
- characterization of the Project's emissions of GHGs, and their placement in the context of provincial, national and global GHG emissions (Section 7.2);
- characterization and modelling of the Project's sound and vibration emissions in the ambient environment, and their transport to nearby noise sensitive receptors (Section 7.3);
- a discussion of how the Project might affect fish habitat in and around the Project Development Area (PDA), resulting in loss of habitat directly and indirectly, and how such habitat loss might be offset (Section 7.4);
- characterization of the potential for acid rock drainage (ARD) and/or metal leaching (ML) to result from ore and wastes from the Project, and potential associated environmental effects to water quality (Section 7.5);
- prediction of how releases from the Project might affect downstream water quality in receiving watercourses (Section 7.6); and
- human health and ecological risk assessment (HHERA) modelling to understand the effect of emissions and releases from the Project on human and ecological health in the surrounding environment (Section 7.7).

7.1 AIR QUALITY MODELLING

Emissions of air contaminants during Construction and Operation of the Project were presented in Section 3.4.1.6.1 and 3.4.2.5.1, respectively. Emissions during Decommissioning, Reclamation and Closure were conservatively assumed to be the same as those occurring during Construction.

Stantec carried out dispersion and deposition modelling of air contaminant emissions resulting from Construction and Operation of the Project for the purposes of:

- predicting changes to ambient air quality arising from the Project's emissions, to determine the potential for exceedances of ambient air quality objectives; and
- providing inputs to the Human Health and Ecological Risk Assessment (HHERA) study for the Project.

Dispersion refers to the dispersal of an exhaust plume from an air contaminant emission source. Plume dispersion occurs due to mixing of the exhaust gases with ambient air. Plume dispersion is modelled to predict air contaminant concentrations downwind at ground-level. Deposition refers to particulate matter or gaseous air contaminants, from a single emission source or a group of sources, which are deposited at the ground surface. There are two forms of deposition: dry, and wet. Dry deposition occurs when air contaminants are transported downwind through dispersion of the exhaust plume, which is eventually deposited at the ground surface. Wet deposition occurs when air contaminants are captured in precipitation and are deposited at the ground surface when precipitation falls. The dispersion and deposition of air contaminants released from the Project is an important component to aid in the understanding of how ambient air quality may be affected by the Project's activities.

7.1.1 Dispersion and Deposition Modelling Methodology

7.1.1.1 Model Selection

As discussed in Section 4.1 of the Terms of Reference (Stantec 2012a), the maximum short-term (1-h, 8-h, and 24-h), and long-term (annual) average ground-level concentrations and annual deposition rates arising from emissions from the Project during Construction and Operation were predicted using the most recent version of the American Meteorological Society and Environmental Protection Agency developed Regulatory Model (AERMOD) dispersion model. The AERMOD model is a commonly used dispersion and deposition model for modelling emissions from point, volume, and area sources of air contaminants. AERMOD has been used for dispersion and deposition modelling applications in New Brunswick for several years, and is accepted by the New Brunswick Department of Environment and Local Government (NBDELG).

7.1.1.2 Model Inputs

The inputs for the dispersion and deposition modelling generally consist of three main components:

- meteorological data;

- receptor grid and terrain data; and
- point source characteristics and emissions data.

These are described in the following text.

7.1.1.2.1 Meteorological Data

The AERMOD model uses hourly meteorological data (*e.g.*, wind speed and direction, temperature) for a continuous 6-year period—in this case, from the beginning of January 2006 to the end of December 2011. The hourly meteorological data for the Fredericton Airport were considered by the Study Team to be representative of the Project site, and were obtained from the National Climatic Data Centre (NCDC 2012) and Environment Canada (Environment Canada 2012).

The model also uses upper air sounding data from a representative upper air station. Twice daily upper air sounding data were obtained for the Caribou, Maine weather station (NOAA 2012), the nearest representative upper air station to the Project site.

Data for the following meteorological parameters are used in the dispersion and deposition model:

- wind speed (m/s) and wind direction (degrees) – surface and upper air;
- temperature (Kelvin or K degrees) – surface and upper air;
- station pressure (kPa) – surface and upper air;
- precipitation (mm/h) – surface only;
- altitude (m) – upper air only;
- cloud cover (tenths of a degree) – surface only; and
- relative humidity (%) – surface and upper air.

Since precipitation data for 2011 were missing for the Fredericton Airport station, precipitation data from the Sisson meteorological station (Northcliff Resources 2012c) were used for the 2011 year.

The raw data (as identified above) for the area were used to calculate stability parameters and mixing layer depths (mixing heights) with the aid of the American Meteorological Society and Environmental Protection Agency developed Regulatory Meteorological Pre-processor (AERMET) meteorological pre-processor. AERMET merges the surface data set with the upper air data, to provide a quality assured and quality controlled meteorological data set. There are three stages to processing the data:

- the first stage extracts meteorological data from archive data files and processes the data through various quality assessment checks;

- the second stage merges all data available for 24-hour periods and stores these data together in a single file; and

- the third stage reads the merged meteorological data and estimates the parameters required by the model.

The AERMET processor requires hourly values of wind speed, direction, temperature, cloud cover as well as the 1200 GMT (7:00 am Local Standard Time) upper air sounding to generate the requisite data for modelling.

7.1.1.2.2 Receptor Grid and Terrain Data

The dispersion and deposition modeling uses a receptor grid covering the Local Assessment Area (LAA) for the Atmospheric Environment (see Section 8.2.1.4) and reflects that recommended in the Terms of Reference (Stantec 2012a).

The receptor grid selected for this modelling is shown in Figure 7.1.1. The receptor grid consisted of a 25 km by 25 km Cartesian grid with the Project site near the centre of the grid. The receptor grid spacing was 100 m apart for the first 10 km by 10 km grid centered near the Project. Receptors were then spaced 250 m apart for the next 3 km from the edge of the 10 km x 10 km grid; this 250 m grid spacing was shifted slightly to the east to cover the community of Napadogan and provide additional resolution in the area where the nearest permanent residences are located. The receptors were then spaced 500 m apart for the remainder of the 25 km by 25 km domain.

Terrain elevation data used in the development of the receptor grid were obtained from Service New Brunswick (SNB 2012).

7.1.1.2.3 Point Source Characteristics and Emissions Data

The source data required to run the AERMOD model include the following:

- the physical location of each of the point, area, and volume emission sources;

- the emission rate (g/s) of the selected air contaminant from each source;

- the physical height (m) of the point emission source (*i.e.,* stack height) above surrounding ground-level;

- the dimensions and release parameters (m) of the area and volume sources;

- the diameter of the stack of each point source (m) at its exit (*i.e.,* stack exit diameter);

- the average stack exhaust gas exit velocity for each point source (m/s); and

- the average stack exhaust gas exit temperature for each point source (Kelvin degrees, or K).

The source parameters were based on operational parameters provided by Northcliff. Emission rates of air contaminants during Construction and Operation were based on emissions inventories developed by Stantec based on operational parameters from Northcliff as well as published emission factors, as presented previously in Sections 3.4.1.6.1 and 3.4.2.5.1.

Tables 7.1.1 and 7.1.2 provide the model input parameters for the point, area, and volume sources[1] included in the modelling of emissions during the Construction phase. The model input parameters for the point, area, and volume sources included in the modelling of emissions during the Operation phase are provided in Tables 7.1.3 to 7.1.5. The emissions were estimated and modelled for the months of the Construction and Operation phases during which the most heavy equipment and trucks would be operational, representing a conservative estimate of emissions during Construction and Operation.

The point source, area source, and volume source input parameters in the tables below are estimated based on the dimensions of each source. The procedure for estimating initial dimensions for volume sources is outlined in the Industrial Source Complex (ISC) dispersion model User Guide Volume I (USEPA 1995).

Table 7.1.1 Dispersion Model Input Parameters – Construction Phase, Point Sources

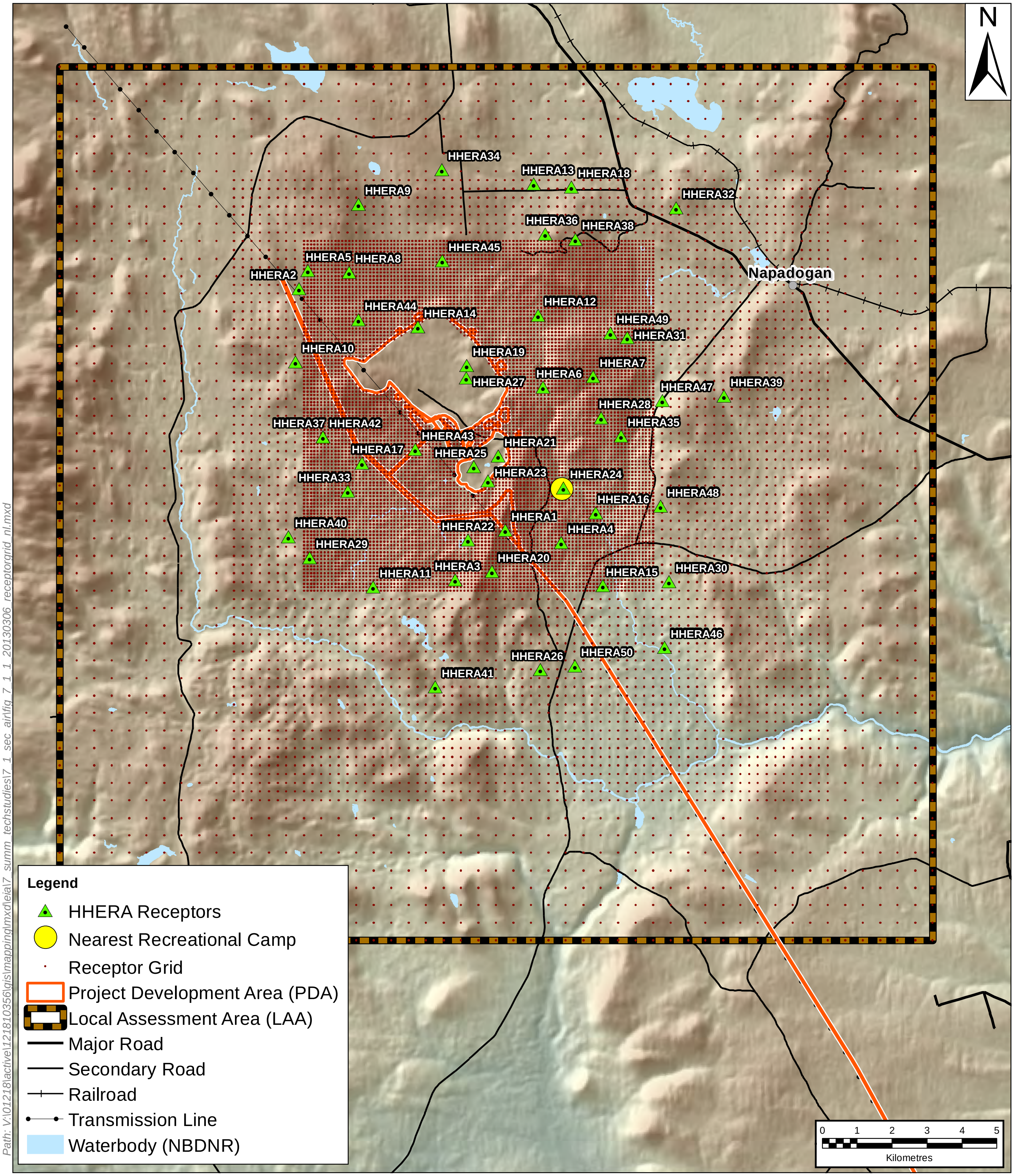
Source	Exhaust Gas Temperature (K)	Exhaust Gas Exit Velocity (m/s)	Exhaust Point Height above ground-level (m)	Exhaust Point Exit Diameter (m)
On-Site Heavy Mobile Equipment	750	25	2.4	0.16

Table 7.1.2 Dispersion Model Input Parameters – Construction Phase, Volume Sources

Source	Initial Lateral Length [a] (m)	Initial Vertical Length (m)	Estimated Release Height Above Ground-level (m)
On-Site Roads			
Open Pit to Crusher (3 sources – total length approx. 465 m)	155	0.93	2.0
Open Pit to Tailings Storage Facility (TSF) (8 sources – total length approx. 1,200 m)	155	0.93	2.0
Quarry to TSF (8 sources – total length approx. 1,200 m)	155	0.93	2.0

Notes:
[a] Haul routes (open pit to crusher, open pit to tailings and quarry to tailings) divided into equal segments in the model to maintain acceptable volume source dimension inputs. The total emissions along each route were also divided equally between each segment/source.

[1] Point sources include releases from stacks and vents. Volume sources include fugitive releases with initial volume. Area Sources include surface based fugitive releases over a specific surface area.



Path: V:\01218\active\121810356\gis\mapping\mxd\eia\7_summ_techstudies\7_1_sec_airfig_7_1_1_20130306_receptorgrid_nl.mxd

NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Receptor Grid for Dispersion and Deposition Modelling

Sisson Project:
Environmental Impact Assessment (EIA) Report, Napadogan, N.B.

Client: Sisson Mines Ltd.

Scale: 1:150,000	Project No.: 121810356	Data Sources: NBDNR	Fig. No.: 7.1.1
Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM	

Stantec

Map: NAD83 CSRS NB Double Stereographic

Table 7.1.3 Dispersion Model Input Parameters – Operation Phase, Point Sources

Category	Exhaust Gas Temperature (K)	Exhaust Gas Exit Velocity (m/s)	Exhaust Point Height Above Ground-level (m)	Exhaust Point Exit Diameter (m)
Mineral Processing				
Haul Trucks	770	30	5.0	0.25
Other Mining Equipment	770	30	2.0	0.15
Primary Crusher	298	10	15	0.5
Ammonium Paratungstate (APT) Plant				
Boiler	423	13.2	13.8	0.6
H_2S Scrubber	293	14.3	15.3	0.6
NH_3 Scrubber	313	14.3	15.3	0.6

Table 7.1.4 Dispersion Model Input Parameters – Operation Phase, Area Sources

Source	Estimated Release Height Above Ground-level (m)	Initial Dimension – X Direction (m)	Initial Dimension – Y Direction (m)	Initial Dimension – Z Direction (m)
Coarse Ore Stockpile	3	43.2	43.2	4.5
Tailings Beaches	2	950	350	3.5

Table 7.1.5 Dispersion Model Input Parameters – Operation Phase, Volume Sources

Source	Initial Lateral Length (m)	Initial Vertical Length (m)	Estimated Release Height (m)
On-Site Roads			
Open Pit to Crusher (3 sources – total length approx. 465 m) [a]	155	0.93	2.0
Open Pit to Tailings Storage Facility (TSF) (8 sources – total length approx. 1,200 m) [a]	155	0.93	2.0
Quarry to TSF (8 sources – total length approx. 1,200 m) [a]	155	0.93	2.0
Material Transfer Points			
Truck Unloading at Crusher	1.16	0.93	2.0
From Crusher to Conveyor	1.16	0.93	2.0
From Conveyor to Stockpile	1.16	0.93	2.0
Miscellaneous			
Pit Blasting	25.6	0.47	1.0

Notes:
[a] Haul routes (open pit to crusher, open pit to tailings and quarry to tailings) divided into equal segments in the model to maintain acceptable volume source dimension inputs. The total emissions along each route were also divided equally between each segment/source.

7.1.1.2.4 Building Downwash

The modelling considers the effects of downwash due to wind flow over and around the surrounding buildings. Since building wake effects may influence the predictions (USEPA 1997), the input file includes building heights and widths using the USEPA Building Profile Input Program (BPIP-PRIME).

7.1.1.2.5 Model Outputs, Data Processing, and Interpretation of Results

After running the dispersion and deposition model, output files were generated for the maximum 1-hour, 8-hour and 24-hour predicted ground-level concentrations and annual average ground-level concentrations at each receptor for the complete 6-year time period spanned by the meteorological input file.

Deposition modelling provides deposition rates for selected Non-Criteria Air Contaminants (Non-CAC) Non-CAC in support of the HHERA. Stantec modelled deposition, including wet and dry particulate and gaseous deposition, of applicable air contaminants. The deposition parameters used for the modelling for each air contaminant are from the document entitled "Deposition Parameterizations for the Industrial Source Complex (ISC3) Model" (Wesley *et al.* 2002).

A screening level modelling analysis of the fugitive particulate matter emissions from road dust due to vehicle movements on off-site access roads during both Construction and Operation was also conducted. This screening level analysis was separate from the modelling of the on-site Project sources since the off-site routes are relatively far from the other sources (>2 km) therefore the resulting ground-level dust concentrations should not overlap. This was modelled with the screening level version of AERMOD (AERMOD Screening Model, AERSCREEN).

Odour threshold values used for comparison with the odour modelling results came from published odour thresholds (Verschueren 1996; AIHA 1989; Amoore and Hautala 1983; Environment Canada 1984; van Gemert 2003; and AENV 2011). It should be noted that odour detection is subjective with different people detecting different odours at varying concentrations or amounts. For this reason, odour is often evaluated by a large group, or odour panel. Odour thresholds are defined as concentrations where 50% of the participants in an odour panel test would detect the odour. To account for potential short-term environmental effects due to odourous compounds, an averaging period of 10 minutes is typically used.

7.1.1.3 Establishing Background Conditions

The Baseline Ambient Air Quality Technical Report (Stantec 2012b) provides measured ambient air quality data to characterize the existing (baseline) ambient air quality conditions. A summary of these existing conditions is also provided in Section 8.2.2. These data establish the background concentrations used in the dispersion and deposition modelling. The dispersion model establishes the incremental changes related to Project activities during the Construction and Operation phases, and includes consideration of these baseline values by adding maximum model-predicted values to measured ambient (*i.e.*, background) air quality values.

The estimate of baseline ambient air contaminant concentrations near the Project for relevant averaging periods considers monitoring data from the baseline monitoring conducted by Northcliff at Napadogan (Stantec 2012b), as well as regional monitoring data from the NBDELG. Wherever available, the baseline uses data from the Napadogan site as it is the nearest monitoring site to the Project. For averaging periods of 24-h or less, the established background value is the maximum 90th percentile of the baseline monitoring data, or the most recent monitored data from NBDELG. The use of the 90th percentile for background concentrations for short-term averaging periods is based on guidance from the Alberta Department of Environment (AENV 2009). For annual averaging periods, the baseline values are the six month averages of the data collected at Napadogan.

Table 7.1.6 presents the Criteria Air Contaminant (CAC) background concentrations used in the modelling analysis. The Non-CAC background concentrations are provided in Table 7.1.7. Ambient baseline values are estimated where data exist for relevant averaging periods. For certain air contaminants, limited or no ambient data exist. For the cases where no data exist, the background concentrations were assumed to be negligible. Where limited data exist, details of the tables below specify the data treatment.

Table 7.1.6 Ambient Background Criteria Air Contaminant (CAC) Concentrations Used for Modelling

Criteria Air Contaminant (CAC)	Averaging Period	Background Ground-Level Concentration Used ($\mu g/m^3$)	Notes
Sulphur dioxide (SO_2)	1-hour [a]	5.5	Based on the maximum 90th percentile of weekly values from baseline monitoring in Napadogan. 1-hour and 24-hour average background concentration estimated using the Ontario Ministry of Environment (OMOE) relation. Annual background concentration based on six month average of weekly values.
	24-hour [a]	2.3	
	Annual	1.1	
Nitrogen dioxide (NO_2)	1-hour [a]	13	Based on the maximum 90th percentile of weekly values from baseline monitoring in Napadogan. 1-hour and 24-hour average background concentration estimated using OMOE relation. Annual background concentration based on six month average of weekly values.
	24-hour [a]	5.5	
	Annual	2.0	
Carbon monoxide (CO)	1-hour [a]	1,818	Estimated using annual average concentration measured at Fredericton (Aberdeen Street) station and OMOE relation.
	8-hour [a]	1,016	
Total particulate matter (PM)	24-hour	23	Based on the maximum 90th percentile of 24-hour values from baseline monitoring in Napadogan. Annual background concentration based on six month average of 24-hour values.
	Annual	11	
Particulate matter less than 10 microns (PM_{10})	24-hour	- (not measured)	No ambient monitoring for PM_{10} near the Project site or at other nearby stations operated by Industry or the NBDELG.
Particulate matter less than 2.5 microns ($PM_{2.5}$)	24-hour	6.1	Based on the maximum 90th percentile of 24-hour values from baseline monitoring in Napadogan.
Ammonia (NH_3)	24-hour	-	No ambient monitoring for Ammonia near Project site or at other nearby stations operated by Industry or NBDELG.
Hydrogen sulphide (H_2S)	1-hour	-	No ambient monitoring for H_2S near Project site. Since the Project site is located in a remote wooded area, background H_2S concentrations are expected to be negligible.
	24-hour	-	

Notes:

[a] Ambient background concentrations (24-h or weekly) were converted to an alternate averaging period using the following equation described in Table 7-1 in the OMOE's document "Procedure for Preparing an Emission Summary and Dispersion Modelling Report", dated July 2005: $C_0 = C_1 \times (t_1/t_0)^n$ where C_0 = the concentration at the averaging period t_0, C_1 = the concentration at the averaging period t_1, and n = 0.28.

Table 7.1.7 Ambient Background Non-Criteria Air Contaminant (Non-CAC) Concentrations Used for Modelling

CAS Number	Non-Criteria Air Contaminant (Non-CAC)	Averaging Period	Background Ground-Level Concentration Used [a] ($\mu g/m^3$)
124-18-5	Decane [e]	24-hour	-
100-41-4	Ethylbenzene [e]	24-hour	-
91-20-3	Naphthalene [e]	24-hour	-
25549-16-0	Tri-isooctylamine [e]	1-hour	-
7429-90-5	Aluminum	1-hour [b, c]	0.70
7440-38-2	Arsenic	24-hour	2.5E-03
7440-43-9	Cadmium	24-hour	8.2E-04
		Annual [d]	7.2E-04
7440-47-3	Chromium (total)	24-hour	1.0E-03
7440-50-8	Copper	24-hour	0.27
7439-92-1	Lead	24-hour	2.7E-03
		30 days [c]	1.0E-03
7439-98-7	Molybdenum	24-hour	1.2E-03
7439-97-6	Mercury	24-hour	8.0E-06
7440-02-0	Nickel	24-hour	1.2E-03
		Annual [d]	1.1E-03
7782-49-2	Selenium	24-hour	4.1E-03
7440-33-7	Tungsten	24-hour	0.03
7440-66-6	Zinc	24-hour	0.02

Notes:

[a] Unless otherwise noted, the maximum annual 90th percentile of 24-h values measured during the baseline monitoring at the Napadogan site was used.

[b] For non-criteria air contaminants with no OMOE criteria, a 1-h averaging period was considered.

[c] Ambient background concentrations (24-h) were converted to an alternate averaging period using the following equation described in Table 7-1 in the OMOE's document "Procedure for Preparing an Emission Summary and Dispersion Modelling Report", dated July 2005: $C_0 = C_1 \times (t_1/t_0)^n$ where C_0 = the concentration at the averaging period t_0, C_1 = the concentration at the averaging period t_1, and n = 0.28.

[d] Six month average of 24-hour concentration data collected at Napadogan site.

[e] No ambient monitoring for air contaminant near Project site or at other nearby stations operated by Industry or NBDELG.

7.1.2 Dispersion and Deposition Modelling Results

The results of the dispersion and deposition modelling carried out for the Project for Construction and Operation are presented in this section.

7.1.2.1 Construction

Tables 7.1.8 and 7.1.9 provide the results of the dispersion modelling of air contaminant emissions resulting from Construction activities.

Table 7.1.8 Dispersion Modelling Results – Maximum Predicted Ground-Level Concentrations of Criteria Air Contaminants (CACs) – Construction Phase – On-site Project Sources

Contaminant	Averaging Period	Background Concentration (µg/m³)	Location of Modelled Maximum Concentration		Maximum Overall Predicted Ground-Level Concentration from the Project (µg/m³)	Maximum Overall Predicted Ground-Level Concentration from the Project plus Background (µg/m³)	Objective, Guideline or Standard (µg/m³)	Percentage of Objective/ Guideline or Standard
			UTM X (m)	UTM Y (m)				
SO_2	1-hour maximum	5.5	650,800	5,135,600	0.16	5.66	900	<1%
	24-hour maximum	2.3	648,900	5,137,100	0.02	2.32	300	<1%
	Annual average	1.1	648,900	5,137,100	0.002	1.10	60	2%
NO_2	1-hour maximum	13	650,800	5,135,600	61.4	74.4	400	19%
	24-hour maximum	5.5	648,900	5,137,100	7.08	12.6	200	6%
	Annual average	2.0	648,900	5,137,100	0.94	2.94	100	3%
CO	1-hour maximum	1,818	650,800	5,135,600	41.4	1,859	35,000	5%
	8-hour maximum	1,016	648,900	5,137,100	8.81	1,025	15,000	7%
PM	24-hour maximum	23	649,300	5,136,700	22.5	45.5	120	38%
	Annual average	11	649,300	5,136,700	1.82	12.8	70	18%
PM_{10}	24-hour maximum	-	649,300	5,136,700	6.83	-	50	14%
$PM_{2.5}$	24-hour maximum	6.1	648,900	5,137,100	1.01	7.11	30	24%

Notes:
A value in **bold** indicates a value in excess of the applicable objective, guideline or standard.

Table 7.1.9 Dispersion Modelling Results – Maximum Predicted Ground-Level Concentrations of Criteria Air Contaminants (CACs) – Construction Phase – Off-site Access Road Dust Emissions

Contaminant	Location	Background Concentration (µg/m³)	Maximum Overall Predicted 24-hour Average Ground-Level Concentration from the Project (µg/m³)	Maximum Overall Predicted 24-hour Average Ground-Level Concentration from the Project plus Background (µg/m³)	Objective/ Guideline/ Standard µg/m³)	Percentage of Objective/ Guideline/ Standard
PM	100 m from access road	23	**553**	**576**	120	**480%**
	Nearest Residence (850 m from access road)		37.0	60.0		50%
	Nearest Camp (1,250 m from access road)		21.4	44.4		37%
PM_{10}	100 m from access road	-	**150**	**-**	50	**299%**
	Nearest Residence (850 m from access road)		10.0	-		20%
	Nearest Camp (1,250 m from access road)		5.80	-		12%
$PM_{2.5}$	100 m from access road	6.1	15.0	21.1	30	70%
	Nearest Residence (850 m from access road)		1.00	7.10		24%
	Nearest Camp (1,250 m from access road)		0.58	6.68		22%

Notes:
A value in **bold** indicates a value in excess of the applicable objective, guideline or standard.

There are no known substantive sources of non-criteria air contaminants expected during the Construction phase. As such, the dispersion modelling results presented above are limited to criteria air contaminants.

Figures 7.1.2 to 7.1.5 depict the predicted maximum ground-level concentrations during Construction for 1-hour NO_2, 24-hour PM, 24-hour PM_{10} and 24-hour $PM_{2.5}$, respectively. These include the predicted ground-level concentrations due to on-site Project sources plus background, with the exception of 24-hour PM_{10}, which does not include background concentrations (as noted above). Since predicted ground-level concentrations of SO_2 and CO associated with the Project were very low compared to background and the associated objective/standard these are not presented graphically. Numerical results for these parameters are provided in Table 7.1.8.

As shown in Table 7.1.8, predicted maximum ground-level concentrations of other contaminants (*i.e.,* SO_2, NO_2, CO, PM, PM_{10} and $PM_{2.5}$) during Construction result in a maximum overall predicted ground-level concentration from the Project plus background that is less than 25% of the objective, guideline or standard, and are thus considered negligible. As shown in Table 7.1.9, the predicted maximum ground-level concentrations of PM, PM_{10} and $PM_{2.5}$ are also well below the applicable objectives and standards at the nearest residences and recreational campsites, but maximum ground-level concentrations of PM and PM_{10} exceed the respective objectives or standards on occasion as a result of fugitive dust emissions on forest resource roads.

There are no substantive emissions of Non-CAC during Construction. Modelling is therefore not required for these parameters.

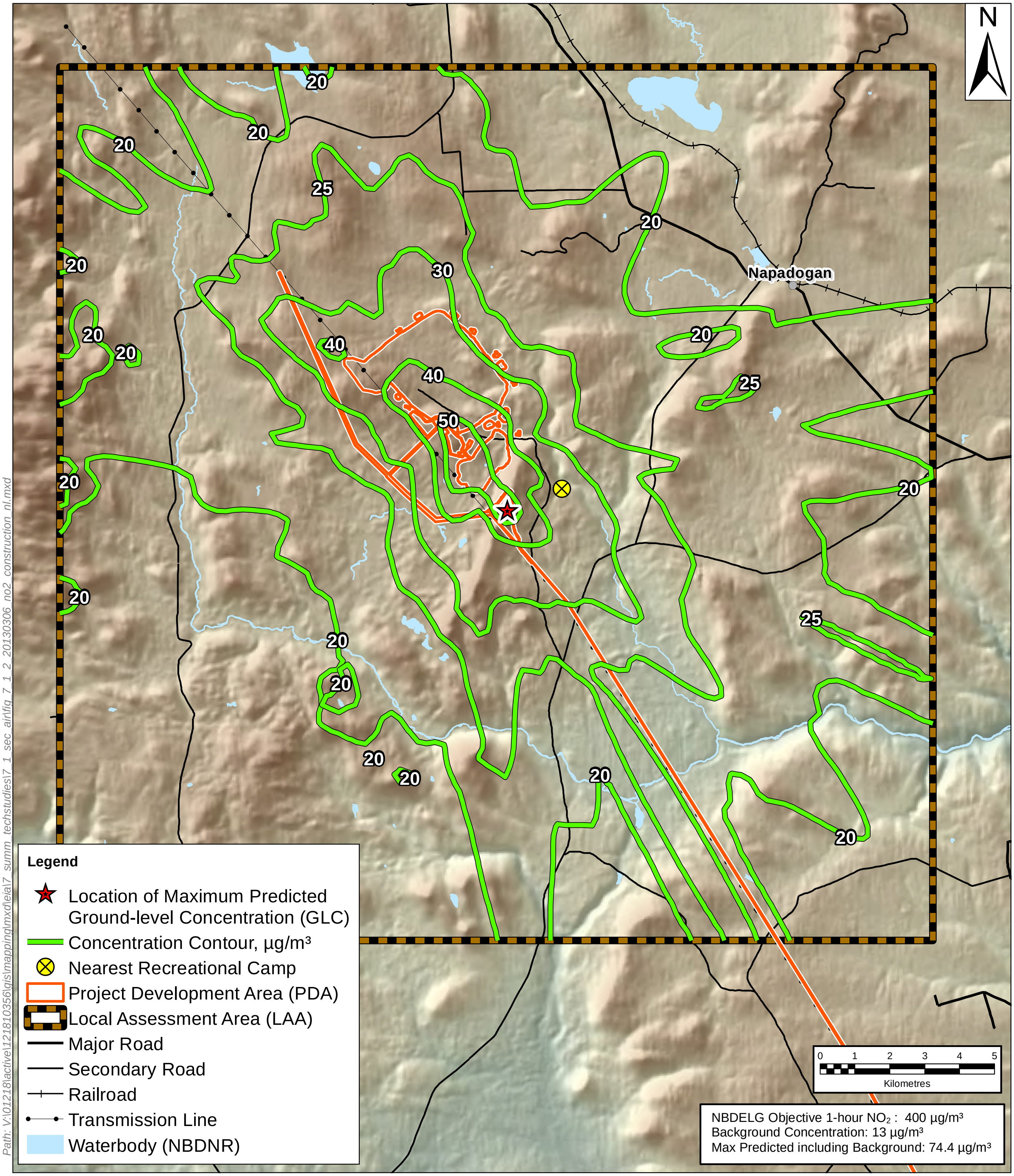
7.1.2.2 Operation

Tables 7.1.10 and 7.1.11 provide the results of the dispersion modelling for criteria air contaminants (CAC) during the Operation phase. Table 7.1.12 provides the dispersion modelling results for the non-CAC emissions during the Operation phase.

Table 7.1.10 Dispersion Modelling Results – Maximum Predicted Ground-Level Concentrations of Criteria Air Contaminants (CACs) – Operation Phase – On-Site Project Sources

Contaminant	Averaging Period	Background Concentration (µg/m^3)	Location of Modelled Maximum Concentration		Maximum Overall Predicted Ground-Level Concentration from the Project (µg/m^3)	Maximum Overall Predicted Ground-Level Concentration from the Project plus Background (µg/m^3)	Objective, Guideline or Standard (µg/m^3)	Percentage of Objective/ Guideline or Standard
			UTM X (m)	UTM Y (m)				
SO_2	1-hour maximum	5.5	648,900	5,137,300	0.12	5.62	900	<1%
	24-hour maximum	2.3	648,800	5,137,400	0.03	2.33	300	<1%
	Annual average	1.1	648,800	5,137,400	0.01	1.11	60	2%
NO_2	1-hour maximum	13	651,400	5,137,600	87.6	101	400	25%
	24-hour maximum	5.5	650,800	5,135,600	20.0	25.5	200	13%
	Annual average	2.0	651,100	5,136,900	3.24	5.24	100	5%
CO	1-hour maximum	1,818	651,400	5,137,600	38.2	1,856	35,000	5%
	8-hour maximum	1,016	651,700	5,136,900	21.7	1,038	15,000	7%
PM	24-hour maximum	23	649,300	5,136,700	**526**	**549**	120	**458%**
	Annual average	11	649,300	5,136,700	14.9	25.9	70	37%
PM_{10}	24-hour maximum	--	649,300	5,136,700	38.8	-	50	78%
$PM_{2.5}$	24-hour maximum	6.1	649,300	5,136,700	6.05	12.1	30	40%
NH_3	24-hour maximum	--	648,800	5,137,400	0.44	-	100	<1%
H_2S	1-hour maximum	--	648,800	5,137,400	4.98	-	15	33%
	24-hour maximum	--	648,800	5,137,400	0.94	-	5	19%

Notes:
A value in **bold** indicates a value in excess of the applicable objective, guideline or standard.



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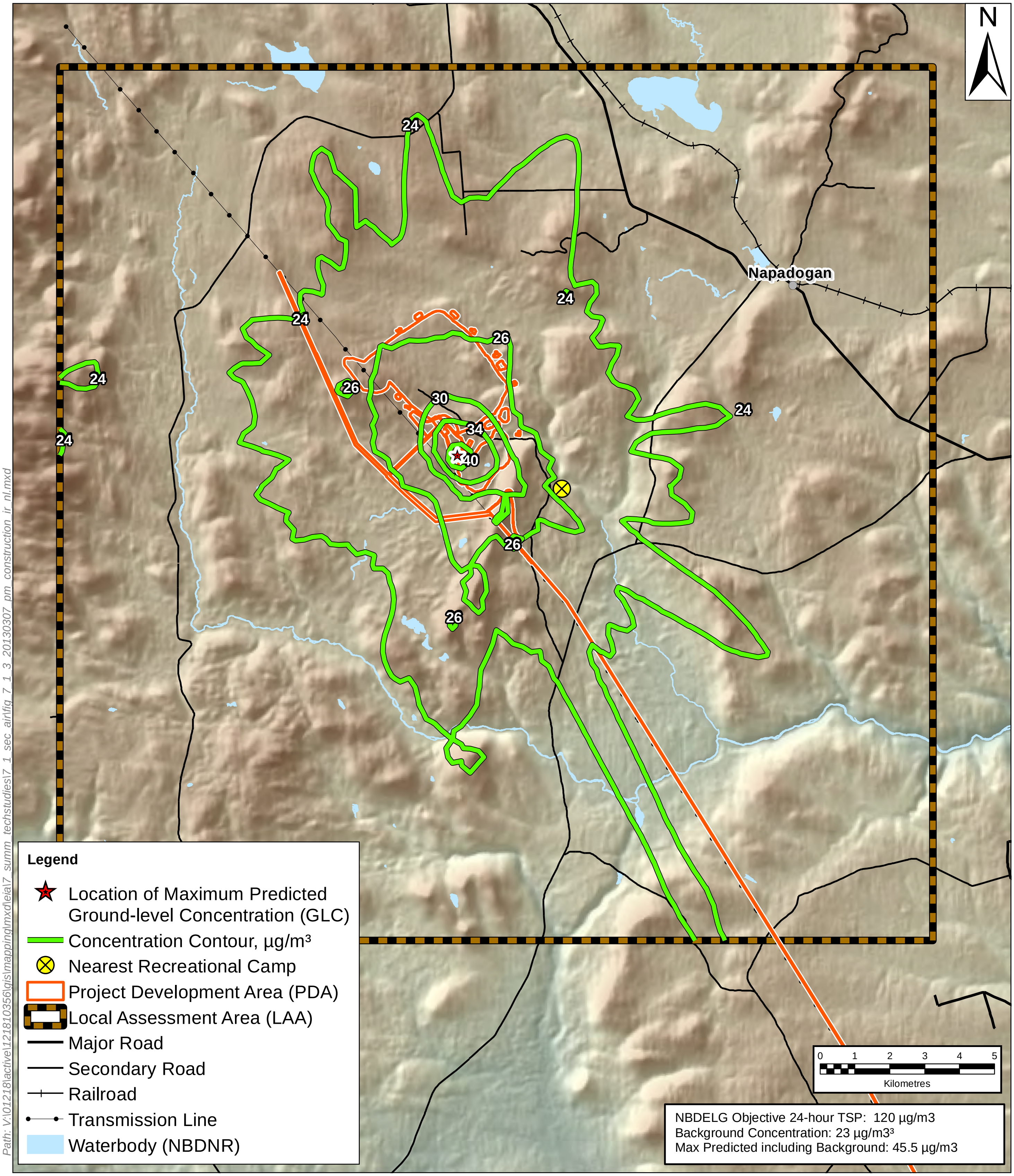
NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 1-Hour Ground-Level Concentrations of Nitrogen Dioxide Construction Phase - Project Plus Background Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356	Data Sources: NBDNR	Fig. No.: 7.1.2	Stantec
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		
Client: Sisson Mines Ltd.					

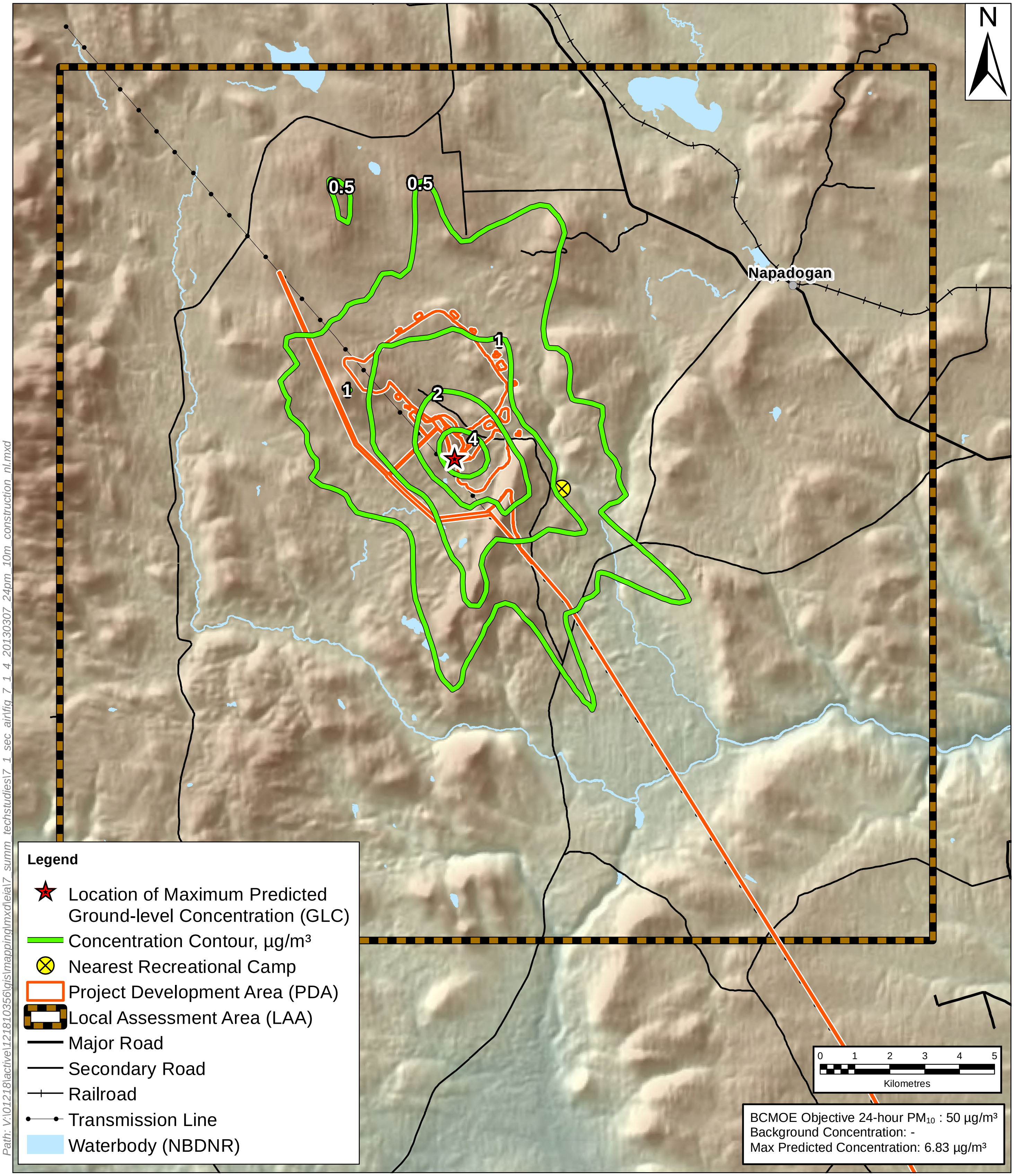
Map: NAD83 CSRS NB Double Stereographic



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Total Particulate Matter Construction Phase - Project Plus Background Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356		Data Sources: NBDNR	Fig. No.: 7.1.3
Client: Sisson Mines Ltd.	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		

Map: NAD83 CSRS NB Double Stereographic



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NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Particulate Matter Less Than 10 Microns Construction Phase - Project Alone

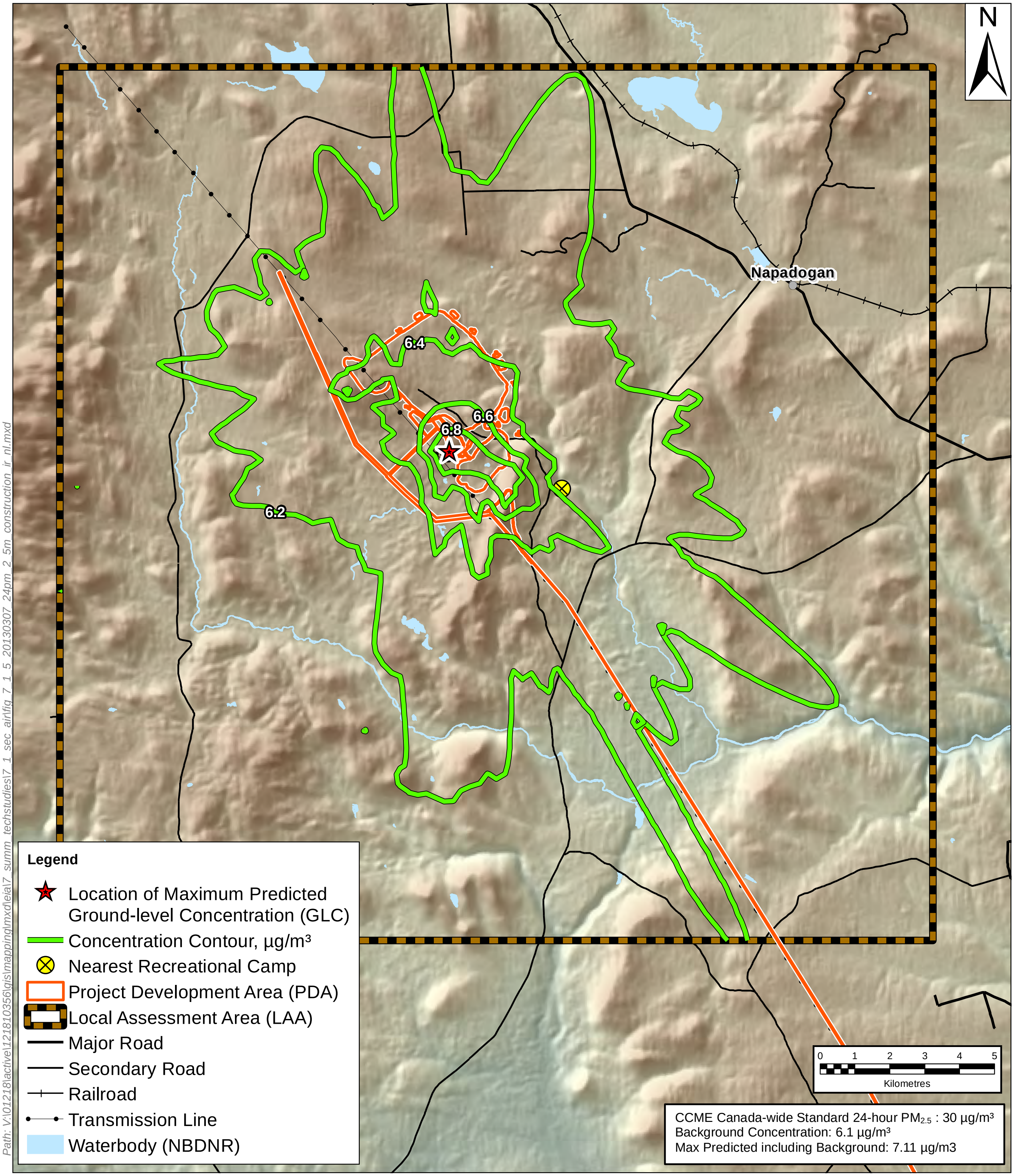
Sisson Project:
Environmental Impact Assessment (EIA) Report, Napadogan, N.B.

Client: Sisson Mines Ltd.

Scale:	1:150,000
Project No.:	121810356
Data Sources:	NBDNR
Fig. No.:	7.1.4
Date: (dd/mm/yyyy)	23/11/2014
Dwn. By:	JAB
Appd. By:	DLM

Stantec

Map: NAD83 CSRS NB Double Stereographic



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NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Particulate Matter Less Than 2.5 Microns - Construction Phase - Project Plus Background Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356		Data Sources: NBDNR	Fig. No.: 7.1.5	Stantec
Client: Sisson Mines Ltd.	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM			

Map: NAD83 CSRS NB Double Stereographic

Table 7.1.11 Dispersion Modelling Results – Maximum Predicted Ground-Level Concentrations of Criteria Air Contaminants (CACs) – Operation Phase – Off-site Access Road Dust Emissions

Contaminant	Location	Background Concentration (µg/m³)	Maximum Overall Predicted 24-hour Average Ground-Level Concentration from the Project (µg/m³)	Maximum Overall Predicted 24-hour Average Ground Level Concentration from the Project plus Background (µg/m³)	Objective/ Guideline/ Standard (µg/m³)	Percentage of Objective/ Guideline/ Standard
PM	100 m from access road	23	**814**	**837**	120	**698%**
	Nearest Residence (850 m from access road)		54.5	77.5		65%
	Nearest Camp (1,250 m from access road)		31.6	54.6		46%
PM_{10}	100 m from access road	-	**217**	**-**	50	**434%**
	Nearest Residence (850 m from access road)		14.5	-		29%
	Nearest Camp (1,250 m from access road)		8.40	-		17%
$PM_{2.5}$	100 m from access road	6.1	22.4	28.5	30	95%
	Nearest Residence (850 m from access road)		1.50	7.60		25%
	Nearest Camp (1,250 m from access road)		0.87	6.97		23%

Notes:
A value in **bold** indicates a value in excess of the applicable objective, guideline or standard.

Table 7.1.12 Dispersion Modelling Results – Maximum Predicted Ground-Level Concentrations of Non-Criteria Air Contaminants (Non-CACs) – Operation Phase

Contaminant	Averaging Period	Background Concentration (μg/m^3)	Location of Modelled Maximum Concentration		Maximum Overall Predicted Ground-Level Concentration from the Project (μg/m^3)	Maximum Overall Predicted Ground-Level Concentration from the Project plus Background (μg/m^3)	Objective, Guideline or Standard (μg/m^3)	Percentage of Objective/ Guideline or Standard
			UTM X (m)	UTM Y (m)				
Decane	1-hour	--	648,800	5,137,400	42.3	--	60,000	<1%
Ethylbenzene	24-hour	--	648,800	5,137,400	0.33	--	1,000	<1%
Naphthalene	24-hour	--	648,800	5,137,400	1.19	--	22.5	5%
Tri-isooctylamine	1-hour	--	648,800	5,137,400	41.9	--	--	--
Aluminium	1-hour	0.70	649,300	5,136,700	226	227	--	--
Arsenic	24-hour	2.5E-03	649,300	5,136,700	0.022	0.024	0.3	8%
Cadmium	24-hour	8.2E-04	649,300	5,136,700	0.011	0.011	0.025	45%
	Annual	7.2E-04	649,300	5,136,700	3.0E-05	7.5E-04	0.005	15%
Chromium	24-hour	1.0E-03	649,300	5,136,700	0.035	0.036	0.5	7%
Copper	24-hour	0.27	649,300	5,136,700	0.10	0.37	50	<1%
Lead	24-hour	2.7E-03	649,300	5,136,700	0.024	0.026	0.5	5%
	30 days	1.0E-03	649,300	5,136,700	9.2E-03	0.010	0.2	5%
Mercury	24-hour	8.0E-06	648,800	5,137,400	6.0E-05	6.8E-05	2	<1%
Molybdenum	24-hour	1.2E-03	649,300	5,136,700	0.029	0.030	120	<1%
Nickel	24-hour	1.2E-03	649,300	5,136,700	0.011	0.012	0.2	6%
	Annual	1.1E-03	649,300	5,136,700	2.5E-04	1.4E-03	0.04	3%
Selenium	24-hour	4.1E-03	649,200	5,136,600	7.8E-04	4.9E-03	10	<1%
Tungsten	24-hour	0.03	649,300	5,136,700	0.051	0.081	--	--
Zinc	24-hour	0.02	649,300	5,136,700	0.079	0.099	120	<1%

Notes:
A value in **bold** indicates a value in excess of the applicable objective, guideline or standard.

The maximum predicted ground-level concentrations during the Operation phase for selected air contaminants are presented in Figures 7.1.6 to 7.1.11. These include the predicted ground-level concentrations due to on-site Project sources plus background, with the exception of 24-hour PM_{10} or naphthalene, which does not include background concentrations (as previously noted).

During Operation, there were no predicted exceedances of the ground-level air quality objectives for NO_2, SO_2, CO, NH_3 and H_2S, including background where applicable. Similarly, the predicted maximum ground-level concentrations of PM, PM_{10} and $PM_{2.5}$ are below the applicable objectives and standards at the nearest residences and recreational campsites. The 24-hour PM objective was exceeded at three receptors near the primary crusher (approximately 20 m to the southwest of the crusher); however, the frequency of exceedance at these receptors is low (*i.e.*, up to four exceedances of the 24-hour PM objective over the 6-year meteorological file, or 0.2% of the time). Additionally, the model predicts maximum ground-level concentrations of PM and PM_{10} above the respective objectives and standards on occasion, along off-site access roads.

Table 7.1.13 provides the maximum predicted ambient ground-level concentrations of odourous compounds as 10-minute averages.

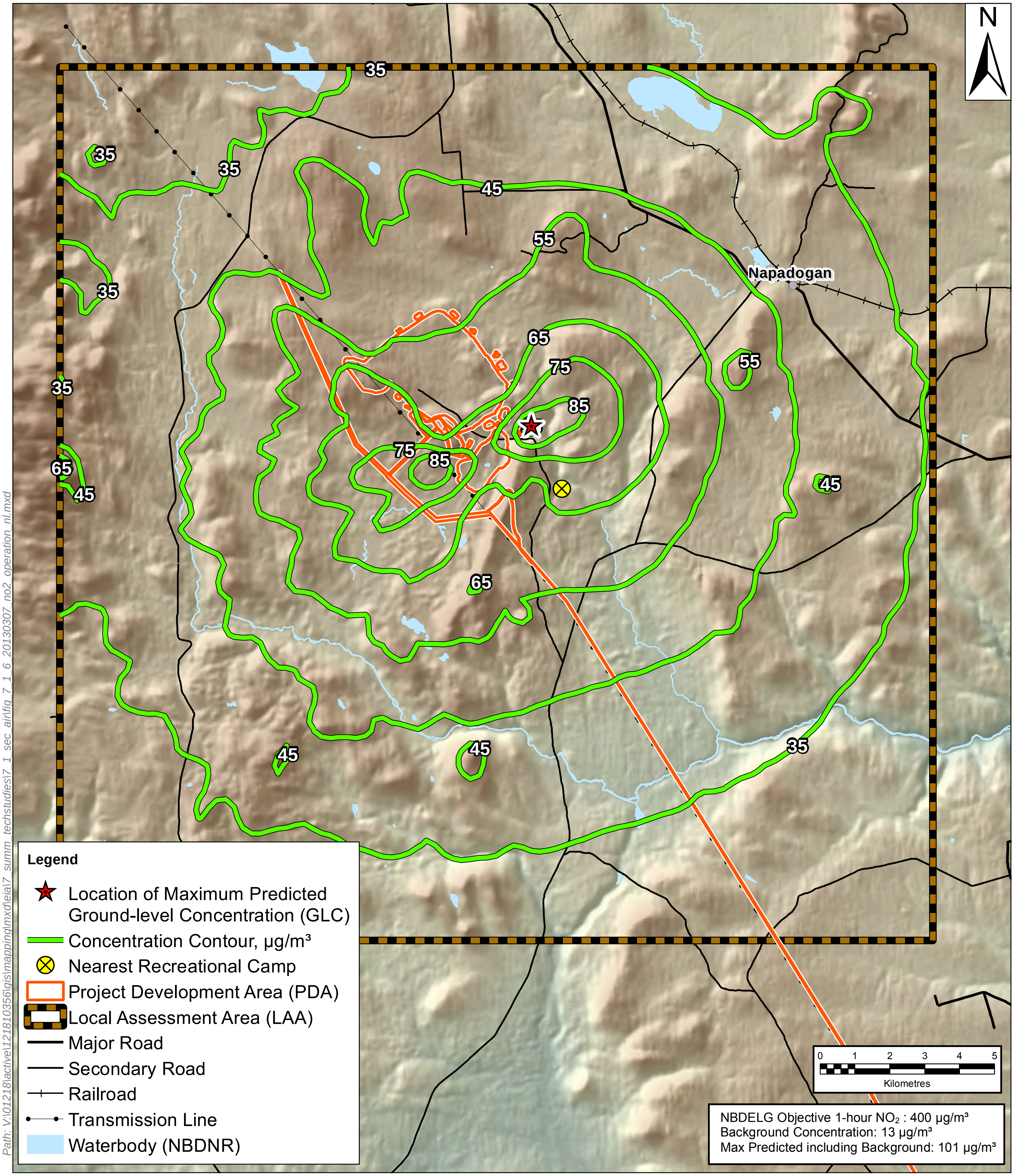
Table 7.1.13 Dispersion Modelling Results – Maximum Predicted 10-minute Ground Level Concentrations of Odourous Compounds – Operation Phase – Project Alone

Odourous Compound	Location of Modelled Maximum Ground-level Concentration		Maximum Overall Predicted 10-minute Ground-Level Concentration from the Project (µg/m³)	Odour Threshold (µg/m³)	Percentage of Odour Threshold
	UTM X (m)	UTM Y (m)			
Ammonia	648,800	5,137,400	0.72	2,312	<1%
Hydrogen Sulphide	648,800	5,137,400	**8.22**	7.4	**111%**
Decane	648,800	5,137,400	313	11,149	3%
Ethylbenzene	648,800	5,137,400	2.39	289	<1%
Naphthalene	648,800	5,137,400	8.66	50	17%

Notes:
A value in **bold** indicates a value in excess of the applicable odour threshold.

During Operation, the model predicts maximum 10-minute H_2S ground-level concentrations above the odour threshold at four locations. At the receptor location with the maximum predicted 10-minute H_2S ground-level concentration, the odour threshold is infrequently exceeded (*i.e.,* nine occurrences over the 6-year meteorological file, or less than 0.03% of the time). These receptors are located within 20 m to the southwest of the APT plant, on the Project site. No perceivable odour is expected beyond approximately 20 m of the APT plant.

Stantec modelled deposition, including wet and dry particulate and gaseous deposition, of applicable air contaminants. The deposition modelling was conducted using AERMOD. The predicted annual wet, dry and total deposition rates of trace metals and naphthalene were provided for inclusion as inputs to the human health and ecological risk assessment modelling.



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NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 1-Hour Ground-Level Concentrations of Nitrogen Dioxide – Operation Phase – Project Plus Background Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356	Data Sources: NBDNR	Fig. No.: 7.1.6
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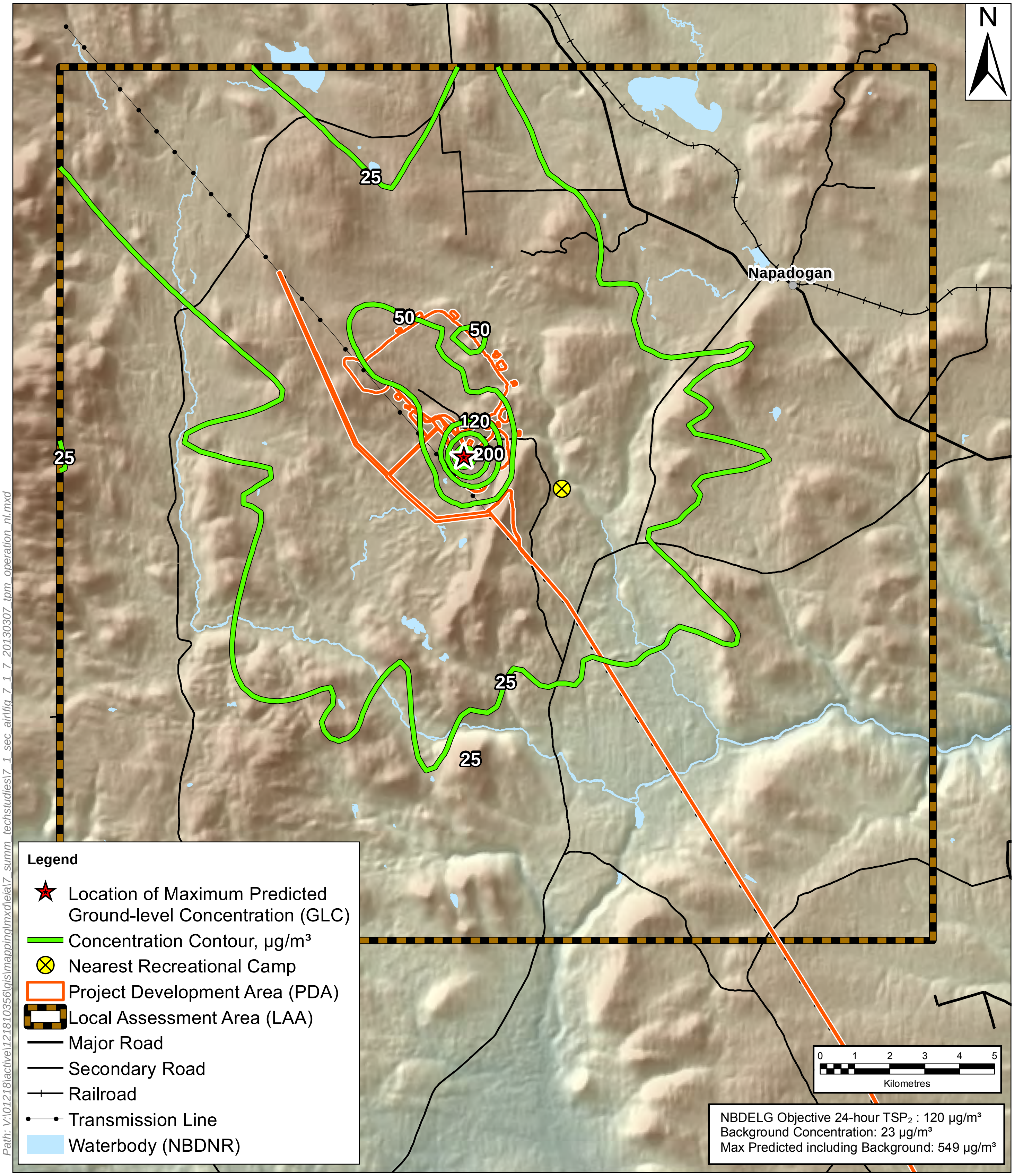
Client: Sisson Mines Ltd.				

Map: NAD83 CSRS NB Double Stereographic



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NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Total Particulate Matter – Operation Phase – Project Plus Background

Sisson Project:
Environmental Impact Assessment (EIA) Report, Napadogan, N.B.

Client: Sisson Mines Ltd.

Scale: 1:150,000

Project No.: 121810356

Date: (dd/mm/yyyy) 23/11/2014

Dwn. By: JAB

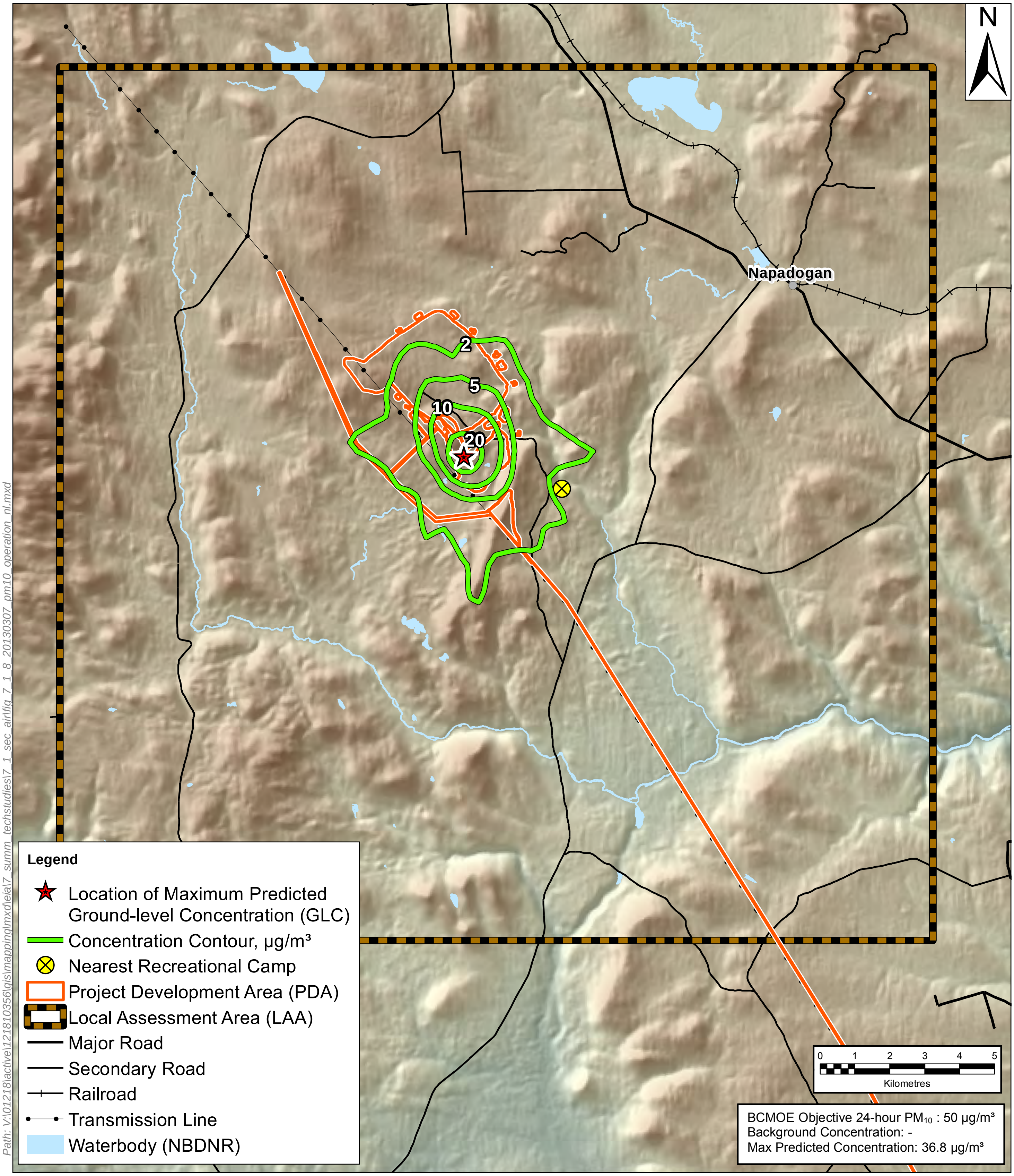
Appd. By: DLM

Data Sources: NBDNR

Fig. No.: 7.1.7

Stantec

Map: NAD83 CSRS NB Double Stereographic



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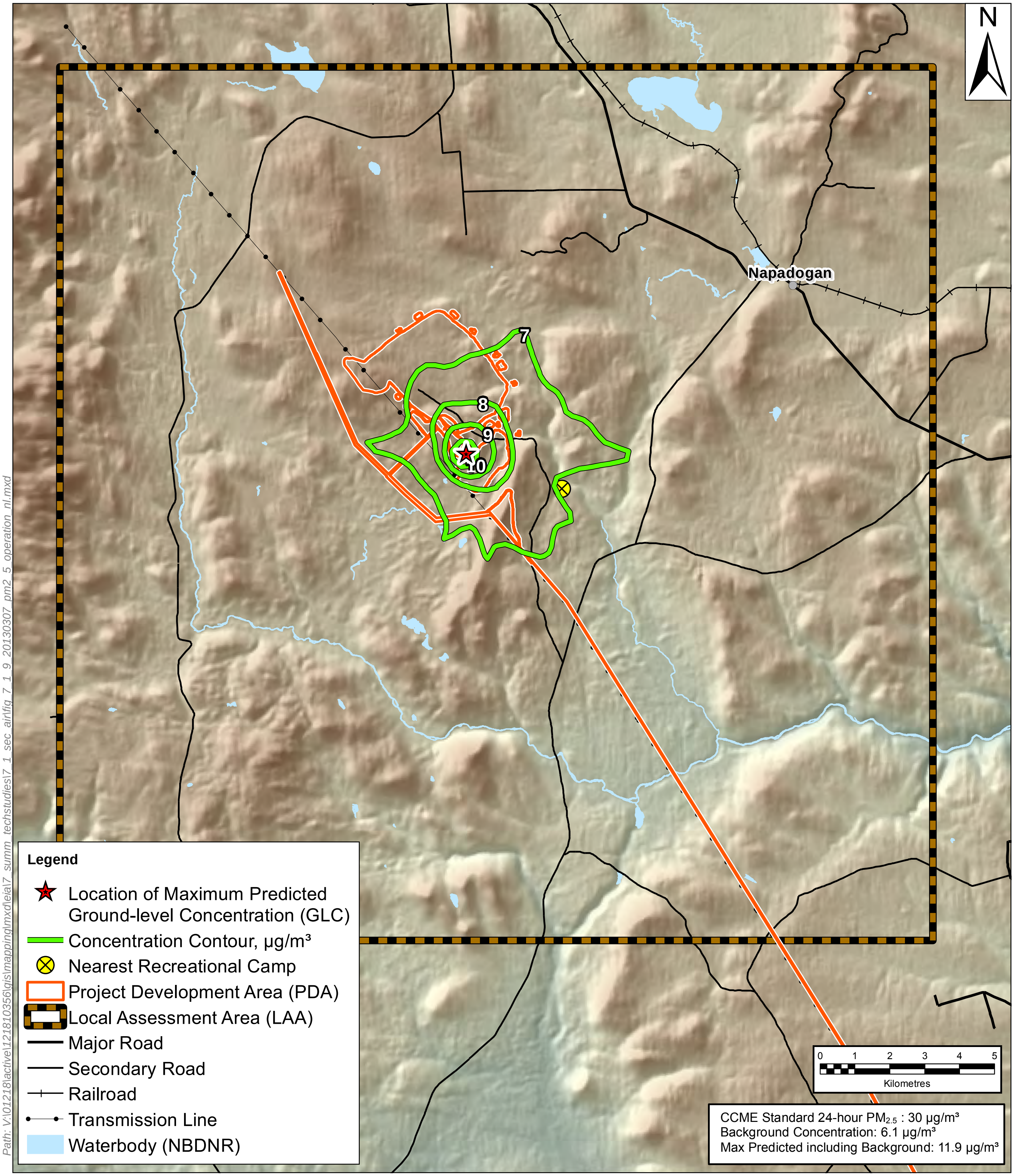
NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Particulate Matter Less Than 10 Microns – Operation Phase – Project Alone Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356		Data Sources: NBDNR	Fig. No.: 7.1.8
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		
Client: Sisson Mines Ltd.					

Stantec

Map: NAD83 CSRS NB Double Stereographic



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NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Particulate Matter Less Than 2.5 Microns – Operation Phase – Project Plus Background Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356		Data Sources: NBDNR	Fig. No.: 7.1.9
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		
Client: Sisson Mines Ltd.					

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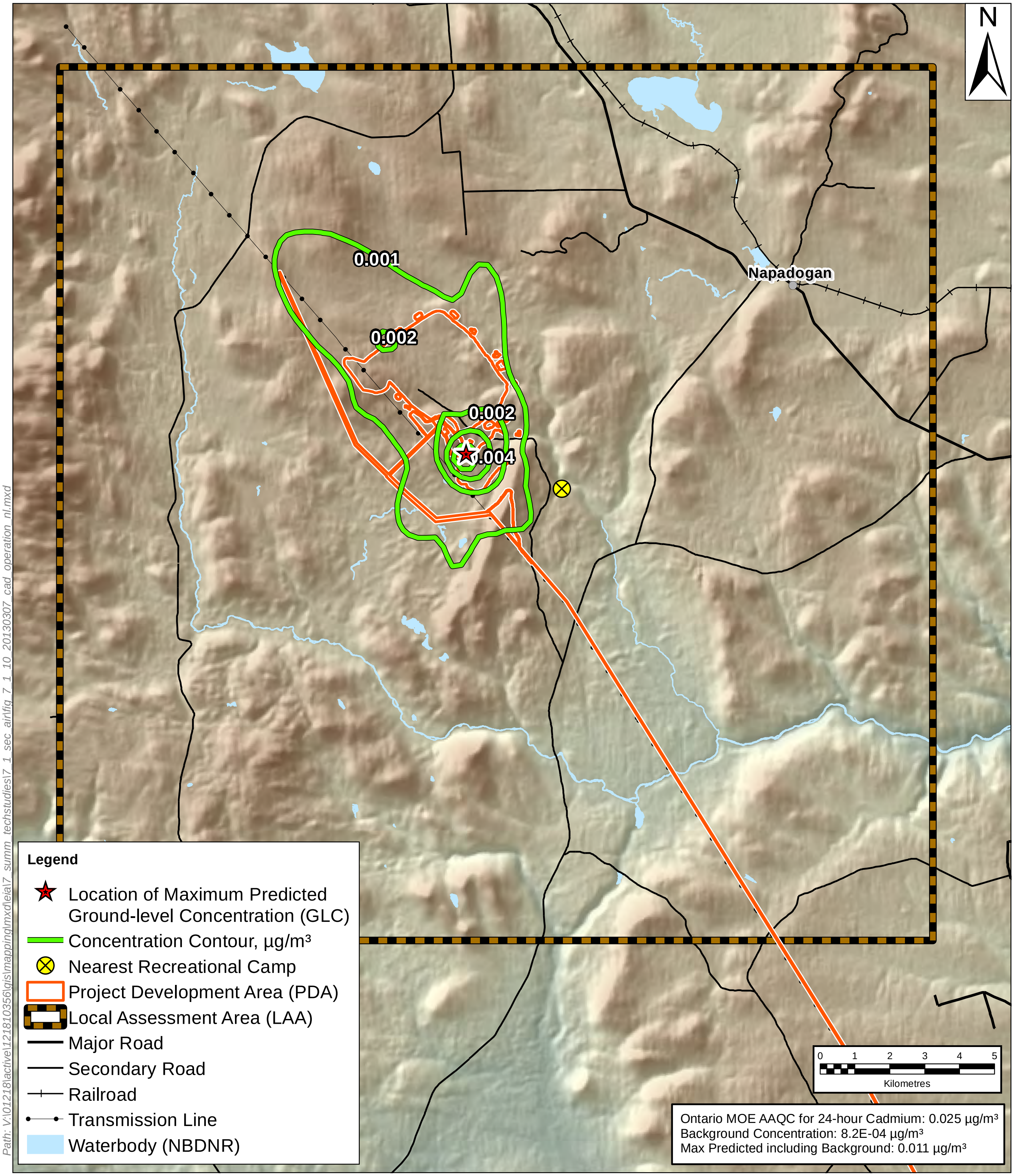

NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Cadmium - Operation Phase - Project Plus Background Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356	Data Sources: NBDNR	Fig. No.: 7.1.10
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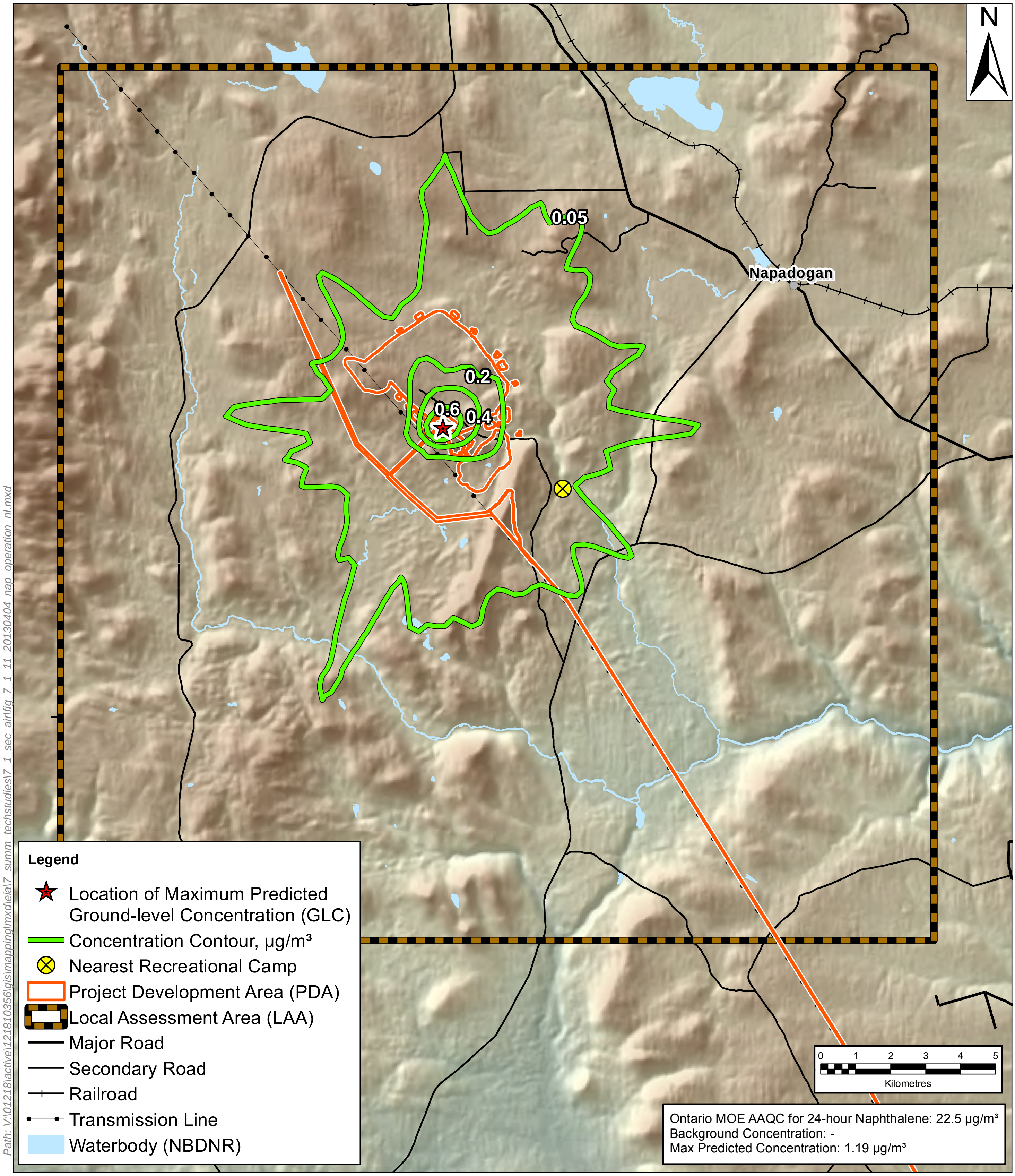
Client: Sisson Mines Ltd.				

Map: NAD83 CSRS NB Double Stereographic



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Maximum Predicted 24-Hour Ground-Level Concentrations of Naphthalene – Operation Phase – Project Alone Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:150,000	Project No.: 121810356		Data Sources: NBDNR	Fig. No.: 7.1.11
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		
Client: Sisson Mines Ltd.					

Map: NAD83 CSRS NB Double Stereographic

7.2 GREENHOUSE GAS (GHG) EMISSIONS

7.2.1 Project GHG Emissions Compared to New Brunswick, Canadian, and Global GHG Emissions

To quantitatively evaluate the change in GHG emissions provincially and globally due to Project Construction and Operation, estimated Project emissions were compared to published summary data for the province, Canada and the world. Table 7.2.1 presents these data.

Table 7.2.1 Comparison of Estimated Project GHG Emissions to Provincial and Global Totals

GHG Source	Total Estimated Emissions (kilotonnes CO_2e/a)
Project Construction (per year, based on 2 years of construction)	13.6
Project Operation – direct – per year	47.7
Project Operation – indirect (electricity) – per year	184
New Brunswick – Electricity and Heating sectors (per year, based on 2010 emissions)	5,470
New Brunswick Total (per year, based on 2010 emissions)	18,600
Canada Total (per year, based on 2010 emissions)	692,000
World Total (CAIT 2012)[a]	34,000,000
Notes: [a] Represents CO_2 only.	

In comparison to other large GHG emitters in New Brunswick, the Project is a relatively small contributor to provincial emissions, estimated to represent less than 0.3% annually during Operation (based on direct emissions).

In terms of indirect GHG emissions related to electricity use, the magnitude of these emissions will be essentially controlled by the emission factor for electricity provided from the New Brunswick electrical grid. The Project's GHG emissions during Operation are less than 3% compared to overall emissions from electrical generation in the province (Project indirect emissions) (New Brunswick Department of Energy 2011). It is important to also note that existing regulations and guidelines, for the most part, focus on direct emissions with the requirement that the emitter is responsible for their emissions management.

7.2.2 Project GHG Emissions Compared to Other Mining Operations in Canada

For comparison, GHG emissions from other operations within the mining industry were also reviewed. Fifteen metal mining operations reported GHG emissions to Environment Canada in 2010 (Environment Canada 2011b). Environment Canada requires reporting of GHG emissions from mining operations that release more than 50 kilotonnes (kt) per year of GHG. A summary of the reported emissions is provided in Table 7.2.2.

Table 7.2.2 Summary of Reported GHG Emissions from Canadian Mines - 2010

Facility	Reporting Company	Province	Material Mined[a]	Mining Type[a]	Reported Emissions (kilotonnes CO_2e/a)
Brunswick Mine	Xstrata Canada Corporation	New Brunswick	Lead, Zinc, Copper, Silver, Gold	Underground with Concentrator	58.3
Carol Project	Iron Ore Company of Canada	Newfoundland and Labrador	Iron	Open Pit with Concentrator	1,128
Fire Lake Mine[b]	ArcelorMittal Mines Canada	Québec	Iron	Open Pit	1.2
Meadow Bank Division	Agnico-Eagle Meadowbank	Nunavut	Gold	Open Pit with Concentrator	135
Mine du Mont-Wright	ArcelorMittal Mines Canada	Québec	Iron	Open Pit with Concentrator	151
Mines Wabush – Sept-Iles	Mines Wabush	Québec	Iron	Concentrator	396
Mount Polley Mine	Imperial Metals Corporation	British Columbia	Copper, Gold	Open Pit with Concentrator	45.3
Musselwhite Mine	Goldcorp Canada Ltd.	Ontario	Gold	Underground with Concentrator	48.8
Raglan Mine	Xstrata Canada Corporation	Québec	Nickel, Copper, Cobalt	Open Pit, Underground, with Concentrator	136
Teck Highland Valley Copper Partnership	Teck Highland Valley Copper Partnership	British Columbia	Copper, Molybdenum	Open Pit with Concentration	182
Thompson Operations	Vale Canada Limited	Manitoba	Nickel, Copper, Cobalt	Open Pit, Underground, with Concentrator	51.9
Usine de Bouletage	ArcelorMittal Mines Canada	Québec	Iron	Iron Pellet Plant	957
Voisey's Bay Mine	Vale Newfoundland and Labrador Limited	Newfoundland and Labrador	Nickel, Copper, Cobalt	Open Pit with Concentrator	67.3
Wabush Mines – Scully	Mines Wabush	Newfoundland and Labrador	Iron	Open Pit with Concentrator	96.1
Xstrata Nickel Sudbury Smelter	Xstrata Canada Corporation	Ontario	Nickel, Copper, Cobalt	Underground	115

Notes:
[a] The Mining Association of Canada (2011).
[b] Only operates between May and October (ArcelorMittal n.d.).

As shown in Table 7.2.2, the reporting mines released between 1.2 kt CO_2e and 1,128 kt CO_2e per year. The Project's estimated GHG emissions of 47.7 kt CO_2e/a during Operation are thus within the range of other mining operations and less than most reported.

Only GHG emissions from sources operated by the mine (*e.g.,* heavy equipment and stationary combustion fuel use) are reportable under the Environment Canada system. For the purpose of this EIA, some third party emissions were also included (*e.g.,* personnel transport, delivery vehicles) although those contributions were minor in comparison to the total facility GHG emissions.

7.2.3 GHG Emissions Intensity from the Project

With regard to GHG emissions intensity, the Sisson Project, with annual direct GHG emissions of approximately 47.7 kt CO_2e and 10.5 million tonnes of processed ore per year, therefore has a calculated GHG emissions intensity of 0.005 t CO_2e per tonne of ore processed.

Stantec conducted a review of available information on GHG intensities from mines in Canada. The Mount Polley mine is an open pit mine in British Columbia with an average mining rate of 20,000 tonnes per day (Imperial Metals 2010). The GHG emissions intensity of this mine is approximately 0.006 t CO_2e per tonne of ore processed. This is similar to the GHG emissions intensity of the Sisson Project.

The direct GHG emissions intensity for mining across all metal mining sectors in Canada in 2010 was approximately 0.014 t CO_2e per tonne of ore milled (CIEEDAC 2012). The GHG intensity of the Sisson Project is below the Canada-wide GHG emissions intensity.

7.2.4 Loss of Carbon Dioxide Sinks

With respect to the loss of carbon storage due to tree removal to accommodate the Project, the mass of carbon dioxide that is stored in trees within the PDA, based on a PDA area of 1,253 ha, is estimated at 8,419 t CO_2. This is a one-time loss that will be released from the aerobic decomposition of trees, which have been conservatively assumed to be cut and allowed to decay, whereas in reality, merchantable timber will be sold and other timber in the area of the TSF will be cut, buried in tailings and flooded before it decays. The total estimated CO_2 storage capacity in trees in New Brunswick is approximately 41 Mt CO_2. It was assumed that the trees in New Brunswick are 50% deciduous and 50% coniferous, with carbon storage data from the United States Department of Energy (USDOE 2000).

7.3 SOUND QUALITY AND VIBRATION MODELLING

As discussed in Chapter 3, the Project will release sound and vibration emissions to the ambient environment through Construction, Operation, and ultimately through Decommissioning, Reclamation and Closure activities. Among other sources, sound and/or vibration emissions may result from:

- the movement and use of heavy equipment on-site during Construction, and from the movement of ore and waste rock during Operation;
- the movement of heavy-duty trucks and passenger vehicles (including medium and light-duty vehicles) on-site and to and from the Project site during Construction, Operation, and Decommissioning, Reclamation and Closure;
- blasting activities during Construction and Operation for the movement of rock for construction purposes, and from ore extraction and mining activities during Operation; and
- operation of the mill and processing facilities, in particular from the crushers and associated conveying equipment, during Operation.

The assessment of the Project-related environmental effects on Sound Quality (Section 8.3) is based on the following three steps:

- monitoring of baseline sound pressure levels in the ambient environment near the Project in 2011 to determine existing (baseline) sound pressure levels in and near the PDA (see Section 8.3.2);
- estimating Project-related emissions of sound and vibration from the anticipated inventory of stationary and mobile sound emission sources associated with the Project during each phase, and anticipated emissions for these sources based on existing literature of sound power levels (see Sections 3.4.1.6.2 and 3.4.2.5.2 for sound emissions inventory during Construction and Operation, respectively); and
- modelling sound pressure levels and vibration emissions in the ambient environment using computer software that simulates how the emitted sound or vibration waves from the Project will propagate in the ambient environment near the Project (this Section).

7.3.1 Modelling Methodology

7.3.1.1 Sound

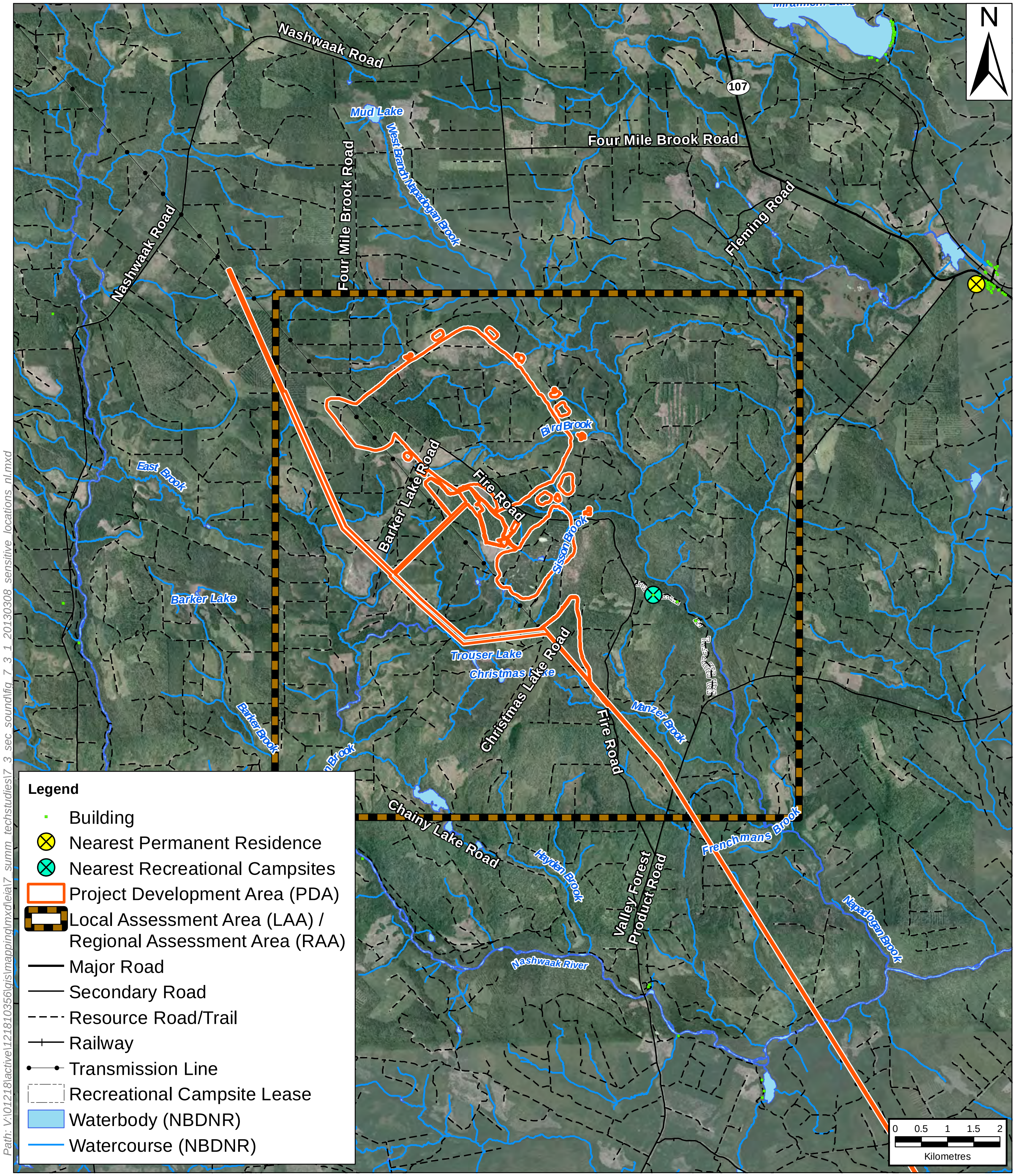
Stantec used the computer modelling software CadnaA (version 4.1.137) to estimate sound pressure levels from Project activities during Construction and Operation. Sound pressure levels from the Project during Decommissioning, Reclamation and Closure were assumed to be similar to those which would result during the Construction phase (*i.e.,* earth moving activities and hauling of decommissioned Project-related infrastructure to and from the Project site).

Inputs to the CadnaA model include: sound power levels at the source for Project-related equipment (*e.g.,* mobile equipment, stationary sources); terrain elevations; estimated hourly traffic volumes during each phase; and the identification of noise sensitive receptors.

The nearest noise sensitive receptors selected for the prediction of Project-related sound emissions were identified as the nearest residential receptor in Napadogan (approximately 10 km to the northeast of the Project site), and the nearest recreational campsite (located approximately 1.5 km to the east of the Project site) (Figure 7.3.1). Recreational campsites at further distances can be expected to experience lower sound pressure levels due to the Project in comparison to this location. This is supported by the model results shown in Figure 7.3.3 and 7.3.4.

Vehicle traffic on the two main access roads to the Project was also included in the model. As shown in Figure 7.3.2, Project-related vehicles may access the Project site via the Valley Forest Products Road (starting in Nackawic, identified in this EIA Report as the "Primary Site Access" route or "PSA") or via the Four Mile Brook Road (starting about 6 km west of Napadogan off Route 107, identified in this EIA Report as the "Secondary Site Access" route, or "SSA"). It was assumed in the model set-up that transportation activities during all phases will only occur during daytime/evening hours (07:00 to 22:00). The Project traffic used in the modelling was provided by Northcliff based on expected activities during each phase (Tables 3.4.10 and 3.4.33).

The existing background sound pressure levels at the recreational campsite and at the nearest residence receptor to the Project in Napadogan were based on measured data (Section 8.3.2). Note that monitoring to represent Napadogan was conducted near the intersection of the Four Mile Brook Road and Route 107, along the SSA route, to represent anticipated sound pressure levels at residential receptors in Napadogan. Based on the proximity to the highway, these data are considered to be representative of the noise from traffic passing through Napadogan and as could be experienced at residential receptors in this community. From the monitoring results, the maximum daytime and nighttime 1-h L_{eq} levels were selected in order to conservatively represent the background conditions. These levels were compared to the 1-h L_{eq} criteria (65 dB_A during daytime and 55 dB_A during nighttime). These criteria are based on typical regulatory values applied in New Brunswick through Certificates of Approval to Operate issued to industrial facilities under Regulation 97-133 of the *Clean Air Act*. For the nearest residential receptor in Napadogan (approximately 10 km northeast of the mine site), the highest daytime and nighttime background 1-h L_{eq} sound levels were established as 59 dB_A, as measured near the intersection of Four Mile Brook Road and Route 107. These measurements indicate that trucking on Route 107 (the main suspected cause of these sound levels) occurs during day and night. At the nearest recreational campsite (approximately 1.5 km east of the open pit location), the highest monitored daytime and nighttime background levels were 62 dB_A and 46 dB_A, respectively. The predicted Project sound emissions were added to these background levels to estimate the combined future sound pressure level at the nearest receptors. The estimates are considered conservative (*i.e.*, worst case) due to the use of the maximum 1-h L_{eq} measured backgrounds, thereby estimating the combined Project and background sound pressure levels during the loudest hour of the day and night.

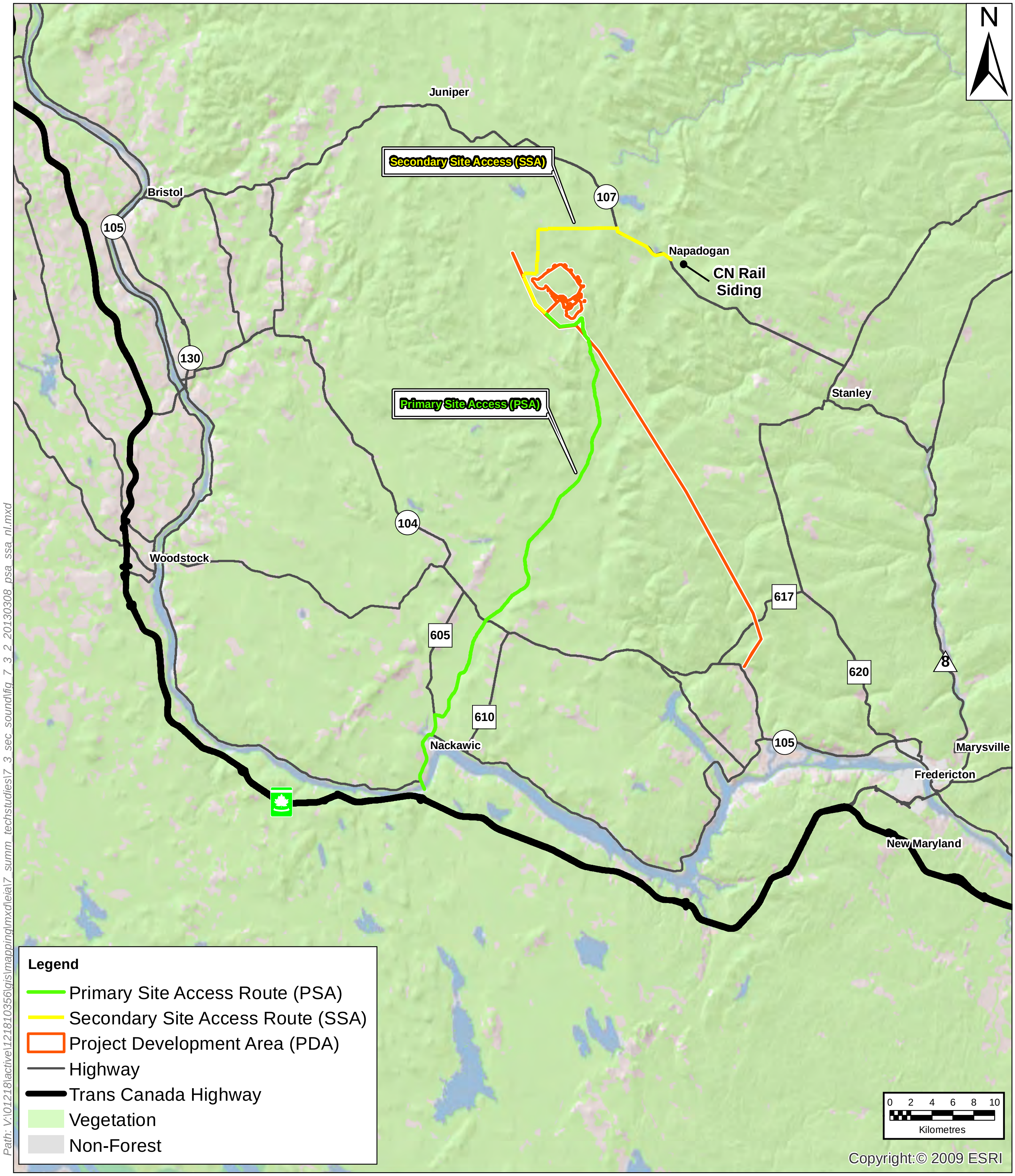


NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Noise Sensitive Locations Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:100,000	Project No.: 121810356	Data Sources: NBDNR	Fig. No.: 7.3.1
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM	
Client: Sisson Mines Ltd.				

Stantec

Map: NAD83 CSRS NB Double Stereographic



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Primary Site Access (PSA) Route and Secondary Site Access (SSA) Route Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:500,000	Project No.: 121810356		Data Sources: NBDNR ArcGIS Online	Fig. No.: 7.3.2
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		
Client: Sisson Mines Ltd.					

Map: NAD83 CSRS NB Double Stereographic

A further comparison was made using the percent highly annoyed metric, as advocated by Health Canada's EA guidance (Health Canada 2010d). The monitored average day-night equivalent (L_{DN}) was used to estimate the average baseline percent annoyed at Napadogan and at the recreational campsite. The 24 1-h L_{eq} values for the average day were added to the predicted Project contribution to determine the percent annoyed during Construction and Operation of the Project. The algorithm to calculate the percent highly annoyed is an empirical relation defined by ISO 1996-1:2003 (Canadian Standards Association 2003) and referenced by Health Canada (Health Canada 2010d).

7.3.1.2 Vibration

The equation to estimate vibration from equipment at various distances is:

$$PPV = PPV_{ref} x(\frac{25}{D})^n$$

Peak particle velocity (PPV) is the estimate of the speed of the wave front at the distance D (the highest value for a given circumstance, soil type as an example), PPV_{REF} is the reference PPV at 7.6 m (25 feet), and n is the attenuation rate. The reference PPV is a value established for a given piece of equipment, and used here as a guideline value for purposes of estimating vibration levels at distances further out from the source. Jones & Stokes (2004) recommend the use of 1.1 for the value of n as a conservative attenuation rate in typical soil. Jones & Stokes developed a manual of practical guidance for the California Department of Transportation for use by engineers, planners, and consultants addressing vibration issues associated with the construction, operation, and maintenance of transportation and construction projects (Jones & Stokes 2004).

Baseline vibration monitoring was not conducted because there are no substantive vibration producing sources near the Project site, and existing levels of vibration are therefore expected to be negligible. In Napadogan, passing vehicles, including transport trucks, may induce a vibration near the roadway. However the transient vibration of passing vehicles would not act cumulatively with Project-related vibration. This is because only one truck would be passing at any given time (in each direction potentially). Therefore an evaluation of the vibration from a passing truck at the nearest residence would be representative of vibration from existing or Project related traffic.

7.3.2 Modelling Results

7.3.2.1 Construction

7.3.2.1.1 Sound

To estimate sound pressure levels from the Project during Construction, Stantec considered the worst case scenario where construction equipment is located at the edge of the PDA nearest the recreational campsite. Due to the planned mining schedule, where the farthest extent of the pit will not be reached until later in the Operation phase, it is likely that construction equipment will actually be at further distances from the recreational campsite than those used in the model. Thus, the modelling should represent conservatively high predictions for sound pressure levels at the recreational campsites during Construction.

Modelling was not conducted for the nighttime period for the Construction phase, as construction activities, including trucking, are not anticipated to occur at night. Hence, the nighttime sound pressure levels were assumed to be identical to the nighttime background levels at each receptor.

The results of the modelling of Construction activities are provided in Tables 7.3.1 (hourly L_{eq} evaluation) and 7.3.2 (change in % highly annoyed evaluation). The predicted sound pressure levels within 100 km^2 surrounding the Project during Construction are also shown graphically in Figure 7.3.3.

Table 7.3.1 Construction Sound Modelling Results – 1-h L_{eq}

Receptor	Daytime Background Level – Maximum Observed 1-h L_{eq} (dB_A)	Predicted Project Daytime 1-h L_{eq} (dB_A)	Project + Background 1-h L_{eq} (dB_A)	Below 65 dB_A?
Closest Residential Receptor (Napadogan, approximately 10 km northeast of Project site)	59	3	59	Yes
Closest Recreational Campsite (approximately 1.5 km east of open pit)	62	29	62	Yes

Notes:
As sound pressure levels are a logarithmic measure, Project + Background L_{eq} is calculated using a logarithmic equation (not directly additive). $L_\Sigma = 10 \cdot \log_{10}(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \cdots + 10^{\frac{L_n}{10}})dB$

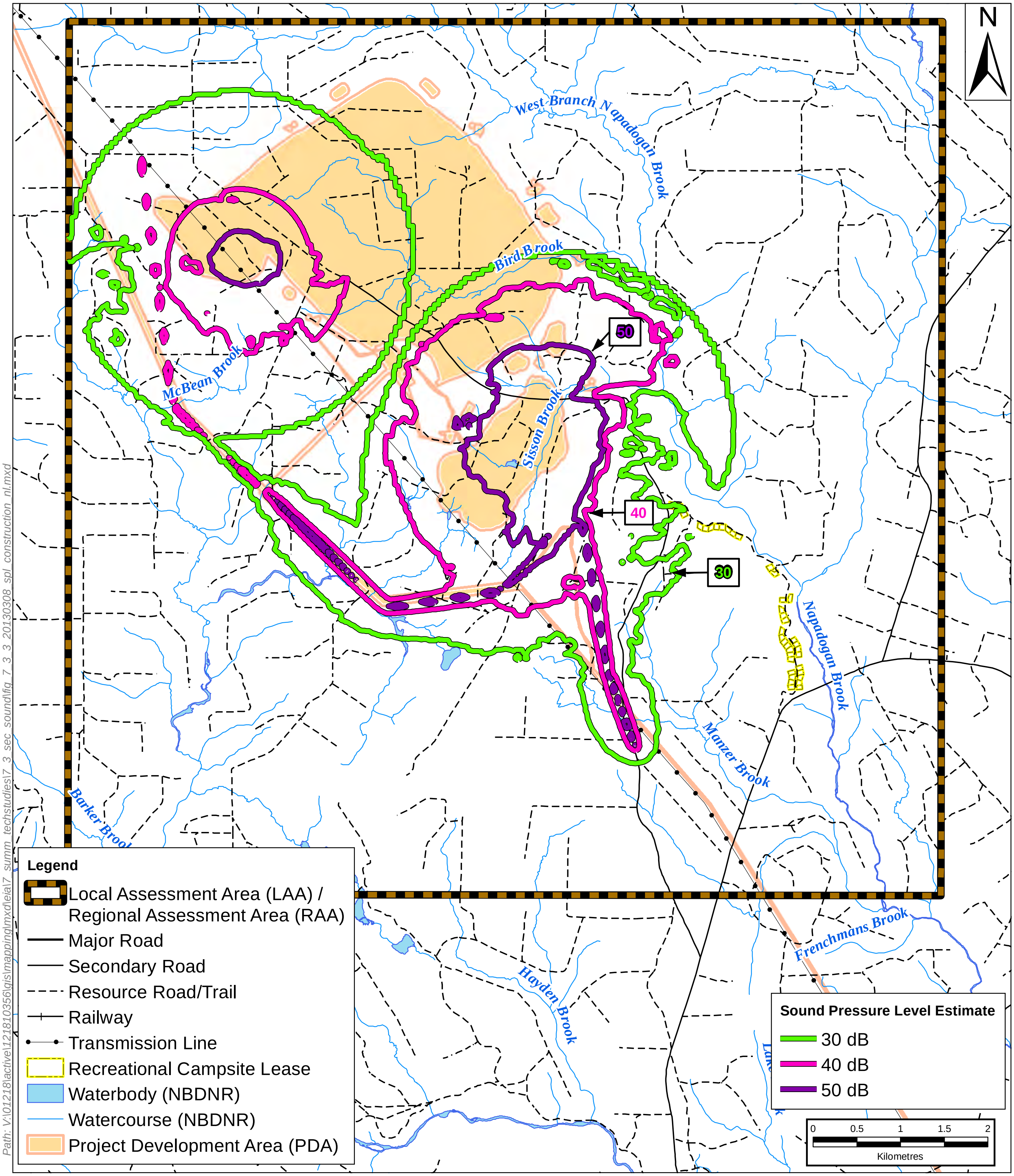
Table 7.3.2 Construction Sound Modelling Results – Percent Highly Annoyed

Receptor	Average Background L_{DN} (dB_A)	Predicted Project Daytime 1-h L_{eq} (dB_A)	Project + Background L_{DN} (dB_A)	% Highly Annoyed Background	% Highly Annoyed (Project + Background)	Difference
Closest Residential Receptor (Napadogan, approximately 10 km northeast of Project site)	58	34	58	5.8	5.8	0
Closest Recreational Campsite (approximately 1.5 km east of open pit)	48	29	48	1.7	1.7	0

Notes:
Percent Highly Annoyed is calculated as described in Annex D of ISO 1996-1:2003, based on Schultz curve, represented by $HA = 100/[1 + \exp(10.4 - 0.132 L_{dn})]\%$

Note that transportation sources on Route 107 are currently the main contributing sources to sound pressure levels in Napadogan.

As presented in Table 7.3.2, the day-night equivalent sound pressure level will not noticeably increase with Project activities, and no change in % highly annoyed is expected.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Sound Pressure Level Estimates - Construction Phase Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:60,000	Project No.: 121810356		Data Sources: NBDNR	Fig. No.: 7.3.3
	Date: (dd/mm/yyyy) 23/11/2014	Dwn. By: JAB	Appd. By: DLM		
Client: Sisson Mines Ltd.					

Map: NAD83 CSRS NB Double Stereographic

7.3.2.1.2 Vibration

The largest piece of mobile construction equipment at the Project site is likely to be a large bulldozer, which has a reference PPV of 2.3 mm/s at a distance of 7.6 m. At a distance of 1,500 m (to the nearest recreational campsite from the edge of the open pit), the estimated PPV due to the operation of a large bulldozer is 0.007 mm/s, which is well below the threshold of perceptibility of 0.15 mm/s for steady-state vibration reported by Jones & Stokes (2004). For context, the largest distance for which vibration from construction activities would be perceivable is approximately 300 m.

No pile driving will be required during Construction.

7.3.2.1.3 Sound and Vibration from Blasting

Blasting at the plant site will be required using a balanced cut and fill method to level the area for the ore processing plant. This blasting will use smaller holes and charges than required in the pit during Operation. Some blasting and crushing of rocky material may occur in the quarry area during Construction. Some blasting in the open pit area will also occur during Construction as stockpiling of ore for start-up begins. Since the quarry and the ore processing plant are located farther from the recreational campsites than the open pit (approximately 5.6 km), the analysis of vibration from the open pit during Construction and Operation will be considered to conservatively evaluate vibration from blasting in other areas during Construction. The sound pressure level due to blasting in the quarry and at the ore processing plant may be noticeably above background at the recreational campsites, but is anticipated to be lower in magnitude than the sound pressure level due to blasting in the open pit once Operation begins (due to the further distance between the recreational campsites and the quarry and ore processing plant, in comparison to the open pit). Thus, if analysis of vibration and sound pressure levels from blasting during Operation of the open pit is shown to be within criteria, it can be inferred that vibration and sound pressure levels from blasting during Construction will also be within the criteria given its farther distance from residential or recreational receptors than the open pit.

7.3.2.2 Operation

7.3.2.2.1 Sound

The modelling of sound emissions from Operation was based on normal Operation activities, including drilling of blasting holes, blasting, ore loading onto the mine trucks, transportation, processing of ore material, and transportation of products. For the purpose of modelling, Stantec placed mining equipment at representative locations throughout the site, including the open pit, the processing building, the tailings storage facility (TSF), and the quarry.

The modelling results are presented in Tables 7.3.3 (1-h L_{eq} evaluation) and 7.3.4 (% highly annoyed). The predicted sound pressure levels within 100 km^2 surrounding the Project during Operation are shown in Figure 7.3.4.

Table 7.3.3 Operation Sound Modelling Results – 1-h L_{eq}

Receptor	Daytime Background Level - Max (dB_A)	Nighttime Background Level - Max (dB_A)	Project Daytime Hourly L_{eq} (dB_A)	Project Nighttime Hourly L_{eq} (dB_A)	Project + Max Background Hourly L_{eq} Daytime (dB_A)	Project + Max Background Hourly L_{eq} Nighttime (dB_A)	Meets 1-h Guidance?
Closest residential receptor (Napadogan, 10 km from site)	59	59	35	No Contribution[a]	59	59	No - maximum background is above 55 dB_A.
Closest recreational campsite (1.5 km from open pit)	62	47	29	23	62	47	Yes

Notes:

[a] It is assumed that there are no trucking activities at night during Operation ,and sound from site activities is predicted to not be perceivable in Napadogan.

1) As sound pressure levels are a logarithmic measure, Project + Background L_{eq} is calculated using a logarithmic equation (not directly additive). $L_{\Sigma} = 10 \cdot \log_{10}(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \cdots + 10^{\frac{L_n}{10}})dB$

Table 7.3.4 Operation Sound Modelling Results – Percent Highly Annoyed

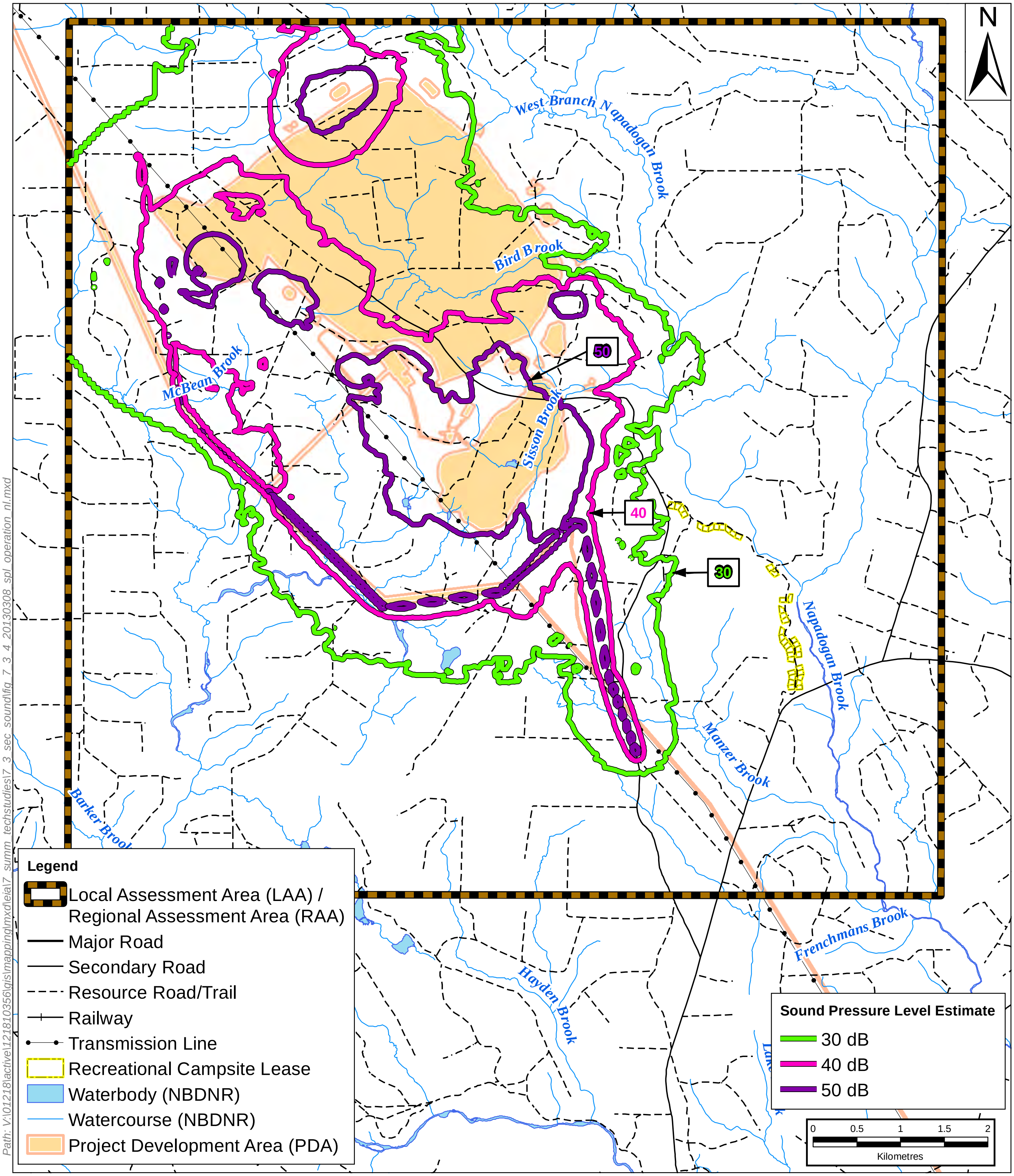
Receptor	Average Background L_{DN} (dB_A)	Project Daytime Hourly L_{eq} (dB_A)	Project Nighttime Hourly L_{eq} (dB_A)	Project + Background L_{DN} (dB_A)	% HA Background	% HA (Project + Background)	Difference
Closest residential receptor (Napadogan, 10 km from site)	58	33	0 (no trucking at night)	58	5.8	5.8	0
Closest recreational campsite (1.5 km from open pit)	48	25	23	48	1.7	1.7	0

Notes:

Percent Highly Annoyed is calculated as described in Annex D of ISO 1996-1:2003, based on Schultz curve, represented by $HA = 100/[1+\exp(10.4 - 0.132L_{dn})]\%$

The instantaneous sound pressure levels (during a two-second blast at the surface and at the commencement of mining before the activity recedes into the pit) from open pit blasting at the nearest recreational campsite and the nearest residential receptor are predicted to be 80 dB_A and 56 dB_A, respectively. For context, a sound pressure level of 75 dB_A can be experienced by standing at the corner of a busy traffic intersection (ERCB 2007b).

The sound pressure level at the recreational campsite is predicted to be above the measured daytime background during blasting; however, considering that the impulse noise will last only for several seconds, the 1-h L_{eq} for any hour with a blasting event will increase slightly (predicted to be to 2 to 15 dB_A considering both the highest and lowest measured daytime L_{eq}). Blasting may occur at night; the subsequent 1-h L_{eq} may be as high as 48 dB_A (considering the minimum 1-h L_{eq} measured as background). At the residences in Napadogan, the sound pressure level due to blasting will be similar or less than the background level.



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NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Sound Pressure Level Estimates - Operation Phase

Sisson Project:
Environmental Impact Assessment (EIA) Report, Napadogan, N.B.

Client: Sisson Mines Ltd.

Scale: 1:60,000

Project No.: 121810356

Data Sources: NBDNR

Fig. No.: 7.3.4

Date: (dd/mm/yyyy) 23/11/2014

Dwn. By: JAB

Appd. By: DLM

Stantec

Map: NAD83 CSRS NB Double Stereographic

7.3.2.2.2 Vibration

The main sources of vibration during Operation are the movement of the loaded trucks from the pit to the crushing equipment and the crushing equipment itself. Similar to the assessment of vibration from construction equipment, reference PPVs from loaded trucks were found and are provided in Table 3.4.11.

The estimated PPV at the nearest residential campsite is 0.007 mm/s, which is below the threshold of perceptibility of 0.15 mm/s for steady state vibration (Jones & Stokes 2004).

7.3.2.2.3 Sound and Vibration from Blasting

Sound and vibration levels due to blasting events were estimated using the prediction graphs in "Guidelines on Information Required for the Assessment of Blasting Noise and Vibration" produced by the Ontario Ministry of Environment (OMOE 1985). The scaled distances for sound and vibration were estimated for an average instantaneous charge of 998 kg and various distances to a receptor; these are shown in Table 7.3.5.

Table 7.3.5 Estimated Sound Pressure Levels and Peak Particle Velocities Associated with Blasting

Emission	Distance From Source (m)				
	1,000	1,500	3,000	5,000	10,000
Sound Pressure Level (dB_A)	85	80	71	65	56
Vibration (mm/s)	4.5	2.4	0.8	0.4	0.1

Notes:
1) Threshold of vibration perception is 0.15 mm/s (Jones & Stokes 2004).
2) The linear dB results were converted to the A-weighted dB scale by subtracting 45 dB (assuming a frequency of 25 Hz for blasting noise).

Ground vibration at the nearest recreational campsite (1,500 m away) during a blasting event may reach a PPV of 2.4 mm/s for several seconds. The PPV perceived during a blast at the nearest campsite would be similar to the vibration experienced when a large bulldozer operates 7.6 m away. The occupants of the recreational campsite may find this PPV perceptible (Jones and Stokes 2004), especially considering that the warning horns would have alerted occupants to an imminent blast. Approximately 8.5 km from the blasting event, the vibration is anticipated to be imperceptible.

7.4 FISH HABITAT LOSS AND PLAN TO OFFSET SERIOUS HARM TO FISH

7.4.1 Overview

As discussed in Chapter 3, the Project will alter the drainage patterns and stream flows in the Napadogan Brook watershed (and to a lesser extent in the McBean Brook watershed) as a result of Project-related activities to be conducted during the Construction, Operation, and ultimately Decommissioning, Reclamation and Closure phases of the Project. These flow alterations will result in both the direct loss of physical habitat for fish and other aquatic organisms, and the indirect loss of habitat due to flow reductions downstream of the Project. Direct loss is the direct destruction of fish habitat that will occur where the physical features and facilities associated with the Project encroach on existing watercourses. Indirect loss is the indirect destruction, reduction, or alteration of fish habitat area that may occur where stream flows are reduced due to Project-induced changes in watershed (or catchment) area, thereby resulting in a reduction in the available area of fish habitat.

As required by the *Fisheries Act*, and as discussed in Section 4.1.2.1, serious harm to fish that are part of a CRA fisheries will need to be authorized under Section 35(2) of the Act. Along with this authorization, the serious harm needs to be offset with an Offsetting Plan approved by DFO. SML has made considerable efforts to avoid or mitigate the direct and indirect loss of aquatic habitat, and the consequent serious harm to fish, during the design and planning phases of the Project. The watercourses within the Project Development Area (PDA) (Figure 1.2.1) that will be lost to the Project facilities, and those that will experience flow reductions as a result of the Project, are discussed in this section in order to characterize both direct and indirect loss of fish habitat, and the consequent harm to fish, that will result from the Project and ultimately require authorization and associated offsetting under the *Fisheries Act*.

As part of this assessment, the prediction of what level of loss of fish habitat could accrue, both directly and indirectly, as a result of the Project features and activities was carried out. As discussed in the sub-sections that follow, these predictions included the direct, physical loss of fish habitat arising from the encroachment of the Project facilities, as well as indirect losses that could arise due to alterations to stream flows in McBean and Napadogan Brook watersheds.

In the sub-sections that follow, the direct loss of fish habitat arising from the construction of Project facilities is discussed. Then, indirect loss of fish habitat arising from flow alterations in Napadogan and McBean Brook watersheds is presented, including the results of numerical modelling that was conducted to quantify these reductions in habitat area in Lower Napadogan Brook using a wetted perimeter approach. The total estimated fish habitat loss arising from both direct and indirect loss as a result of the Project is then quantified. Finally, an Offsetting Plan for the serious harm to fish and fisheries that would result from this total habitat loss is presented.

7.4.2 Direct Habitat Loss

Direct loss of fish habitat, when discussed in this EIA report, is defined as fish habitat that is directly lost through Project activities and that is no longer present or functional and able to support aquatic life. Habitat that is within the areas to be occupied by the open pit and tailings storage facility (TSF) will be lost completely, and these are examples of direct loss of fish habitat. Direct loss will only occur within the PDA, which includes the Project components and the linear facilities corridors. However, no direct loss will occur as a result of the new 138 kV transmission line or the relocated 345 kV transmission line, since all transmission line structures will be placed outside of riparian zones and no disturbance will occur within 30 m of watercourses, in order to avoid encroachment on watercourses and associated habitat loss. Similarly, no direct loss will occur as a result of the relocated Fire Road, since although watercourse crossings will be required, temporary disruption to fish habitat is not considered by DFO to result in serious harm to fish.

7.4.2.1 Methodology: Estimating Direct Habitat Loss

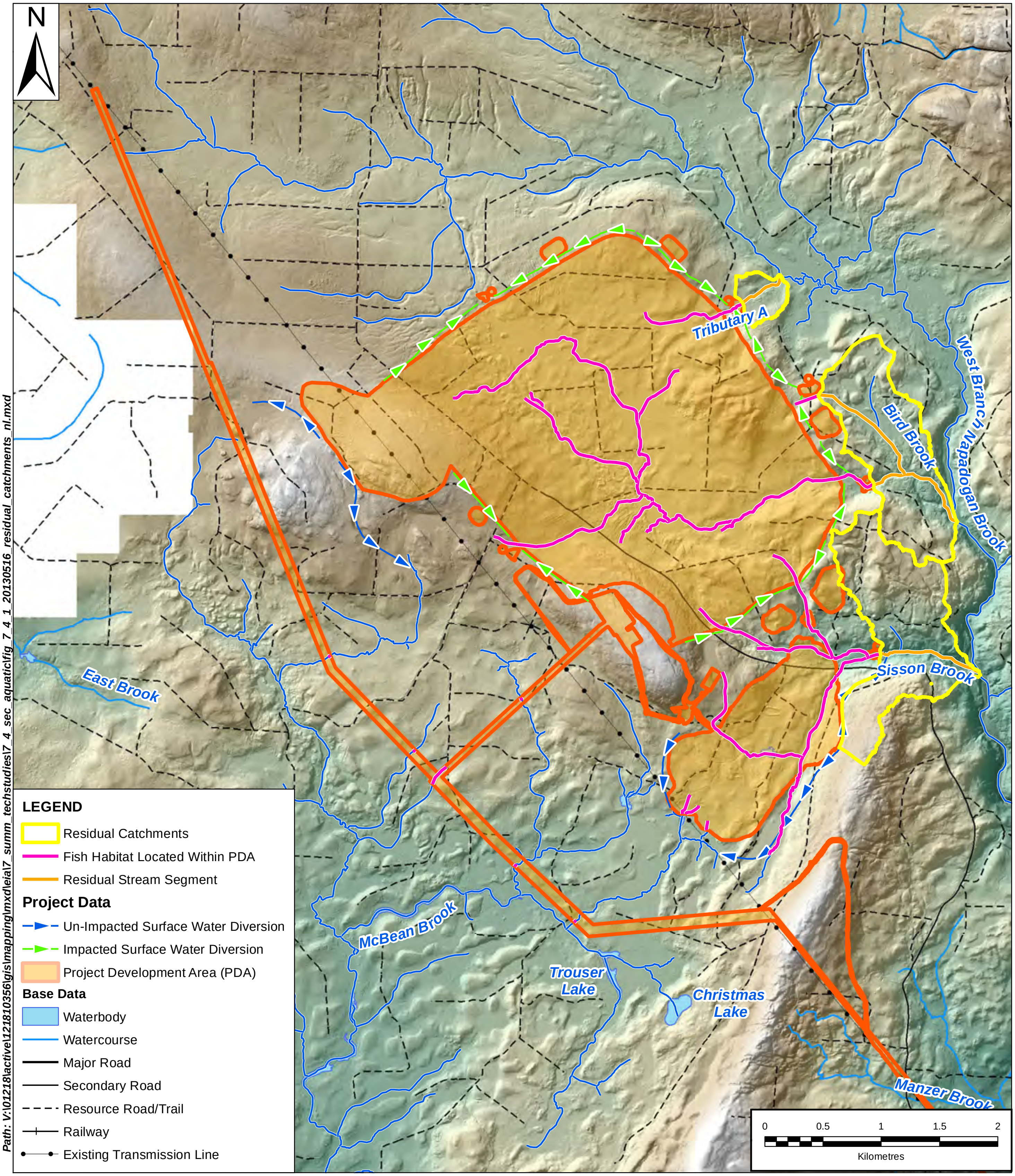
The direct loss of fish habitat was estimated using field data collected as part of extensive aquatic field surveys carried out in the PDA, as documented in the Baseline Aquatic Environment Technical Report (Stantec 2012d). The geographic extent and quality of the fish habitat in the watercourses that are directly affected by the mine were characterized through an extensive aquatic field survey program carried out in 2011 (Stantec 2012d), with further characterization of fish habitat to be affected by the Fire Road relocation carried out in 2012 (Stantec 2013c). As part of these programs, all watercourses within the PDA were surveyed in their entirety, and measurements of bankfull width, watercourse length, and other data were recorded for each reach of these watercourses.

The total surface area of the watercourses within the PDA was calculated from these measurements and using a geographic information system (GIS) supplemented by LiDAR data. The total direct loss of fish habitat was assumed to be represented by the total surface area of the watercourse lost. This approach for calculating the habitat area does not differentiate on habitat suitability, but conservatively assumes that the entire length and width of the stream that is lost is equally suitable for supporting aquatic life.

Several beaver dams were observed during the aquatic surveys. These dams resulted in ponded areas upstream of the dams, and thus increased the stream widths within the ponded areas. The stream widths at these ponded areas were not used in the calculations of habitat areas due to the ephemeral nature of beaver ponds. Instead, stream widths for the ponded areas upstream of beaver dams were estimated based on upstream and downstream widths. This approach was accepted by Fisheries and Oceans Canada (DFO) (Parker, E. Personal communication, November 6, 2012).

7.4.2.2 Results: Direct Habitat Loss

There will be direct loss to the PDA of a portion of a small unnamed tributary to the West Branch Napadogan Brook (referred to as Tributary “A”), portions of Bird Brook and Sisson Brook and their tributaries, and portions of small fingertip tributaries to McBean Brook (Figure 7.4.1). A summary of the loss of fish habitat within the PDA and its function in relation to the life processes of warm and cold water fish species for each of the affected watercourses is provided below. Table 7.4.1 outlines that direct loss to watercourses within the PDA. The habitat loss areas are presented in 100 m^2 “fish habitat units” as is typical for large-scale projects.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Location of Directly Affected Fish Habitat and Catchment Areas of Residual Stream Segments	Scale: 1:45,000		Project No.: 121810356	Data Sources: Leading Edge Geomatics NBDNR	Fig. No.: 7.4.1	Stantec
Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Date: (dd/mm/yyyy) 23/10/2012	Dwn. By: JAB	Appd. By: GPY			
Client: Sisson Mines Ltd.						

Map: NAD83 CSRS NB Double Stereographic

Table 7.4.1 Direct Fish Habitat Loss by Major Project Component in the PDA

Project Component	Affected Watercourse	Type of Loss	Area Lost (fish habitat units[1]), Requiring Compensation/Offsetting	Rationale	Offsetting and Authorization
Open Pit	Sisson Brook	Direct	112	Permanent direct habitat loss = serious harm.	*Fisheries Act* Section 35(2)
	McBean Brook	Direct	2	Permanent direct habitat loss = serious harm.	*Fisheries Act* Section 35(2)
Tailings Storage Facility (TSF)	Bird Brook	Direct	172	Permanent direct habitat loss from deposition of tailings = serious harm.	*MMER* Schedule 2 amendment
	Bird Brook	Direct	72	Permanent direct habitat loss from construction of TSF embankment = serious harm.	*Fisheries Act* Section 35(2)
	Sisson Brook	Direct	2	Permanent direct habitat loss from construction of TSF embankment = serious harm.	*Fisheries Act* Section 35(2)
	Tributary "A" to West Branch Napadogan Brook	Direct	6	Permanent direct habitat loss from construction of TSF embankment = serious harm.	*Fisheries Act* Section 35(2)
Total Direct Habitat Loss, Required for Compensation/Offsetting			**366**		

Notes:
[1] fish habitat unit = 100 m^2 of fish habitat.

Further discussion of these losses and the associated habitat characteristics of these watercourses as determined by the aquatic field surveys conducted in 2011 (Stantec 2012d) is as follows. Further details can be found in Section 8.5.2 and Stantec (2012d).

Tributary "A" to the West Branch Napadogan Brook

Direct loss will occur to a total of 6 fish habitat units along a 971 m long section of Tributary "A" to the West Branch Napadogan Brook (WBNB) as a result of the Project. Tributary "A" is a first-order watercourse that flows directly to the West Branch Napadogan Brook (Figure 7.4.1) at the northern extent of the TSF.

The upper 130 m of this tributary has a steep grade with no defined channel and does not provide fish habitat though it is conservatively included in the calculations of habitat loss. Habitat was of average quality in the lower reaches and was suitable for spawning and rearing of brook trout and other warm and cold water species. Portions of the watercourse sustain brook trout and are suitable for rearing, spawning and feeding for all life stages. There are also portions of watercourse that are marginal or fair, such as beaver ponds that support fish but are not ideal habitat.

Bird Brook and Tributaries

Direct loss will occur to a total of 244 fish habitat units along 10,276 m of Bird Brook and its tributaries within the PDA, due to the presence of the TSF. There are six first-order tributaries to Bird Brook, two second-order sections of tributary to Bird Brook, and the third-order main stem of Bird Brook within the PDA (Figure 7.4.1).

First-order tributaries start in the headwaters with intermittent flow and increase in size moving downstream. First-order habitat and water quality, and habitat structure is suitable rearing habitat for brook trout outside of the headwater sections. The two second-order tributaries within the PDA meet at a small wetland pond to form the main stem of Bird Brook. Fish were observed in the pond and water quality was suitable in the ponded areas along with the flowing sections within the PDA for cold and warm water fish species (CCME 1999).

Second-order tributaries are a mix of high quality habitat for feeding and rearing and poor quality impounded habitat that is generally not supportive of most fish.

The third-order section of Bird Brook has some ponding of water present in the middle reach as a result of an old beaver dam. Overall, third-order habitat and water quality of Bird Brook within the PDA represents good to high quality fish habitat suitable for spawning, feeding and rearing of cold and warm water fish species.

There were several locations on all first-order tributaries with low dissolved oxygen (DO) and pH, generally these are areas surrounded by or passing through wetlands, or in headwater areas with groundwater upwelling. Poor water quality in second-order tributaries are the result of slow moving waters through beaver impoundments, as well as wetland that surrounds much of Bird Brook. There were no issues with water quality within the third-order sections of Bird Brook.

Bird Brook as a whole has habitat that ranges from poor to very high quality for brook trout. Wetland surrounds much of Bird Brook, resulting in lower pH and in some cases extremely low concentrations of DO. Habitat within the PDA is not suitable for Atlantic salmon; however, sections of Bird Brook downstream of the PDA are salmon habitat (Stantec 2012d).

Sisson Brook and Tributaries

Direct loss will occur to a total of 114 fish habitat units along 7,393 m of Sisson Brook and its tributaries within the PDA, due to the presence of the open pit, and another 2 fish habitat units due to the presence of the TSF. There are four first-order tributaries, two second-order tributaries and a portion of the third-order main stem of Sisson Brook located within the PDA (Figure 7.4.1).

The two southernmost first-order tributaries are low grade and surrounded by wetlands and beaver ponds. A large beaver pond encompasses the majority of the tributary that lies in the centre of the proposed open pit location. The two northernmost first-order tributaries are high grade with intermittent flow in the headwaters. Habitat structure and water quality within the all the first-order tributaries of Sisson Brook represents good to excellent rearing habitat for brook trout.

There are two second-order tributaries to Sisson Brook within the PDA. The southernmost tributary has wetland meadow in its upper reach; both tributaries increased in grade moving downstream. Second-order tributaries of Sisson Brook are good to excellent brook trout habitat (spawning, rearing and feeding).

Overall, Sisson Brook has habitat that ranges from poor to excellent quality fish habitat. Headwater habitats are variable ranging from wetland beaver ponds to steep rocky valleys. There is a natural barrier to fish passage, a waterfall, located approximately 280 m upstream of the mouth of Sisson Brook which likely limits the migration of all fish species except American eel (which can scale vertical surfaces when young).

Tributaries to McBean Brook

Direct loss will occur to a total of 2 fish habitat units along 415 m of first-order tributaries of McBean Brook within the PDA (Figure 7.4.1) due to the presence of the open pit.

A total of 415 m of headwater habitat will be lost in McBean Brook within the PDA. The three first-order tributaries all flow into a small beaver pond under the existing transmission line. All tributaries are surrounded by wetland meadow and the watercourses are often undefined and braided through the wetland. Existing habitat is marginal brook trout habitat as a result of the wetland characteristics and lack of flow.

Overall, the habitat within McBean Brook to be directly lost as a result of Project activities is fair to good fish habitat. Habitat to be directly lost is headwater habitat made up of mostly wetland drainage and pond. The habitat present is most suitable for warm water fish species that prefer slow moving or ponded waters.

7.4.2.3 Summary of Direct Habitat Loss

As summarized in Table 7.4.1, a total of 366 fish habitat units will be directly lost within the PDA. The habitat to be lost ranges from poor quality habitat comprised of wetland ponds and beaver pond, to excellent quality riffle run ideal for salmonid spawning, rearing and feeding. Water quality in all the watercourses within the PDA is relatively good to high quality, with a few locations that are not suitable for most fish species.

7.4.3 Indirect Habitat Loss

Indirect loss of aquatic habitat, when discussed in this EIA report, is defined as habitat that is lost as an indirect consequence of Project activities due to decreased flow in watercourses downstream of the PDA. Indirect losses are considered for two groups of watercourses: residual watercourse segments; and flow reductions in downstream watercourses, specifically Napadogan and McBean brooks.

7.4.3.1 Indirect Habitat Loss in Residual Watercourse Segments

Relatively small residual watercourse segments will remain after the direct losses described in Section 7.4.1 in Bird Brook and Sisson Brook, and a tributary to WBNB, as shown in Figure 7.4.1.

Methodology: Indirect Habitat Loss in Residual Stream Segments

The residual stream segments identified on Figure 7.4.1 will experience stream flow reductions due to Project activities that will alter the watershed drainage areas upstream of these segments. The reduction in stream flow as a ratio of the pre-development (pre-Project) mean annual flow (MAF) can be estimated directly from the ratio of the reduction in watershed area. The reduction in watershed area shown in Table 7.4.2 is equivalent to the reduction in MAF through a process called areal proration. As an example, direct losses in Bird Brook will result in an 84% reduction in watershed area, which will in turn result in an 84% reduction in MAF.

Table 7.4.2 Reduction in Watershed Area for Residual Stream Segments

Watercourse	Existing Watershed Area (km^2)	Watershed Area Lost (km^2)	Reduction in Watershed Area (%)
Tributary to WBNB	1.5	1.3	87
Bird Brook	8.1	6.8	84
Sisson Brook	5.2	3.0	58

Source: Knight Piésold (2012h).

The scientific literature suggests that stream flow reductions greater than 30% of MAF will result in fundamental ecological change in the stream (Bradford and Heinonen 2008; Poff *et al.* 2010). As shown in Table 7.4.2, the stream flow reductions in the residual stream segments are predicted to be greater than 30%. Therefore, the entire length of the residual stream segments are conservatively considered a total indirect loss.

The habitat area for these residual stream segments is estimated in the same manner as the direct losses described in Section 7.4.1.1.

Results: Indirect Habitat Loss in Residual Stream Segments

There will be indirect loss of fish habitat in residual stream segments of Tributary “A” to WBNB, Bird Brook and Sisson Brook (Figure 7.4.1). A summary of the habitat within these stream segments and its function in relation to the life processes of warm and cold water fish species for each of the affected watercourses is provided below. Table 7.4.3 outlines the indirect loss to residual stream segments. A brief discussion of the indirect loss in these residual stream segments and their associated habitat characteristics as determined by the aquatic field surveys conducted in 2011 (Stantec 2012d) follows Table 7.4.3.

Table 7.4.3 Indirect Fish Habitat Loss by Major Project Component

Project Component	Affected Watercourse	Type of Loss	Area Lost (fish habitat units), Requiring Compensation/Offsetting	Rationale	Offsetting and Authorization
Residual Stream Segments	Sisson Brook	Indirect	36	Serious harm due to substantial reduction in catchment area of residual stream segment.	*Fisheries Act* Section 35(2)
	Bird Brook	Indirect	77	Serious harm due to substantial reduction in catchment area of residual stream segment.	*Fisheries Act* Section 35(2)
	Tributary “A” to West Branch Napadogan Brook	Indirect	10	Serious harm due to substantial reduction in catchment area of residual stream segment.	*Fisheries Act* Section 35(2)
Downstream Flow	Lower Napadogan	Indirect	55	Serious harm due to indirect loss due to mean	*Fisheries Act* Section 35(2)

Table 7.4.3 Indirect Fish Habitat Loss by Major Project Component

Project Component	Affected Watercourse	Type of Loss	Area Lost (fish habitat units), Requiring Compensation/Offsetting	Rationale	Offsetting and Authorization
Reductions	Brook			annual flow reductions downstream >10%.	
Total Indirect Habitat Loss, Required for Compensation/Offsetting			**178**		

Notes:
1 fish habitat unit = 100 m^2 of fish habitat.

Tributary "A" to West Branch Napadogan Brook

Indirect loss will occur to a total of 10 fish habitat units along the residual first-order watercourse of Tributary "A" to West Branch Napadogan Brook. The watercourse is of moderate grade that decreases as it nears the WBNB. There is a small beaver dam in the lower section resulting in some ponding. Water quality was good and habitat in the residual stream segment for the tributary to the WBNB was found to be good to excellent brook trout habitat for rearing, spawning and feeding.

Bird Brook

Indirect loss will occur to a total of 77 fish habitat units along the residual segments of Bird Brook. The existing habitat in the first-order sections of Bird Brook that will experience indirect loss of watershed area are marginal fish habitat. First-order watercourses flow intermittently though wetland. Water quality ranged from poor to good within the first-order tributaries. Headwater sections were not suitable fish habitat, lower sections likely support brook trout as were found in similar watercourses inside and outside of the PDA (Stantec 2012d).

Second-order sections of Bird Brook that will experience indirect loss of watershed area represent good fish habitat. Second-order watercourses have good water quality, were of moderate grade and flowed through some sections of old beaver impoundments. Existing habitat in third-order sections of Bird Brook are excellent quality fish habitat, suitable for spawning, rearing and feeding of Salmonids and Cyprinids.

Sisson Brook

Indirect loss will occur to a total of 36 fish habitat units along the residual segments of Sisson Brook. Approximately 823 m of third-order stream channel outside of the PDA will experience total indirect loss. There is also a first-order tributary of Sisson Brook that flows northeast that will be truncated and diverted to McBean Brook by the construction of the open pit and experience indirect loss (Figure 7.4.1) (with corresponding increase in stream flow in McBean Brook watershed as a result of this diversion).

Existing habitat in the first-order tributary of Sisson Brook that will experience indirect loss is good quality habitat. The first-order watercourse section flows through several wetlands and old beaver meadows. The third-order section of Sisson Brook consists of high quality fish habitat. Water quality in this reach was excellent. Habitat in this section of Sisson Brook is good to excellent spawning rearing and feeding brook trout habitat. A waterfall approximately 280 m from the mouth of Sisson Brook likely prevents migration of fish into Sisson Brook with the exception of American eel.

7.4.3.2 Indirect Habitat Loss in Napadogan Brook

Stream flow reductions in Napadogan Brook will result from the stream flow reductions in Tributary "A" to West Branch Napadogan Brook, Bird Brook, and Sisson Brook, and will result in indirect habitat loss in Napadogan Brook. This section describes the methodology used to predict the indirect loss of fish habitat in Lower Napadogan Brook, first regarding how the flow reductions were calculated and then how the habitat loss was determined due to the flow reductions. The section concludes with the overall results of the indirect habitat loss calculations.

Methodology: Predicting Flow Reductions in Lower Napadogan Brook

Predictions of stream flow alterations in Napadogan Brook were conducted by Knight Piésold (2012h). These predictions are based on long-term unit area flows developed for station NB-2B, located on Napadogan Brook, upstream of the confluence of West Branch Napadogan Brook with East Branch Napadogan Brook. The unit area flows were then multiplied by the catchment areas of the seven numbered locations in Napadogan Brook, as shown on Figure 7.4.2. In this section, Lower Napadogan Brook refers to the portions of Napadogan Brook that will be affected by stream flow reductions arising from the Project, starting on the West Branch Napadogan Brook immediately above its confluence with Bird Brook, to the combined West Branch Napadogan Brook and East Branch Napadogan Brook immediately prior to their confluence with the Nashwaak River.

A range of flows was selected for the modelling to assess the potential variability of changes to wetted perimeter under various conditions that may be observed in Lower Napadogan Brook. The seven different stream flow scenarios selected for the analysis are listed in Table 7.4.4. As shown in the table, the statistics vary across the expected range of flows in Lower Napadogan Brook, from high flows (0.15^{th} percentile) to low flows (95^{th} percentile).

Table 7.4.4 Flow Scenarios for HADD Modelling in Lower Napadogan Brook

Scenario Number	Flow Percentile [a]	Corresponding Description
1	0.15	Maximum Annual Flow
2	32	Mean Annual Flow (MAF)
3	61	DFO Maintenance Flow A [b]
4	74	DFO Maintenance Flow B [c]
5	88	Winter Low Flow
6	94	Summer Low Flow
7	95	Minimum Annual Flow

Notes:

[a] Percentile values represent percentage of time the flow statistic is equaled or exceeded on the flow duration curve. Percentile values were provided by Knight Piésold (2012h).

[b] DFO Maintenance Flow A: The 50% exceedance of the flow duration curve is multiplied by 0.7 to determine the required Maintenance Flow. (Currie, T. Personal communication, April 12, 2012).

[c] DFO Maintenance Flow B: Maintenance flow is 25% of predicted mean annual flow. (Currie, T. Personal communication, April 12, 2012).

The flow statistics for baseline and future case scenarios were developed at the seven locations intended to represent the upper and lower boundaries of six key hydraulic sub-reaches of Lower Napadogan Brook. These locations are listed below and are shown in Figure 7.4.2:

1. above confluence with Bird Brook (River station 13881.3);

2. below confluence with Bird Brook (River station 13307.8);
3. below confluence with Sisson Brook (River station 11677.5);
4. below confluence with East Branch Napadogan Brook (River station 8370.4);
5. below confluence with Manzer Brook (River station 4144.4);
6. below confluence with Frenchman Brook (River station 2186.2); and
7. above confluence with Nashwaak River (River station 300.6).

The flow reductions were then used as inputs to the model used to calculate the indirect loss of fish habitat in downstream Lower Napadogan Brook, using a technique called wetted perimeter modelling. Wetted perimeter modelling uses a one dimensional (1-D) numerical model called Hydrologic Engineering Centers River Analysis System ("HEC-RAS"), developed by the United States Army Corps of Engineers (USACE 2010), discussed further below. The wetted perimeter model was developed at each of the seven locations above for two cases:

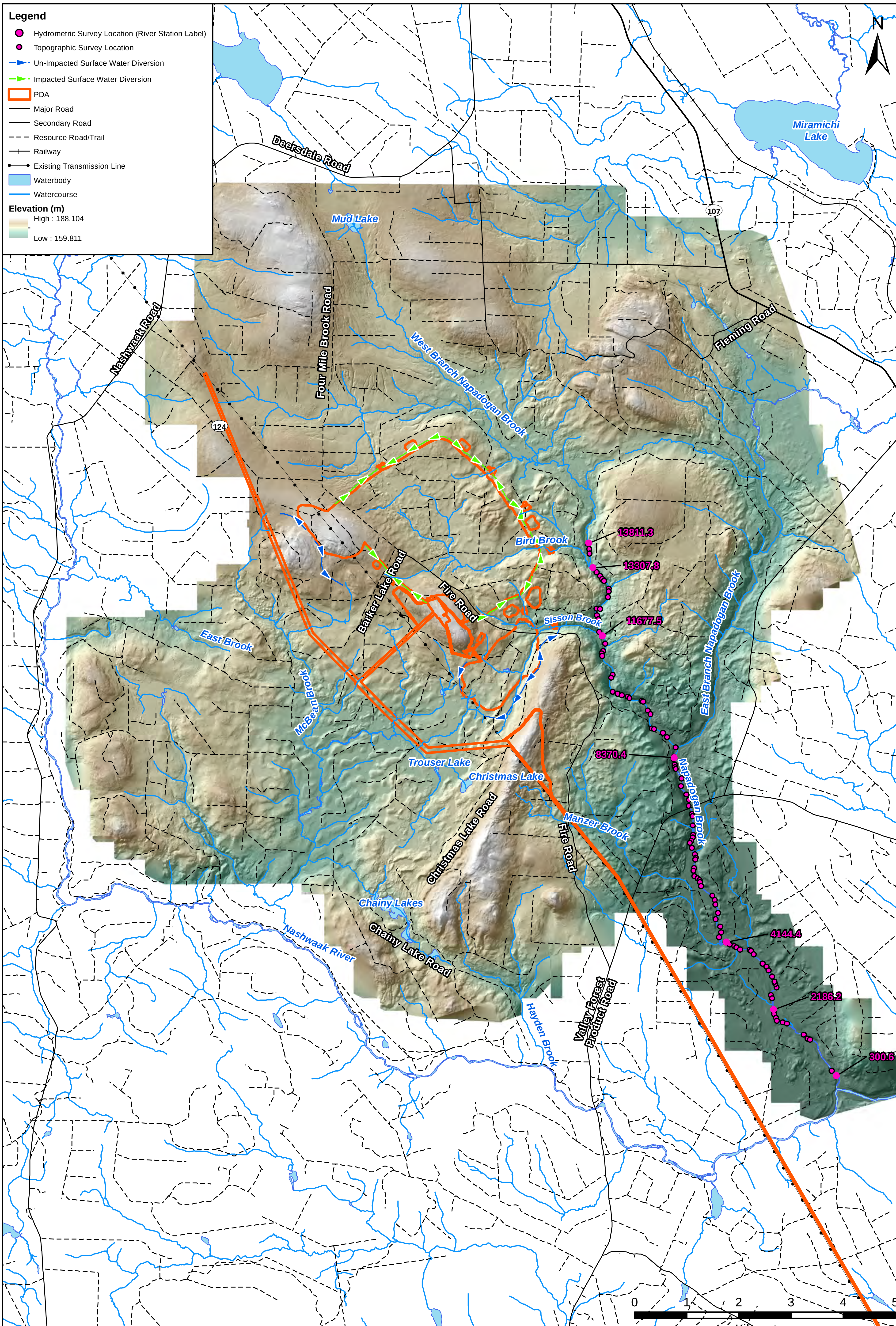
- a "baseline conditions" case, to simulate flows and associated areal extent of fish habitat currently in the absence of the Project; and
- a "future conditions" case, to simulate flows and associated areal extent of fish habitat in the future, once the Project is operational and water from Tributary "A" to WBNB, Bird and Sisson Brooks is no longer discharged to Napadogan Brook as a result of direct loss and indirect loss in residual stream segments.

The inputs to the wetted perimeter model for each of the seven flow statistics at each location were provided by Knight Piésold (2012h). These flows were used as inputs to the wetted perimeter model on a sub-reach basis. Stream flows within each sub-reach are assumed to be constant within the model.

It is important to note that the "future conditions" case (*i.e*., once the Project is in Operation) assumes zero discharge of water from the Project and all water contained within the PDA is sequestered. This will be the case during Years 1-7 of Operation, when all mine contact water within the PDA will be stored in the TSF. However, starting in about Year 8 of Operation, water in the TSF will be in a surplus condition, and thus surplus water will be treated (as necessary to meet discharge requirements) and released to the former Sisson Brook channel, thereby restoring some flow to Lower Napadogan Brook. Similarly, while the open pit is being filled during Closure, over a period of about 12 years, there will be no discharge to the former Sisson Brook channel, but surplus water will be treated and discharged thereafter. For the purpose of this analysis, it has been assumed that no surplus water is released to the Sisson Brook channel. This results in the most conservative estimates of areas of indirect habitat loss in Lower Napadogan Brook, as there will be surplus water to discharge at different stages during Operation and at Post-Closure.

The modelling uses channel transect data collected in lower Napadogan Brook during the months of September and October 2011. Data collected include topographic surveys of channel geometry at the transects (*i.e.*, stream width, channel bottom elevations and water surface elevations) and spot stream discharge data from stream depths and velocity measurements. These data were collected at

106 locations along Napadogan Brook, from above Bird Brook to the mouth of Napadogan Brook where it meets the Nashwaak River (Figure 7.4.2). These data were used to prepare a one-dimensional (1-D) HEC-RAS model to assist in the assessment of potential changes of fish habitat arising from the loss of wetted perimeter due to downstream flow reductions in the brook. In addition, a range of flow statistics were calculated from Project stream flow monitoring, and modelling data and were used to assess potential changes in wetted perimeter resulting from Project development.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Location of Developed Flow Statistics Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:68,000	Project No.: 121810356	Data Sources: NBDNR, SNB, Leading Edge Geomatics Ltd.	Fig. No.: 7.4.2	Stantec
Client: Sisson Mines Ltd.	Date: (dd/mm/yyyy) 02/04/2013	Dwn. By: JAB Appd. By: DLM			

Map: NAD83 CSRS NB Double Stereographic

Methodology: Estimating Habitat Areas in Lower Napadogan Brook

The HEC-RAS model was developed to estimate the area of habitat that exists within Lower Napadogan Brook for a variety of baseline and projected future flow conditions (Stantec 2012l). HEC-RAS is a one-dimensional steady/unsteady flow hydraulics program capable of simulating a full network of open channels such as watercourses and man-made channels, as well as hydraulic structures such as bridges, culverts, and weirs, with variable spatial discretization (USACE 2010). HEC-RAS is widely used, is in the public domain, and has been applied to a variety of ecosystem function problems such as simulating floodplain inundation, evaluating fish passage through culverts, and predicting changes to aquatic habitat.

The Lower Napadogan Brook model was created from surveyed transects along the length of the brook from above Bird Brook to its confluence with the Nashwaak River. A sample cross-section for a transect in the HEC-RAS model that was created from the survey data is shown in Figure 7.4.3 (note that there is considerable vertical exaggeration in this figure, for illustration purposes). The model was calibrated to site conditions (stage and flow) observed during the months of September and October, 2011.

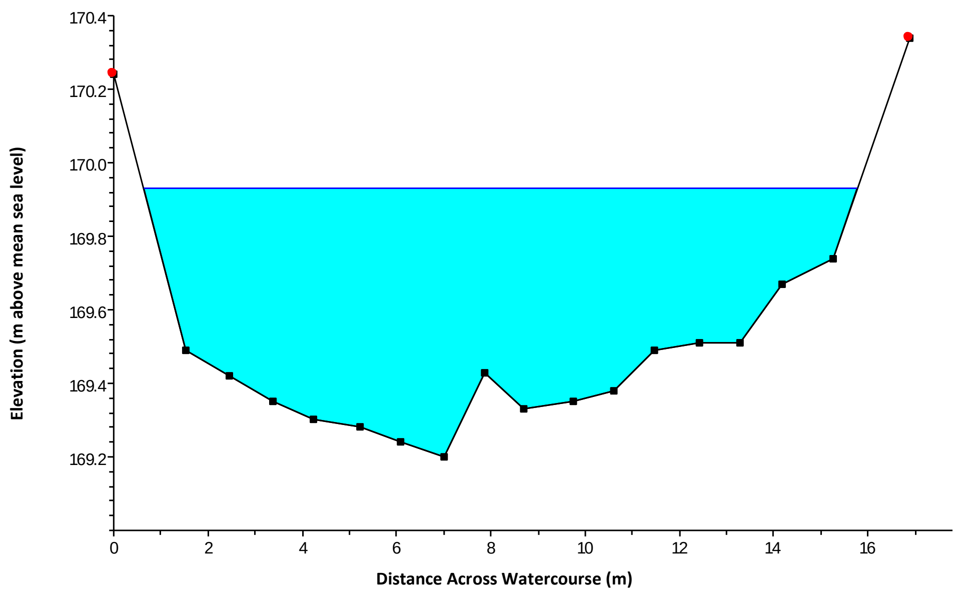


Figure 7.4.3 Sample Transect Cross-Section from HEC-RAS Model

The flow statistics prepared by Knight Piésold are presented on Tables 7.4.5 and 7.4.6 for the baseline conditions case and the future conditions case, respectively. The River Station locations provided are shown on Figure 7.4.2.

Table 7.4.5 Scenario Stream Flow Rates (m^3/s) under Baseline Conditions (Pre-development) Case

Flow Percentile	River Station (m upstream of confluence with Nashwaak River)						
	13811.3	13307.8	11677.5	8370.4	4144.4	2186.2	300.6
0.15	8.9	11.3	13.5	26.2	31.1	33.8	34.8
32	0.807	1.025	1.227	2.379	2.823	3.067	3.158
61	0.312	0.396	0.473	0.919	1.090	1.184	1.219
74	0.202	0.256	0.307	0.595	0.706	0.767	0.790
88	0.102	0.125	0.147	0.262	0.304	0.327	0.336
94	0.062	0.077	0.092	0.173	0.204	0.221	0.228
95	0.056	0.070	0.084	0.158	0.186	0.202	0.208

Table 7.4.6 Scenario Stream Flow Rates (m^3/s) under Future Conditions (Development) Case

Flow Percentile	River Station (m upstream of confluence with Nashwaak River)						
	13811.3	13307.8	11677.5	8370.4	4144.4	2186.2	300.6
0.15	8.4	8.9	10.2	22.9	27.8	30.5	31.5
32	0.765	0.805	0.929	2.081	2.525	2.769	2.860
61	0.295	0.311	0.358	0.804	0.975	1.069	1.104
74	0.191	0.201	0.232	0.520	0.631	0.692	0.715
88	0.097	0.101	0.115	0.233	0.276	0.299	0.308
94	0.058	0.061	0.070	0.153	0.184	0.201	0.207
95	0.053	0.056	0.064	0.139	0.167	0.183	0.189

The predicted reductions in flows along Lower Napadogan Brook are summarized in Table 7.4.7 for each station. For example, a 24% reduction in mean annual flow is predicted in Napadogan Brook at the confluence with Sisson Brook (River Station 11677.5). The reduction falls to about 12% below the confluence with East Branch Napadogan Brook (River Station 8370.4), and to about 9% at the confluence with the Nashwaak River (River Station 300.6), depending on the flow scenario (percentile). It is important to recall that these are conservative estimates since water discharged to Sisson Brook during Operation, and especially Post-Closure, will reduce these environmental effects.

Table 7.4.7 Reduction of Stream Flow Rates (m^3/s) and Percentage Reductions (%) of Future Conditions Compared to Baseline Conditions

Flow Percentile	River Station (m upstream of confluence with Nashwaak River)						
	13811.3	13307.8	11677.5	8370.4	4144.4	2186.2	300.6
0.15	0.500 (6%)	2.40 (21%)	3.30 (24%)	3.30 (13%)	3.30 (11%)	3.30 (10%)	3.30 (9%)
32	0.042 (5%)	0.220 (21%)	0.298 (24%)	0.298 (13%)	0.298 (11%)	0.298 (10%)	0.298 (9%)
61	0.017 (5%)	0.085 (21%)	0.115 (24%)	0.115 (13%)	0.115 (11%)	0.115 (10%)	0.115 (9%)
74	0.011 (5%)	0.055 (21%)	0.075 (24%)	0.075 (13%)	0.075 (11%)	0.075 (10%)	0.075 (9%)
88	0.005 (5%)	0.024 (19%)	0.032 (22%)	0.029 (11%)	0.028 (9%)	0.028 (9%)	0.028 (8%)
94	0.004 (6%)	0.016 (21%)	0.022 (24%)	0.020 (12%)	0.020 (10%)	0.020 (9%)	0.021 (9%)
95	0.003 (5%)	0.014 (20%)	0.020 (24%)	0.019 (12%)	0.019 (10%)	0.019 (9%)	0.019 (9%)

The HEC-RAS model was run for each of the seven flow scenarios for the baseline conditions case as well as for the future conditions case. Habitat areas were estimated for the flow simulations by multiplying the simulated wetted perimeter at each surveyed transect by half the upstream and downstream distance between transects.

An example of the simulated change in wetted perimeter ("WP") calculated using the HEC-RAS model is shown in Figure 7.4.4. In the figure, the wetted perimeter associated with the baseline conditions case ($WP_{baseline}$) is shown in light blue solid line, and the wetted perimeter associated with the future conditions case (WP_{future}) is shown in a darker blue dashed line. As shown in Figure 7.4.4, the wetted perimeter for the future conditions case is smaller than that for the baseline conditions case, due to the withholding of water from Bird and Sisson Brooks by the Project.

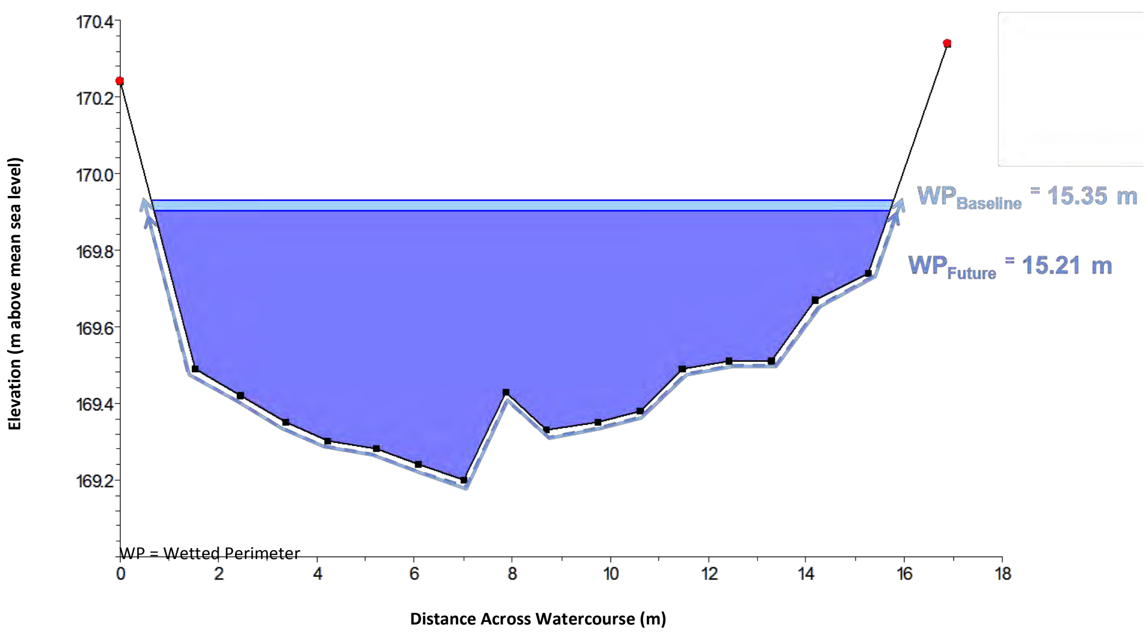


Figure 7.4.4 Simulated Change in Wetted Perimeter for a Sample Transect

The changes to available fish habitat were calculated by summing the differences between the estimated areas for the baseline conditions case and the future conditions case for stream reaches that are predicted to experience more than 10% reduction in MAF. Reductions in mean annual flow that are less than 10% are assumed to not cause serious harm to CRA fisheries (DFO 2013b). The percentage reductions in MAF (which corresponds to the 32nd flow percentile in Napadogan Brook) are shown by stream reach on Table 7.4.7. A summary of the cumulative calculated areas that experience more than 10% reduction in MAF is presented in Table 7.4.8.

Results: Indirect Habitat Loss in Lower Napadogan Brook

The reduction in fish habitat for the various flow statistics is presented in Table 7.4.8. The reduction is calculated as the sum of all changes in habitat area that experience more than 10% reduction in MAF; that is, the total habitat calculated during the baseline conditions case less the total habitat calculated during the future conditions case.

Table 7.4.8 Estimated Total Reductions to Habitat Areas for Various Flow Scenarios

Flow Percentile	Future Conditions Case: Reduction in Fish Habitat		
	(m^2)	(fish habitat units)	(% reduction[a])
0.15	n/a	n/a	n/a
32	2,380	24	1.3
61	4,480	45	2.7
74	5,150	52	3.5
88	4,760	48	4.0
94	5,540	55	5.4
95	4,760	48	5.0

Notes:
[a] % reduction as compared to baseline conditions case.

As shown in Table 7.4.8, changes in habitat area are not provided for the 0.15th flow percentile scenario, as these flow conditions resulted in the model predicting water levels above the banks of the main channel. This model was not calibrated to account for overbank flow conditions, as all observations were collected when the water levels were within the bank-full width of the channel. Therefore, this condition could not be properly simulated in the model using available data. Furthermore, this condition is not representative of fish habitat, as peak flows occur for a very short periods of the year. For these reasons, this scenario is not considered further.

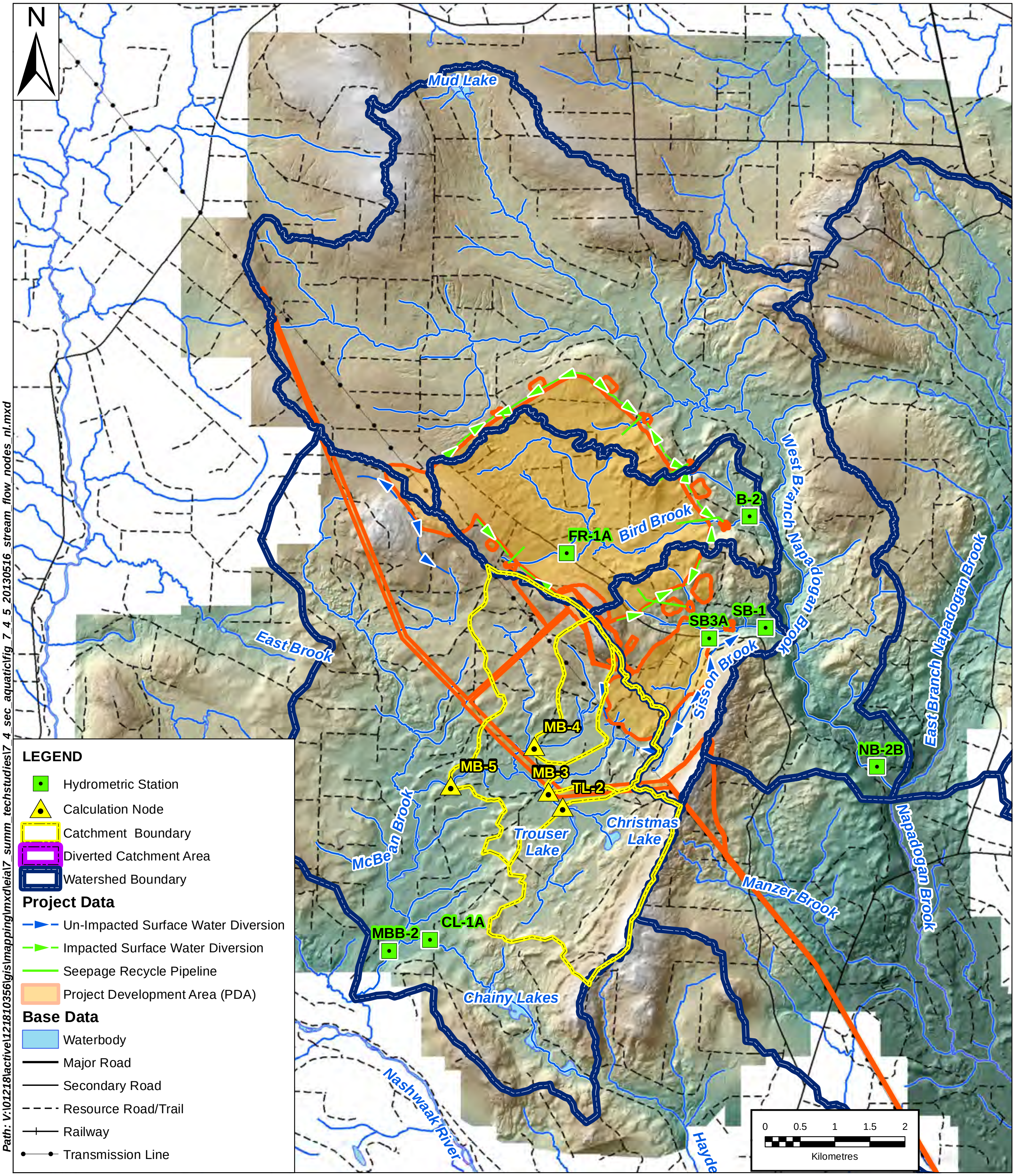
The modeling scenarios conducted indicate an indirect loss of aquatic habitat between 24 and 55 fish habitat units depending on which flow statistic is used. In order to maintain the conservative nature of the estimates of indirect habitat loss already employed, the largest loss estimate of 55 fish habitat units was conservatively assumed for Lower Napadogan Brook. This is assumed to be a permanent loss for which authorization from DFO with associated compensation will be sought, whereas flow may be partially restored at some stages of the Project life as surplus treated water is released. Seeking authorization for this loss and associated compensation is thus a conservative approach.

7.4.3.3 Indirect Habitat Loss in McBean Brook

Stream flow reductions in McBean Brook will result from the stream flow reductions in the first-order tributaries that will be directly lost as described in Section 7.4.2.2.4. However, as is illustrated below, this will be in part offset by the diversion of a portion of the Sisson Brook watershed area into McBean Brook.

Methodology: Predicting Indirect Habitat Loss in McBean Brook

Stream flow reductions in McBean Brook as a result of the Project activities over the life of the mine were estimated by Knight Piésold (2012f). The flows were estimated at several nodes within the McBean Brook watershed using the watershed model developed for the Project (Knight Piésold 2012b) as shown on Figure 7.4.5. The stream flow is calculated at each node as the sum of water from direct runoff of precipitation and contributions from groundwater discharge within the drainage area of each node.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Location of Stream Flow Estimation Node in McBean Brook Watershed Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:75,000	Project No.: 121810356		Data Sources: Leading Edge Geomatics NBDNR	Fig. No.: 7.4.5
Client: Sisson Mines Ltd.	Date: (dd/mm/yyyy) 02/04/2013	Dwn. By: JAB	Appd. By: GPY		

Map: NAD83 CSRS NB Double Stereographic

The predicted stream flow reductions in McBean Brook are presented in Table 7.4.9. As shown in the table, the greatest reduction in stream flow is predicted at node MB-4, while an increase in stream flow is predicted at node MB-3. The combined effect of stream flow alterations at node MB-5, located downstream of the combined flows from nodes MB-3 and MB-4, is a reduction of one percent of the mean annual flow.

Table 7.4.9 Predicted Flow Reductions in McBean Brook Watershed

Node	Average Annual Flow (L/s)				Maximum Reduction in Average Annual Flow (%)
	Baseline	Year 2	Year 15	Year 27	
TL-2	105	105	105	103	2
MB-3	36	53	44	41	-14
MB-4	33	32	31	29	12
MB-5	277	294	284	274	1

Source: Knight Piésold (2012f).

It is important to note that the predicted reductions in stream flow at TL-2, MB-4 and MB-5 are due mostly to baseflow reductions, which increase over the life of the mine with increased development of the open pit. Once dewatering of the open pit ceases, the baseflow contributions to these streams are anticipated to return to the baseline levels.

Results: Indirect Habitat Loss in McBean Brook

As a result of the direct loss of habitat in McBean Brook described in Section 7.4.2.2.4, and the reductions in baseflow predicted above, there will be a small indirect loss downstream in three first-order tributaries. Indirect losses due to stream flow reductions upstream of station MB-4 are anticipated to be offset by enhancements to habitat due to stream flow gains at station MB-3, due to the diversion of stream flow from a portion of Sisson Brook. The one percent flow reduction predicted in McBean Brook at MB-5 is negligible, and would not result in any reduction in habitat area. Therefore, no net indirect loss of habitat is anticipated for McBean Brook.

Existing habitat in the first-order watercourse of McBean Brook provide fair to good fish habitat. Habitat to be directly lost is headwater habitat made up of mostly wetland drainage and pond. The habitat present is most suitable for warm water fish species that prefer slow moving or ponded waters.

7.4.3.4 Summary of Indirect Habitat Loss

A total of 178 fish habitat units will be indirectly lost downstream of the PDA as a result of Project activities. This includes 55 fish habitat units that are predicted to be lost as a result of in stream flow reductions in Napadogan Brook. A summary of the indirect habitat loss is provided in Table 7.4.10.

Table 7.4.10 Summary of Indirect Loss by Category

Indirect Loss Category	Indirect Habitat Loss (fish habitat units)
Indirect Loss from Residual Stream Segments	123
Indirect Loss from Downstream Flow Reductions in Napadogan Brook	55
Indirect Loss from Downstream Flow Reductions in McBean Brook	0
Total	**178**

Notes:
1 fish habitat unit = 100 m^2 of fish habitat.

The habitat to be lost ranges from fair to excellent quality, first-order headwaters to fourth order watercourse. Habitat that will be indirectly lost ranges from ideal for salmonid spawning, rearing and feeding habitat in Napadogan Brook to fair salmonid habitat in first-order tributaries of Bird Brook.

7.4.4 Total Estimated Fish Habitat Loss

As summarized in Table 7.4.11, a total of 544 fish habitat units are estimated to result from the Project.

Table 7.4.11 Summary of Habitat Loss by Category

Loss Category	Habitat Loss (fish habitat units)
Total Direct Loss	366
Total Indirect Loss	178
Total	**544**

Notes:
1 fish habitat unit = 100 m^2 of fish habitat.

A conceptual plan to offset for the loss of fish habitat, and the consequent serious harm to fish and fisheries, is summarized in Section 7.4.5 below.

7.4.5 Offsetting Plan for Serious Harm to Fish and Fish Habitat

7.4.5.1 Regulatory Overview

The *Fisheries Act* is administered by Fisheries and Oceans Canada (DFO) and is the main legislation protecting fish, fisheries, and fish habitat in Canada. Under Section 35 of the *Fisheries Act*, a project or development cannot cause "serious harm to fish that are part of a commercial, recreational or Aboriginal fishery" without authorization from DFO. "Serious harm" to fish is defined in the *Fisheries Act* as "the death of fish or any permanent alteration to, or destruction of, fish habitat". Authorization will not be granted unless the proponent agrees to offset any serious harm to fish that were part of or supported a commercial, recreational or Aboriginal fishery such that they would maintain or improve the productivity of the fisheries. The Offsetting Plan is evaluated by DFO following the "Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting" (DFO 2013).

Offsetting is also required under Section 36 of the *Fisheries Act*, which stipulates that *"no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish"* without authorization. Authorizations for metal mines to deposit deleterious substances into waters are permitted under the *Metal Mining and Effluent Regulations* (*MMER*). Where water or places set out in Schedule 2 contain fish habitat and have been designated as a tailings impoundment area, Section 27.1 of *MMER* requires a plan to offset the fish habitat resulting from the deposit of a deleterious substance into the tailings impoundment area and is approved by the Minister. The *MMER* also requires that the proponent submit an irrevocable letter of credit to cover the cost of the fish habitat offset plan.

In addition to requirements under the *Fisheries Act*, Section 16(1)(d) of the *Canadian Environmental Assessment Act* (*CEAA*) requires that the EIA must consider "*mitigation measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project*". In this light, compensation measures that are technically and economically feasible may constitute part of the overall mitigation approach to minimize the potential for significant adverse environmental effects arising from the Project.

7.4.5.2 Estimated Amount of Fish Habitat Offsetting Required

While under the *Fisheries Act* as amended in 2012, the focus is on sustaining the productivity of CRA fisheries, the amount of fish habitat units affected by a project, and in an offsetting project, remains an indicative metric. Under the *Fisheries Act* before it was amended in 2012, DFO typically required that lost habitat be compensated for at a 3:1 ratio. Thus, by the fish habitat unit metric, the total required offsetting arising as a result of the Sisson Project would be 544 habitat units times three, or 1,632 habitat units.

7.4.5.3 Fish Habitat Offsetting Opportunities

Given the relatively large amount of offsetting fish habitat indicated for the Project, it is impractical to attempt offsetting with typical industry standard small-scale compensation measures, or limiting their geographic extent to be near to the Project. Similarly, it is impractical to compensate exclusively in habitats that are like the small watercourses where loss of fish habitat and productivity will occur.

Therefore, large-scale opportunities are preferred, supplemented by small-scale opportunities if necessary. Large-scale opportunities are considered to be significant physical works like dam removals, installation of fish passes around large natural barriers such as waterfalls, or other opportunities that offer major habitat offsetting credit. Small-scale opportunities include replacement or modification of standard culverts, bank stabilization, or other opportunities that typically result in smaller habitat offsetting credit.

Opportunities Evaluated

Large-scale opportunities were identified on a map provided by DFO, which reportedly included input from provincial regulators and Ducks Unlimited Canada (DUC). Of the identified opportunities, the following three were selected for further evaluation in consultation with DFO and NBDNR:

- establishment of a fish pass at Dunbar Stream Falls;
- removal of Campbell Creek Dam;
- removal of Lower Lake Dam; and
- removal of an existing water-level control dam and road culvert on the Nashwaak River just below its exit from Nashwaak Lake.

The locations of these four opportunities are shown on Figure 7.4.6.

Dunbar Stream Falls is a natural waterfall that is 3.35 m in height and completely prevents the passage of Atlantic salmon. Excellent Atlantic salmon habitat exists above and below the falls, so the opportunity for compensation is to provide upstream migratory access for adult Atlantic salmon to the spawning habitat located upstream of the falls. Through consultation with provincial regulators, it was determined that introduction of fish species into habitat where they have not historically occurred due to natural barriers is undesirable, and therefore this opportunity was not considered further as compensation for the Project.

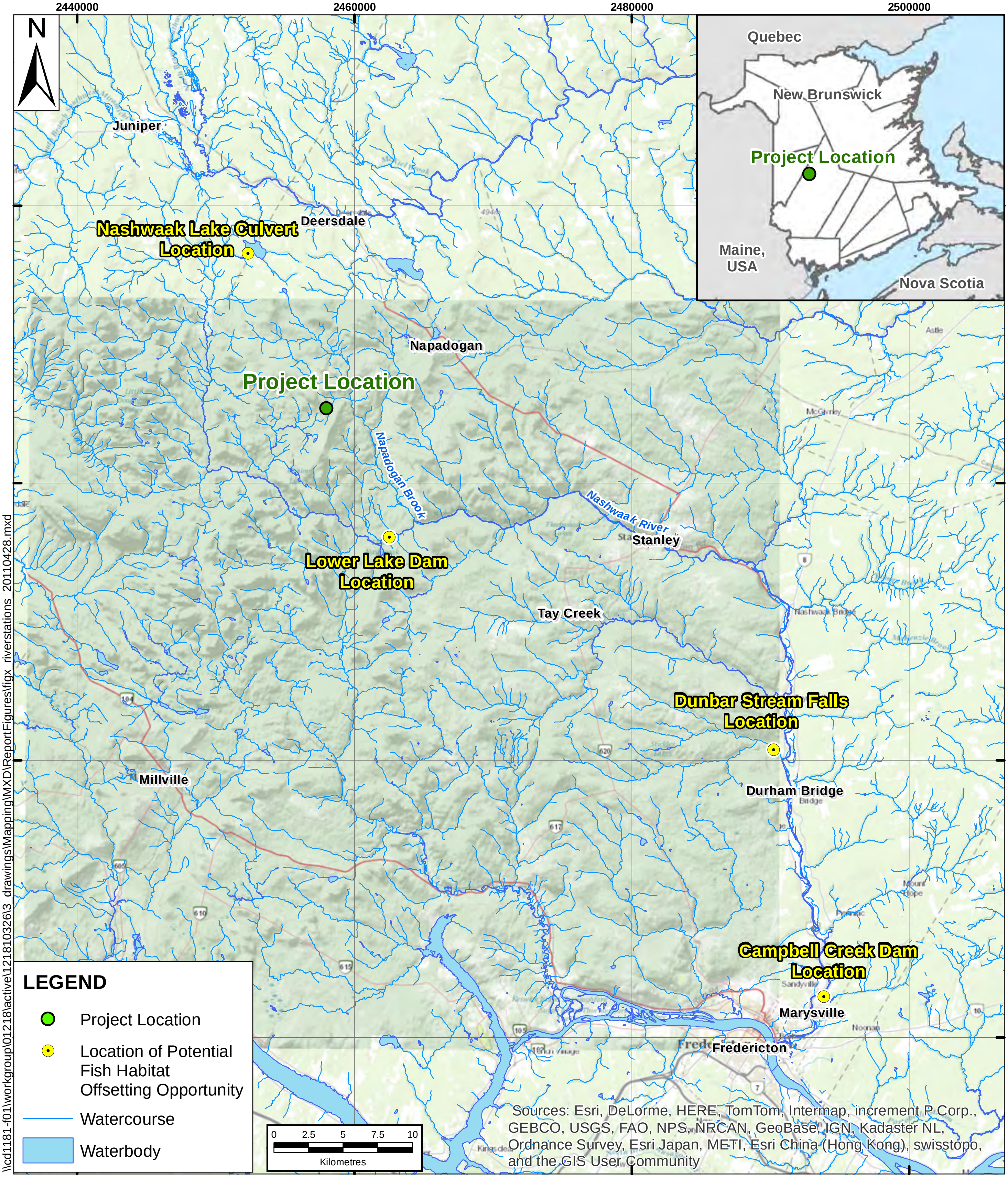
Campbell Creek Dam, north of Fredericton, was built in the early 1900s to provide water to the Marysville cotton mill, and its presence is a complete barrier to fish passage in both directions. Campbell Creek above the new Route 8 likely provides good quality habitat for brook trout, Atlantic salmon, and American eel and so the opportunity for compensation is to provide the opportunity for improved/renewed use of this habitat by these species. During the evaluation process, it was determined that the offsetting credit for undertaking this opportunity is not sufficient (approximately 10% of the required total habitat offset) to justify the considerable expense and other risks associated with the undertaking. Therefore this opportunity was not considered further as compensation for the Project.

The Lower Lake Dam is located on the Nashwaak River, approximately 2.5 km upstream of the Napadogan Brook confluence. It was constructed in the 1960s to facilitate log drives on the river to support lumbering activity in the area. Following submission of the EIA Report to governments in July 2013 in which removal of this dam was proposed as the selected habitat offsetting opportunity, it was demonstrated that Lower Lake Dam is a partial barrier to fish passage – for some species at some flows. While removal of the dam would probably increase the fish productivity of the Nashwaak River watershed above the dam, it became clear that the beneficial effect to fish productivity would be difficult to predict and demonstrate in a scientifically defensible manner. Thus, removal of this dam was removed from consideration as an offsetting project.

Therefore, only removal of the existing water-level control dam and road culvert on the Nashwaak River was determined to be a viable potential opportunity to achieve the offsetting requirements for the Sisson Project. It is discussed below.

Selection of Opportunity: Nashwaak Lake Dam/CulvertReplacement

To offset the serious harm as a result of the Sisson Project, SML proposes to remove an existing water-level control dam and road culvert on the Nashwaak River just below its exit from Nashwaak Lake to facilitate the passage of various fish species. The location of the Nashwaak Lake culvert is shown in Figure 7.4.6. The structure is a timber “box” with steel beams supporting the road deck (Photo 7.4.1). It is presently owned by NBDNR.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Location of Potential Large-Scale Fish Habitat Offsetting Opportunities Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: 1:375,000	Project No.: 121810356	Data Sources: ArcGIS World Topo, NBDNR, SNB	Fig. No.: 7.4.6
Client: Sisson Mines Ltd.	Date: (dd/mm/yyyy) 04/02/2013	Dwn. By: JAB / Appd. By: DLM		Stantec

Map: NAD83 CSRS NB Double Stereographic

Photo 7.4.1 Barrier to Fish Passage Structure at Entrance to Nashwaak Lake.

The water plunges from the flat bottom of the structure, with an air space behind the water, thereby creating a vertical leap barrier. Immediately downstream is a series of cascading steps that do not provide sufficient depth for fish to make the leap (Plante, F. Personal communication, October 24, 2013). For these reasons, the structure is considered to be a partial to full barrier to upstream fish passage, thereby preventing most fish species within the Nashwaak River from accessing the habitat in Nashwaak Lake.

It is proposed that the existing water-level control dam and road culvert be removed, and replaced with a standard "woods road" bridge. The proposed bridge structure would consist of a structural steel frame bearing on concrete, timber crib, or gabion abutments, with a timber driving surface (see Figure 7.4.7). The approach slopes currently consisting of timber cribbing may be left in place; however, during removal of the existing structure they may be damaged and need to be removed.

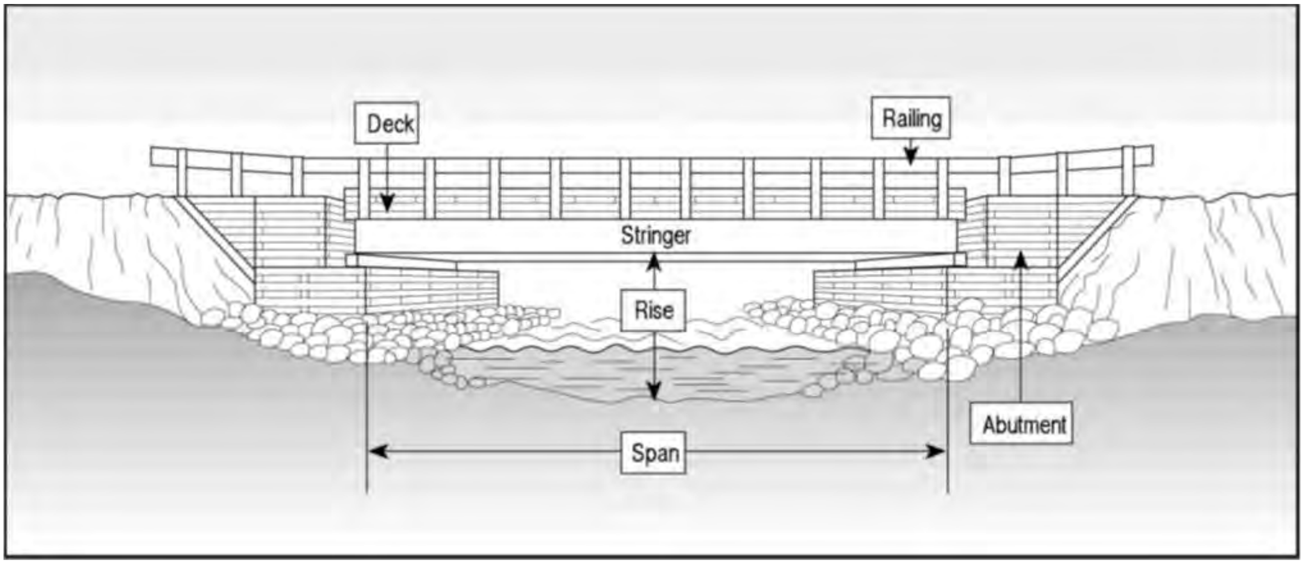


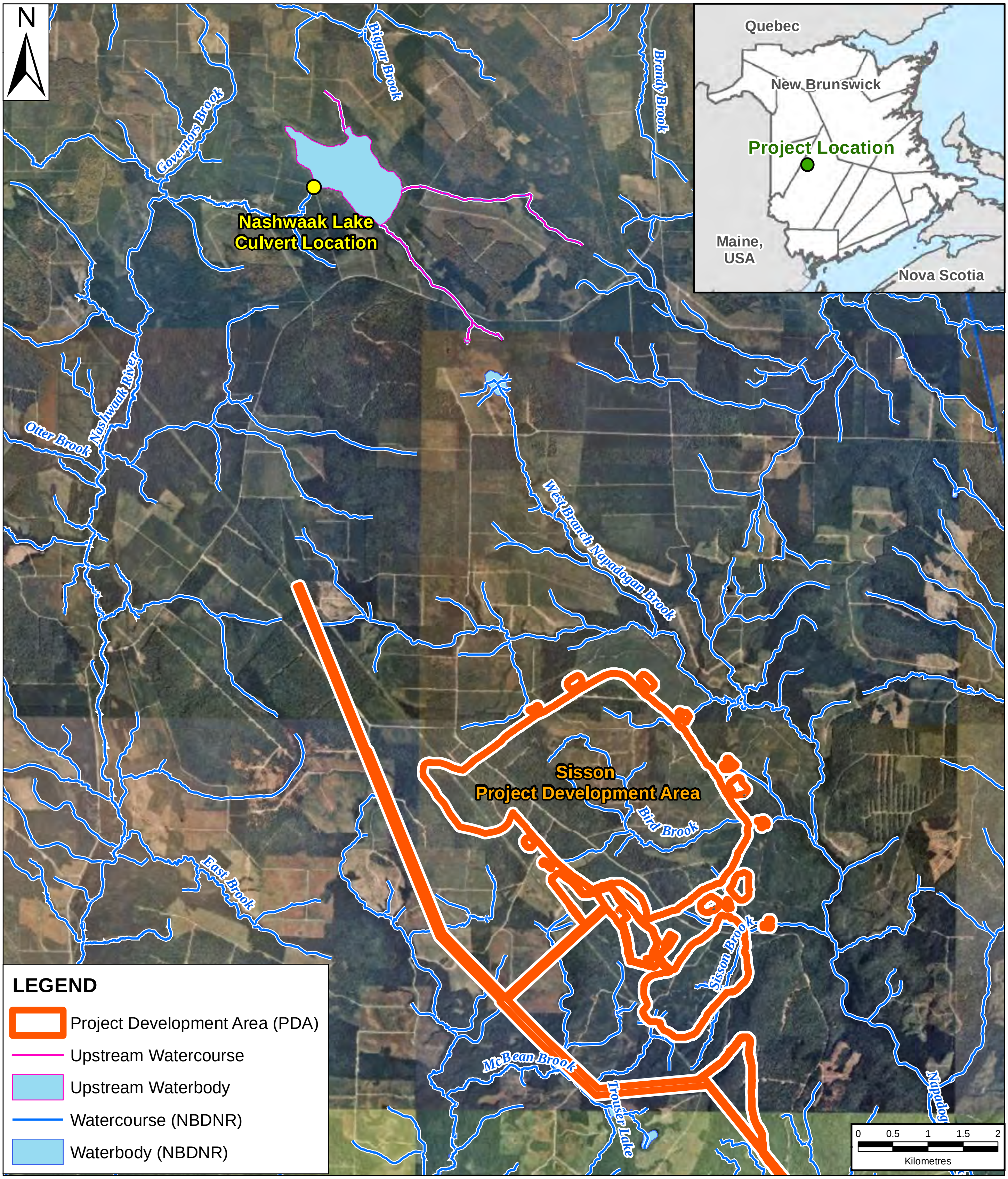
Figure 7.4.7 Typical One-Lane "Woods Road" Bridge

How the Opportunity Offsets Serious Harm

The Offsetting Plan for the removal of the existing water-level control dam and road culvert at Nashwaak Lake meets all of the "Guiding Principles" for fisheries protection (DFO 2013a). At this time, DFO is still working with provinces and territories to determine how Federal/Provincial/Territorial Fish Management Objectives will be incorporated for use in the regulatory review process. Local priorities do include the removal of anthropogenic barriers to fish migration, such as the removal of the existing water-level control dam and road culvert at Nashwaak Lake. In terms of productivity, the removal of the existing water-level control dam and road culvert will increase ecological productivity as defined in DFO (2012) as "the capacity of a given habitat or area". Therefore, for the purposes of the Sisson Project and the required offsetting, fish productivity is inferred from the quantity of fish habitat, which is available to all CRA fish species.

Nashwaak Lake is located within the Nashwaak River watershed, the same watershed as the Project. The project is considered by DFO to provide "in-kind" offsetting as it offsets for habitat lost to brook trout, and possibly other species which are present within the area where serious harm is occurring. The Offsetting Plan proposes the existing water-level control dam and road culvert will be replaced with a clear span bridge which will provide the opportunity for the unimpeded movement of alewife, brook trout, possibly Atlantic salmon and other species between the Nashwaak River and the lake and its first and second-order tributaries. The majority of habitat upstream of the existing water-level control dam and road culvert is different from the PDA, in that it is lacustrine, and the habitat within the PDA is riverine; however brook trout are found in lake habitats and will likely benefit.

Nashwaak Lake (Figure 7.4.8) is a natural water body, with freshwater input from two first-order watercourses and one second-order watercourse. The lake has a maximum depth of 8.5 m (28 feet, as shown in Figure 7.4.9), with a fairly uniform trough-like bottom contour running in a northwest to southeast direction. There is a relatively shallower bay on the northern side of the lake. The lake has a diverse fish community which includes both resident and stocked brook trout.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Nashwaak Lake and its Tributaries

Sisson Project:
Environmental Impact Assessment (EIA) Report, Napadogan, N.B.

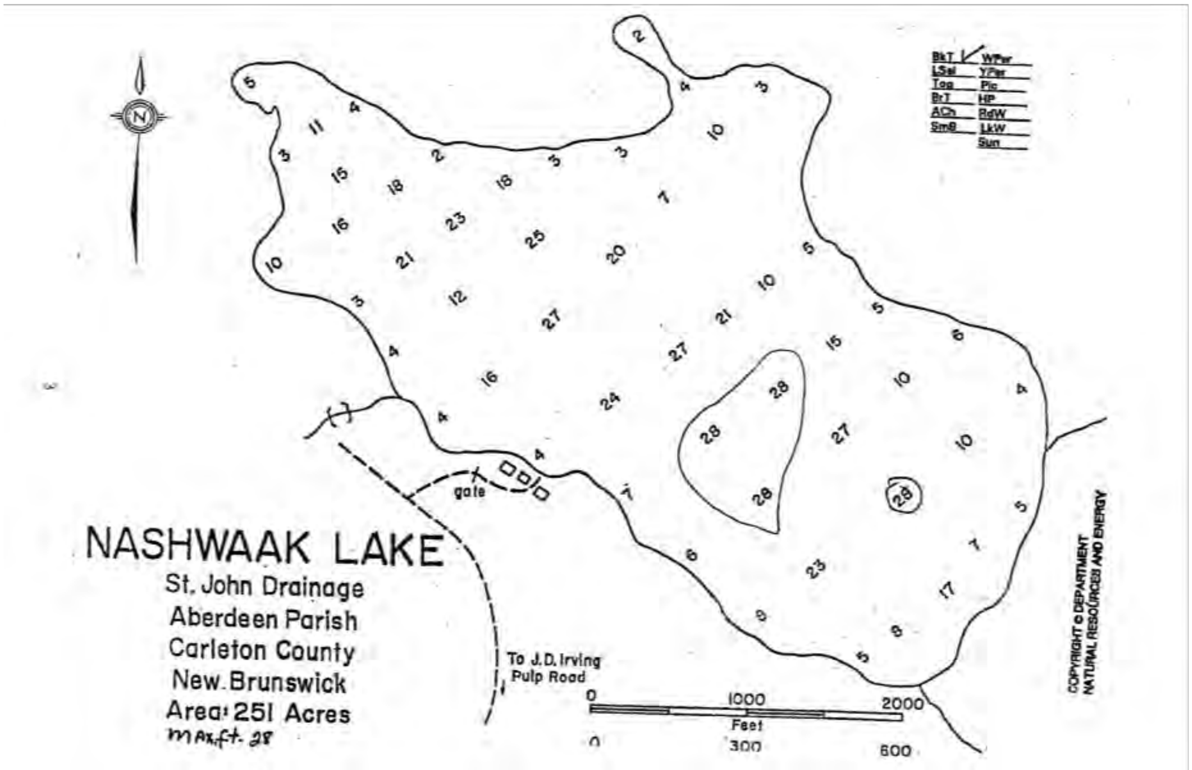
Client: Sisson Mines Ltd.

Scale:	Project No.:	Data Sources:	Fig. No.:
1:75,000	121810356	NBDNR SNB	7.4.8

Date: (dd/mm/yyyy)	Dwn. By:	Appd. By:
13/11/2014	JAB	DLM

Stantec

Map: NAD83 CSRS NB Double Stereographic



Source: Seymour, P. Personal communication, October 24, 2013.)

Figure 7.4.9 Bathymetry of Nashwaak Lake

The largest increase in the productivity of CRA fish species that is anticipated from the removal of the existing water-level control dam and road culvert at Nashwaak Lake is due to the additional habitat that will be available for the spawning of alewife (*Alosa pseudoharengus*) and rearing of early life stages of juveniles. Although alewife and blueback herring (*Alosa aestivalis*) are commonly called “gaspereau”, it is commonly understood that blueback herring do not spawn in lakes, and therefore it is likely that only alewife will benefit.

Alewife are a commercially important species, used fresh or salted for human consumption, and used as bait, fish meal and fish oil (Pardue 1983). Within the maritime region the larger commercial fisheries for gaspereau (<1,000 t annually) occur in the St. John River and Miramichi River (DFO 2001). In the St. John River and most of Atlantic Canada, the majority of the gaspereau run is made up of alewife (DFO 2001). Alewives spawn in large rivers, small streams, ponds and lakes (Pardue 1983). Spawning substrates include gravel, sand, detritus, and submerged vegetation with sluggish water flows and water depths of 15 cm to 3 m (Pardue 1983).

It is likely that alewife did spawn in Nashwaak Lake prior to the downstream development of water control dams and road crossing structures (Seymour, P. Personal communication, November 5, 2013). With the recent removal of Barker Dam, the only other known potential fish passage impediment between Nashwaak Lake and the St. John River is the Lower Lake Dam on the main stem of the Nashwaak River.

Brook trout may make use of the deeper areas of the lake as cold water refugia during summer months, and may also reside there during winter months. They may also make use of the habitat within the lake for spawning or rearing. Brook trout will also likely use the habitat found in the tributaries which flow into the lake for spawning and rearing, or for thermal refuge during summer months.

The proposed Offsetting Plan provides additional benefits to fisheries productivity by allowing alewife, a species that was likely historically present in Nashwaak Lake, to access spawning and rearing habitat in the lake. Allowing alewife access into Nashwaak Lake may also increase lake productivity by increasing marine nutrients through excretion and morality each year, with the potential to affect food web dynamics and nutrient cycling with in the lake (Walters *et al.* 2009). It may also improve CRA fisheries productivity by increasing or improving access to additional lacustrine habitat for brook trout, and additional habitat for Atlantic salmon within the tributaries flowing into Nashwaak Lake. The removal of the Nashwaak Lake culvert will generate self-sustaining benefits in the long-term as the culvert removal is permanent and will allow access for CRA species into perpetuity.

The offsetting will begin during Project Construction in order to reduce the delays associated with offsetting at a later time, as the majority of serious harm will occur during the Construction phase of the Project. The removal and replacement of the culvert will take place during the first year of the Offsetting Plan and the associated monitoring will take place the following year. The purpose of this Offsetting Plan is to generate self-sustaining benefits to fisheries productivity by improving access to the lake and its associated tributaries as habitat for migratory fish species into perpetuity.

7.4.6 Estimate of the Offsetting Credit

To estimate the amount of offsetting of serious harm to fish that would be achieved by restoring fish passage at this location, existing aerial imagery and GIS was used to calculate the total surface area of the lake, and the lengths of the tributaries. The width of the tributaries was assumed to be 3 m, which is consistent with first-order streams in this region. Using this methodology, the total surface area of the Nashwaak Lake itself is estimated as 11,238 fish habitat units, and the total combined surface area of the three tributaries and outlet is 199 fish habitat units. The combined total area is thus 11,437 fish habitat units.

Given that the lake presently provides habitat for a number of fish species, it is unlikely that a full credit would be granted for this entire area. For example, when considering the Dunbar Stream Falls project, DFO suggested that the credit for providing access to Atlantic salmon would equal 25% of the upstream habitat area. Applying the same factor to the Nashwaak Lake culvert project, a more likely offsetting credit is estimated at 2,859 fish habitat units (25% of 11,437), to be confirmed with DFO. Thus, in terms of the productivity measure represented by fish habitat units, the habitat offsetting from the removal of the existing water-level control dam and road culvert at Nashwaak Lake and its replacement with an open span bridge is more than five times the amount required for the Sisson Project (544 habitat units). Thus, the removal of the existing water-level control dam and road culvert will likely allow sufficient increases in productivity to account for any uncertainty associated with the offsetting and any time lags associated with implementing the offsetting during the Construction phase of the Project.

7.4.7 Supplementary Small-Scale Habitat Enhancement Opportunities

Separately, SML may consider funding small-scale opportunities to enhance fish habitat as part of its community or First Nations relations programs over the life of the Project, but these would not be part of the offsetting compensation or authorization requirement under the *Fisheries Act* for the loss of fish habitat and associated fish productivity associated with the Project.

These potential projects would be identified by community members, special interest groups and First Nations and brought to the Community Liaison Committee for review and consideration. SML is committed to working with the communities around the mine and First Nations to develop opportunities that will result in a positive contribution to the community and the environment over the life of the Project, *i.e.,* during Construction and Operation.

7.5 GEOCHEMICAL CHARACTERIZATION OF WASTE MATERIALS

Information presented in this sub-section has been provided by SRK Consulting based on SRK (2013).

As described in Chapter 3, the Project will generate various waste materials, which for the purposes of the geochemical characterization include wastes produced by mining and ore processing (barren rock and tailings), mid-grade ore, pit walls exposed by mining, and borrow materials used for Construction purposes (quarry rock). Because these materials have the potential to result in metal leaching and acid rock drainage (ML/ARD), a geochemical characterization of their ML/ARD potential was conducted by a number of analytical laboratory and field techniques (SRK 2013) so that potential environmental effects could be mitigated if necessary. The methodology and characterization results of Sisson Project waste materials are described in the following sections.

7.5.1 ML/ARD Assessment Methods

7.5.1.1 Geological Context for ML/ARD Potential

A description of the geological setting of central New Brunswick is provided in Section 6.3.1, and a description of the Sisson deposit is provided in Section 3.1.3, however a summary of the geological setting of the PDA is provided here as it relates to characterizing ML/ARD potential.

The Sisson deposit has been described as a granite-related porphyry tungsten-molybdenum-copper deposit (Geodex 2009). Regional metamorphism is overprinted by contact metamorphism due to the intrusion of the Howard Peak Granodiorite. Porphyry-style alteration is present, although it is not as intense or widely distributed as typical copper porphyry systems. The most common alteration observed is biotite and sericite, with strongest alteration along the contact of the western gabbro with the eastern section of the deposit, referred to as the Porten Road formation. Tungsten and molybdenum are predominantly present as scheelite and molybdenite that appear to be vein and fracture controlled. As it is currently understood, the economically-viable part of the deposit is made up of Zone III and the Ellipse Zone (see Figure 3.1.2). Zone III is a roughly north-south striking, while the Ellipse Zone is northwest-southeast striking, south of Zone III. The western half of Zone III is predominantly gabbro, and lithologies to the east of the gabbro intrusion and north of the Ellipse Zone are metamorphosed, consisting predominantly of volcanic and sedimentary rocks. The Ellipse Zone is made up of quartz diorite and lesser gabbro. The major lithologies are listed in Table 7.5.1 including a brief description and the associated lithocodes used in Figures 7.5.1 to 7.5.3.

Table 7.5.1 Summary of Major Rock Types Expected in Barren Rock at Sisson

Lithocode	Rock Name	Description
FTA	Felsic Tuff With Augen	Similar to FTQ but contains up to >10% large feldspar augen. Very strong metamorphic fabric. Locally important rock type.
FTQ	Felsic Tuff With Quartz	Medium to coarse-grained, commonly strong foliation, well-annealed.
IGB	Gabbro Intrusion	Gabbro intrusion; medium-grained, equigranular, weak to no metamorphic fabric.
IQD	Quartz Diorite Intrusion	Quartz diorite intrusion, mostly found in Ellipse Zone; possible dykes encountered in 2010 drill holes. Medium-grained, equigranular to porphyritic, weak to no metamorphic fabric.
MTF	Mafic Tuff	Fine-grained, massive, can have a strong foliation.

Table 7.5.1 Summary of Major Rock Types Expected in Barren Rock at Sisson

Lithocode	Rock Name	Description
WKB	Biotite Wacke	Mostly fine-grained and laminated foliation. A meta-sedimentary rock type with high concentration of biotite.
WKS	Biotite Wacke With Sericite	Similar to WKB but muscovite accompanies biotite.

The sulphide minerals pyrite and pyrrhotite typically average 1 to 2%, with minor arsenopyrite, sphalerite, galena and bismuth. Carbonates appear to be minor and are associated with narrow (*i.e.,* less than 50 cm) quartz veins. Based on geologic observation, there appears to be potential for ARD given the presence of sulphides and limited amounts of carbonate minerals.

7.5.1.2 Barren Rock, Pit Walls, and Mid-Grade Ore

The rock types selected to represent barren rock, pit walls, mid-grade ore, and quarry material for this geochemical characterization include the major lithologic areas of the Sisson deposit referred to as Zone III and the Ellipse Zone. They include gabbro, felsic volcanic rocks, mafic volcanic rocks, meta-sedimentary rocks and quartz diorite. Tungsten and molybdenum mineralization is vein and fracture controlled at Sisson, and large blocks of different lithologic zones with inherent varying alteration patterns will be mined.

Acid-base accounting (ABA) tests were performed on the composite drill core samples using the modified neutralization potential (NP) method (MEND 1991), paste pH, paste conductivity, total sulphur, sulphur as sulphate (sodium carbonate and hydrochloric acid methods) and total carbonate analysis. Element analysis included a scan by inductively coupled plasma mass spectrometry (ICP-MS) following *aqua regia* digestion, and total barium, low level mercury and total fluoride. In total, 269 barren rock, 68 pit wall, and 20 mid-grade ore drill core composites were tested by the methods listed above.

Laboratory humidity cells were started on September 19, 2011, and at the time of finalizing SRK (2013), results for 89 weeks of testing had been received. There are currently 13 cells being tested on barren rock samples and one mid-grade ore composite. Samples were selected to represent the range of major lithologies and sulphide concentrations expected in barren rock, pit walls and mid-grade ore. The testing procedure is following the protocol outlined by the Mine Environment Neutral Drainage (MEND) program (1991) with weekly monitoring of water volume, pH and conductivity, and bi-weekly analysis of acidity, alkalinity, sulphate, chloride, fluoride, low level mercury and a metal scan by ICP-MS. For quality assurance and quality control purposes (QA/AC) one barren rock sample was tested as a duplicate, and one blank cell was also included in the testing.

Saturated column tests were started on March 8, 2013 to evaluate water quality expected from barren rock submerged in the TSF and, at the time of finalizing SRK (2013), nine weeks of results were available.

Mineralogical characterization of representative splits from all humidity cells included optical petrography, quantitative (Rietveld) X-ray diffraction, and electron microprobe analysis of sulphide and carbonate grains selected during optical petrography observations.

Field kinetic tests (barrels) were started on September 13, 2011 and, at the time of finalizing SRK (2013), results from nearly two years of testing had been received. The field barrels were set up at the

Sisson Project site to evaluate leaching under site conditions for comparison with laboratory tests. Five barrels contain approximately 300 kg of barren rock representing gabbro, felsic tuff, mafic tuff, biotite wacke and quartz diorite. Samples were selected from drill core and crushed and blended by SGS Lakefield prior to being placed into the 200 L field barrels. During the open-water season, leachate was monitored weekly for pH, conductivity and oxidation-reduction potential (ORP), and samples were collected once a month for analysis of the same parameters as the humidity cells listed above. One barrel was set up as a field blank for QA/QC purposes. Splits of all five barrel samples were also set-up as humidity cells.

7.5.1.3 Quarry Rock (Borrow)

A quarry will be used to source rock for the TSF embankment construction. The quarry will be located near the north-west corner of the TSF and the primary rock types are gabbro and granite. Approximately 29,066 m^3 of rock will be quarried. Six drill core composites were selected from the proposed quarry location.

The same testing procedure as outlined for barren rock (Section 7.5.1.2) was performed on quarry material, with the exception of mineralogical characterization and field barrel testing. Two humidity cells were started on September 10, 2012 and, at the time of finalizing SRK (2013), 38 weeks of data had been received. The two samples represent a composite of gabbro and a composite of granite with the same testing frequency and parameters as barren rock.

7.5.1.4 Tailings

Tailings from metallurgical processing of a master ore grade composite were generated for ML/ARD characterization. The master composite was comprised of the six major lithologies expected at Sisson and assumed to represent the average ore characteristics of the first ten years of mining. Two tailings streams were produced from molybdenum concentration and tungsten concentration, with cleaner and rougher fractions for each. Tungsten will be refined in an ammonium paratungstate (APT) plant. Residues from the APT plant have not been tested as they will be stored in sealed drums off-site.

Tailings samples were separated into three size fractions (+0.149 mm; -0.149+0.074 mm; and -0.074 mm) and then submitted for the same composition analyses as performed on barren rock (Section 7.5.1.2).

Two humidity cells were set up for tungsten rougher tailings (combined particle size), one on April 2, 2012 and the other on November 5, 2012. At the time of finalizing SRK (2013), 61 weeks of data had been received for the initial humidity cell and 28 weeks for the second humidity cell test. The testing frequency and parameter list was the same as barren rock. The one addition was the analysis of nitrogen forms. Humidity cell testing was not completed on the molybdenum sample as this material was assumed to require water submergence due to the high sulphide concentration in the tailings.

Mineralogical characterization (as per Section 7.5.1.2) was also completed on the tungsten rougher tailings.

Additional testing completed for understanding TSF water included tailings supernatant chemical characterization as well as supernatant aging tests.

7.5.1.5 QA/QC Measures

Quality assurance and quality control were a major component of all test work. Approximately 10% of all samples were tested as duplicates, in addition to blanks being tested for 10% of all leachate analyses. Any duplicate samples with relative percent differences (RPDs) greater than ±15% were re-analyzed, in addition to any leachate analyses with ion balances with RPDs greater than ±15%.

7.5.1.6 ARD Potential Classification Criteria

Acid rock drainage potential classification of all waste material was based on neutralization potential (NP) to acid potential (AP) ratios (hereafter referred to as NPRs). Samples with a NPR less than 1 were classified as potentially acid generating (PAG), samples between 1 and 2 as uncertain, and samples greater than 2 as non-potentially acid generating (NPAG). In addition, if the sulphur concentration was less than 0.1%, samples were classified as NPAG, regardless of the NPR.

The use of NPR greater than 2 to classify materials as NPAG (as opposed to 3) was determined based on findings from mineralogical characterization and nearly two years of humidity cell testing. The former showed that carbonate is present primarily as calcite. The latter showed that materials with NPR values greater than one are not expected to produce acid.

7.5.2 Sisson Waste Material ML/ARD Characterization

7.5.2.1 Barren Rock Characterization

Approximately 54% of the barren rock samples were classified as PAG, 16% as uncertain, and 30% as NPAG. NPRs ranged from a minimum of 0.1 to a maximum of 7.6, with an average of 0.9 (Figure 7.5.1). The dashed line in Figure 7.5.1 represents 0.1% sulphur, while the solid lines define the 1:1 and 2:1 NP/AP ratios for ARD classification.

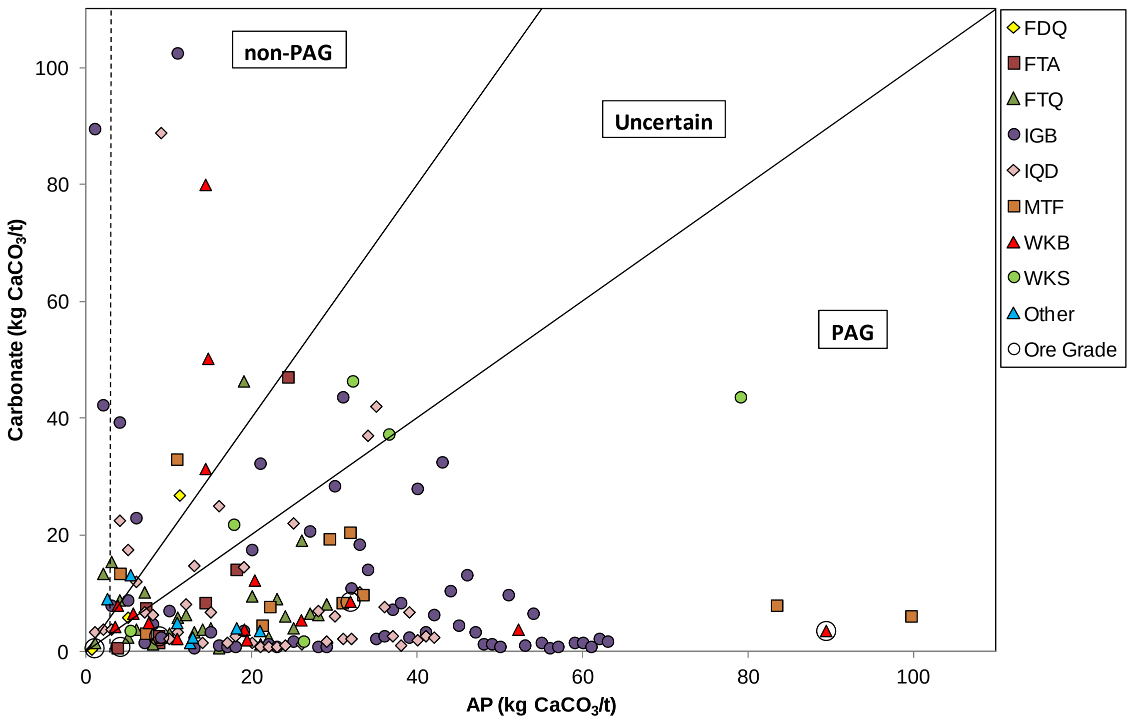


Figure 7.5.1 Carbonate NP Versus Sulphide AP

Based on the current understanding of the local geology and mine plan, PAG zones do not appear to be restricted to certain lithologies or mineable blocks. As a result, all barren rock has been assumed to be PAG for the purpose of barren rock management planning, and it will be stored sub-aqueously within the TSF to effectively inhibit potential generation of acid and metal leaching.

Delay to onset of ARD was estimated from one year of humidity cell testing and applying a geochemical scaling factor of 0.14. Oxidation rates from field barrel testing results and experience at other mine sites were used to calculate the geochemical scaling factor. Generally (at least in Canada), slower sulphide oxidation rates are observed in full-scale waste facilities compared to laboratory rates. The main difference is due to colder temperatures on-site. Gas exchange can also be limited in full scale facilities and limit oxidation rates, but this has not been taken into consideration here.

Geochemically "scaled" rates based on kinetic testing in the laboratory and field have been interpreted to indicate that the average delay to onset of ARD is 100 years, with the fastest rate estimated at 10 years. A comparison of humidity cell leachate pH for all samples is provided in Figure 7.5.2.

Metal leaching from barren rock is anticipated for arsenic, based on comparison to global crustal averages reported by Price (1997). Based on mineralogical and kinetic testing results, this is due to sulphide oxidation; measures to limit sulphide oxidation through sub-aqueous storage of barren rock in the TSF should also effectively inhibit arsenic leaching from barren rock.

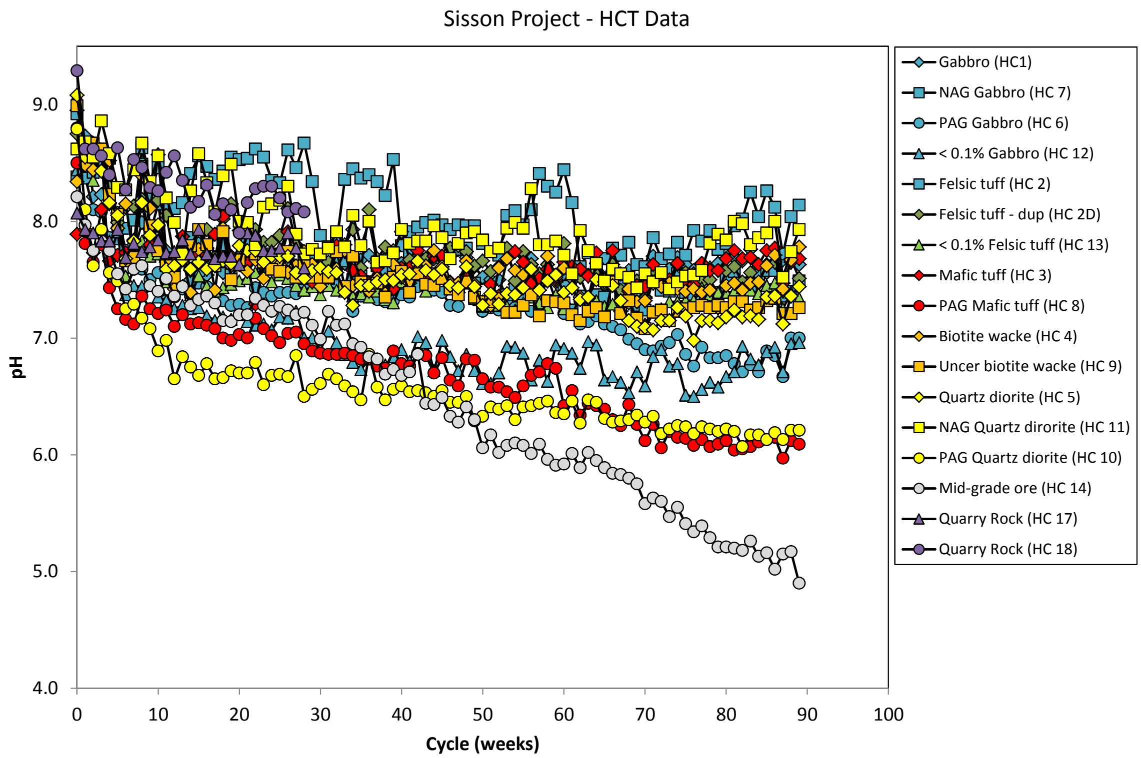


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Figure 7.5.2 Humidity Cell Leachate pH for Barren Rock and Mid-Grade Ore Samples

7.5.2.2 Pit Walls Characterization

Pit wall material has been classified as PAG with an average NPR ratio of 0.5 (mineralogical carbonate used for NP). By depth, no trends were apparent. Drill hole NPRs are illustrated in Figure 7.5.3, with an average for all samples and a moving average by 50 m intervals shown in dashed lines. The drill holes were selected to spatially cover the extent of the pit wall limits at end of mine life.

Timing to onset of ARD is estimated to be greater than 100 years, which is based on oxidation rates of barren rock humidity cells in the laboratory with similar sulphur and carbonate composition and geochemically scaled in the same manner as barren rock. Flooding of the pit is expected to occur in less than 100 years and this will effectively inhibit ARD production. Arsenic leaching is anticipated from pit walls because of elevated concentrations in the wall rock when compared to global crustal averages reported by Price (1997). However, this will be due to sulphide oxidation, and flooding of the pit walls should inhibit long-term arsenic leaching.

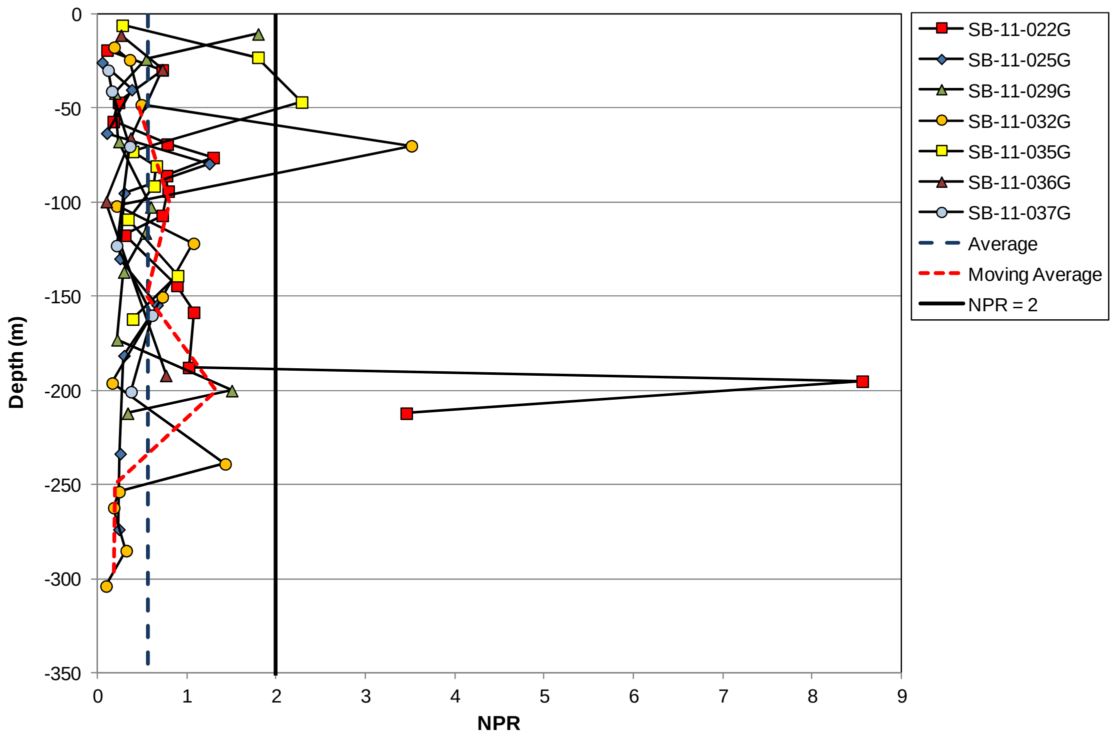

Figure 7.5.3 Pit Wall NPRs by Drill Hole and Depth

7.5.2.3 Mid-Grade Ore Characterization

Mid-grade ore has been classified as PAG. Delay to onset of ARD is estimated at 10 years when a 0.14 geochemical scaling factor is applied to the laboratory humidity cell oxidation rate. Metal leaching due to sulphide oxidation is possible due to enriched concentrations of arsenic, copper, molybdenum and selenium. Fluorine (as fluoride) is also enriched. Placement of the mid-grade ore within the TSF area for eventual sub-aqueous storage, if it is unused, should effectively inhibit potential generation of acid and metal leaching.

7.5.2.4 Quarry Rock Characterization

Quarry rock for embankment construction of the TSF was classified as NPAG based on static and kinetic testing of material to date. Sulphur concentrations were generally below detection (*e.g.,* 0.02% total sulphur) and metals and other contaminants were also near or below analytical detection limits.

7.5.2.5 Tailings ML/ARD Potential

Two tailings streams are expected from processing ore from the Project: a molybdenum tailings stream, and a tungsten tailings stream. The ore composite was classified as PAG due to an NPR of 0.7.

A summary of acid-base accounting (ABA) testing to date is provided in Figure 7.5.4. The dashed red line in Figure 7.5.4 denotes 0.1% sulphur.

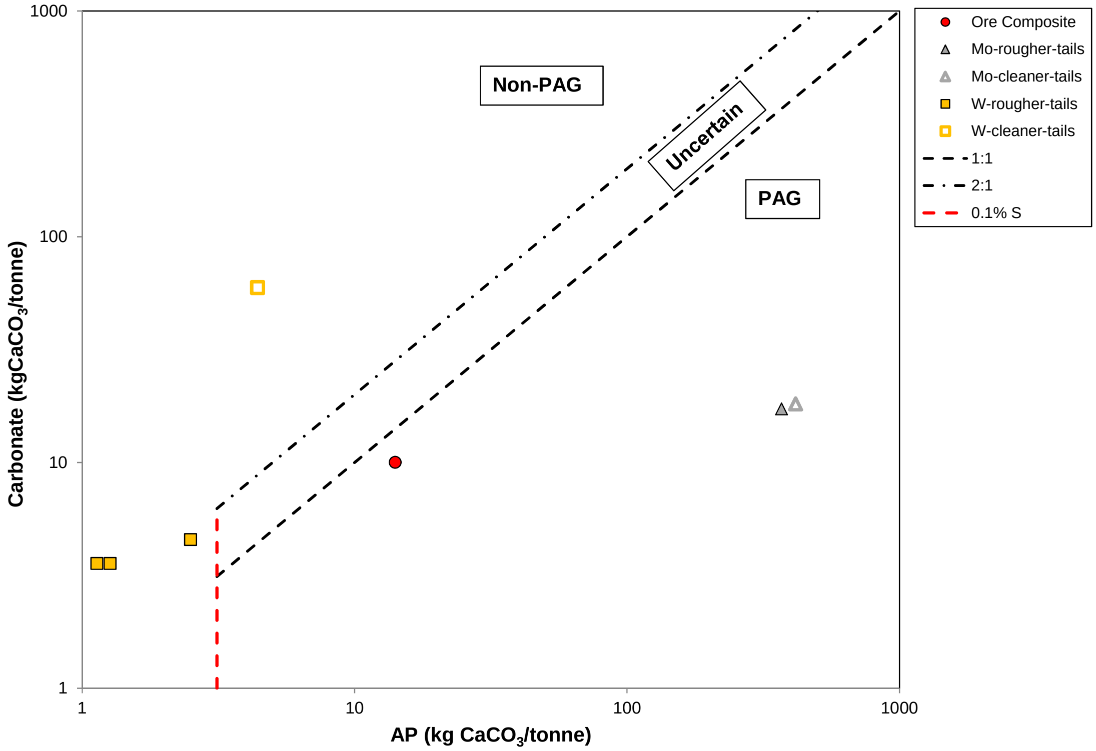

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Figure 7.5.4 Tailings NP Versus AP Comparison

Metallurgical concentration of molybdenite produced tailings enriched in iron sulphides and tailings were classified as PAG. Metal leaching potential exists for arsenic, cadmium, copper, lead, molybdenum, selenium, silver, uranium and zinc due to sulphide oxidation. Sub-aqueous storage of molybdenite tailings in the TSF will effectively inhibit sulphide oxidation and metal leaching.

Concentration of tungsten is performed after sulphide removal and as a result, the tailings were classified as NPAG based on NPRs greater than 2 and low sulphur concentrations (*e.g.,* < 0.1%). In addition to the samples tested herein, results from metallurgical lock cycle testing also revealed very low sulphur concentrations (*e.g.,* < 0.1%) in tungsten tailings. Based on static testing, 61 weeks of humidity cell testing, and mineralogical characterization, ARD is not expected from the tungsten rougher or cleaner tailings. Leaching of trace elements and other parameters (*e.g.,* fluoride) are not expected to exceed background concentrations.

The TSF pond water (*i.e.*, process water) for Sisson is expected to initially be alkaline and dominated by sulphate, thiosalts, carbonate, bicarbonate, sodium, and potassium. As the pond water ages, pH is predicted to decrease to approximately 8 due to equilibration with atmospheric carbon dioxide (formation of carbonic acid), conversion of carbonate to bicarbonate and oxidation of thiosalts to sulphate.

7.5.3 Drainage Chemistry Predictions

For each mine waste component, drainage chemistry was predicted in the form of waste material source terms. The suite of parameters predicted were inclusive of *Metal Mining Effluent Regulations* (*MMER*) and calculated as follows.

- Full scale waste facility leaching rates were generated by applying geochemical scaling factors to humidity cell leaching rates to account for the effects of temperature, particle size and contact factor. For all waste materials except tailings, the applied scaling factor was 0.07 based on rates obtained from field barrel tests. For tailings, the scaling factor was 0.2 as test material and full-scale material was assumed to have the same particle size.

- Scaled rates were inherently conservative for two reasons: based on experience, the scaling rate from barrel tests is likely overestimated as no consideration was given to decreased gas exchange in full scale facilities and laboratory rates used 95th percentile concentrations for sulphur and trace elements wherever possible.

- Scaled leaching rates in mg/kg/week were applied to various mine components and concentrations calculated based on estimated waste composition, volume, net precipitation, and infiltration.

- The majority of tailings will be submerged with sulphide oxidation effectively inhibited. Small portions of the beaches will be unsaturated and source terms for these areas were calculated assuming oxygen only penetrates up to 10 m.

- Waste materials classified as PAG were assumed to be submerged in water prior to onset of ARD.

- Although it is predicted that, under average hydrometeorological conditions, the pit will be filled by Year 39, approximately 12 years after the completion of Operation, the pit was conservatively assumed to fill within 20 years post-Closure. After the pit is filled, only a small hanging wall (*e.g.,* average height estimated at 20 m) will remain exposed.

- Concentrations were assessed with respect to mineral solubility limits determined using the equilibrium modeling program Phreeqc (Parkhurst et al. 1999). Any minerals oversaturated were allowed to saturate and concentrations set to equal the maximum concentration of the individual mineral’s solubility. For example, the mineral ferrihydrite was used to limit the concentration of iron at neutral pH.

- Predictions for leaching of explosive residues from barren rock and pit walls leading to soluble nitrate, nitrite, and ammonia was calculated using the Ferguson and Leask (1988) method.

- Solubility-adjusted concentrations for each waste facility were provided to Knight Piésold to model water quality expected from the Project (Section 7.6). Detailed results are provided in SRK (2013).

7.6 WATER QUALITY AND WATER BALANCE MODELLING

Information presented in this sub-section has been provided by Knight Piésold Ltd. (Knight Piésold 2013c and 2014).

7.6.1 Water Management Plan

7.6.1.1 General

The following sections outline the mine site water balance and the water management plan for the Project from pre-production (Year -2) through Post-Closure. The mine site water balance forms the basis for the predictive water quality modelling (Section 7.6.3).

7.6.1.1.1 Water Management during Construction

The Construction water management plan will commence approximately 24 months prior to mill commissioning (*i.e.,* 24 months before the commencement of Operation). Construction is characterized by:

- extensive clearing, grubbing, and stripping;
- development of a site access road and internal haul roads; and
- establishing water management and sediment control structures including coffer dams, pumping systems, run-off collection ditches, and diversion channels.

Some of the temporary works such as coffer dams and by-pass diversion channels will be decommissioned once the initial tailings storage facility (TSF) starter embankments have been constructed. Sediment collection ponds and collection channels will remain in place throughout the life of the Project.

7.6.1.1.2 Water Management during Operation

All water that has been in contact with mine facilities or associated construction areas (referred to as mine contact water), including the open pit, ore processing plant site and soil stockpiles, will be controlled and managed. The operational water management plan for the site includes the following components.

- Diversion channels upstream of the Project facilities, including the TSF, plant site, and other infrastructure, will direct non-contact water back to the natural environment to the extent possible. This water may be collected to control sediment before discharge if needed.
- All un-diverted run-off from within the footprints of the project facilities (*e.g.,* plant site) will be collected in channels and routed to water management ponds.
- All un-diverted run-off from within the TSF catchment will be directed to the TSF.

- Water from the open pit will be pumped to a collection pond near the pit rim, and subsequently pumped to the TSF.
- Tailings will be selectively deposited from the crest of the TSF embankments to develop tailings beaches, which will function as an extensive low permeability zone to mitigate seepage through the embankments. The operational supernatant pond will be managed to reduce the potential for dust generation and to ensure that sufficient storage exists for operational flexibility and storm inflow storage.
- Process water contained in the tungsten and molybdenum tailings will be discharged into the TSF with the tailings slurry at an average rate of approximately 2,022 m^3/h at full production.
- Tailings supernatant water will be reclaimed, treated, and pumped back to the mill to the extent possible to meet the average process water requirement of approximately 2,003 m^3/h at full production.
- Water will be discharged from the TSF to a water treatment plant (WTP) when the facility is operating in a water surplus condition, likely starting in Year 8 of the mine life under average climatic conditions, to maintain an acceptable TSF operating pond volume.
- Water management ponds (WMPs) at low points around the TSF perimeter will collect seepage and run-off from the TSF embankments. This water will be pumped back to the TSF unless the water quality is suitable for discharge.
- Groundwater monitoring wells will be located below the WMPs. Groundwater pump-back wells will be developed and operated as necessary to return groundwater to the WMPs and TSF if seepage quality may jeopardize downstream water quality.

7.6.1.1.3 Water Management during Decommissioning, Reclamation and Closure

Water Management during Closure

Closure includes the period between the end of active mining and processing operations and the time at which the open pit has filled with water. It is estimated that closure will begin in Year 28 and the open pit will be filled by about Year 39. The water management plan for the site during the Decommissioning, Reclamation and Closure phase includes the following elements.

- Diversion channels will be maintained upstream of the Project facilities that have not yet been removed or reclaimed to direct non-contact water back to the natural environment to the extent possible. This water may be collected to control sediment before discharge if needed. Once Project-affected areas have been fully reclaimed and stabilized, surface drainage will be re-directed to mimic the pre-Project regime wherever possible.
- All un-diverted run-off from within the footprints of the Project facilities (*e.g.,* TSF embankments) will be collected in channels and directed to water management ponds until water quality is suitable for discharge. Once water quality from reclaimed areas meets applicable discharge

criteria, the water management structures (*i.e.,* collection channels and water management ponds) will be decommissioned.

- All un-diverted run-off from within the TSF catchment will flow to the TSF.
- The tailings beaches will be reshaped to enhance drainage towards the TSF pond and to meet the end land use objectives for the site. The tailings surface will be capped with rock and soil to minimize erosion by water and wind, provide a trafficable surface, and allow re-vegetation.
- The TSF quarry area will be connected to the TSF pond with a channel excavated in rock.
- An outlet channel will be constructed between the TSF pond and the open pit to allow excess water from the TSF to flow into the open pit. This will help fill the open pit more quickly during Closure.
- Water management ponds at low points around the TSF perimeter will continue to collect seepage and run-off from the TSF embankments. This water will be pumped back to the TSF until the water quality is suitable for discharge.
- Groundwater monitoring wells will be maintained below the water management ponds. Groundwater pump-back wells will be operated as necessary.

Water Management during Post-Closure

The Post-Closure period begins when the open pit has completely filled with water and discharge begins to the downstream environment. The water management plan for the site in Post-Closure includes the following.

- The diversion channel on the southeast side of the open pit will be maintained to continue providing flow to the McBean Brook watershed.
- All water management features that are no longer needed will be reclaimed as open water features, wetlands, and/or other appropriate end land uses.
- The outlet channel between the TSF pond and the open pit will continue to allow excess water from the TSF to flow into the open pit.
- The water level in the pit lake will be maintained by pumping the water to the WTP, and treating it as necessary prior to discharge. The lake level will be maintained at an elevation that ensures all groundwater flows into it. All water that needs to be discharged will be treated for as long as is necessary to meet the Project’s permit conditions for discharge water quality. It is expected that the water treatment facility used during Operation will be re-mobilized for this purpose, although it may need to be refurbished and/or reconfigured to suit Post-Closure water treatment requirements.

- When the pit lake water is of sufficient quality to allow its discharge into downstream drainages, pumping and treatment will cease, the pit will be allowed to fill completely, and the pit lake will discharge to Sisson Brook through an engineered channel at the low point on the pit rim.

- Groundwater monitoring wells will be maintained below the water management ponds. Groundwater pump-back wells will be operated as necessary.

7.6.2 Operational Water Balance Model

7.6.2.1 General

A stochastic analysis was carried out on the base case monthly operational mine site water balance using the GoldSim© software package. The intent of the modelling was to estimate the magnitude and extent of the water surplus and/or deficit conditions in the TSF based on a range of possible climatic conditions. The modelling timeline includes one pre-production year (Year -1), and 27 years of mine operation (Years 1 to 27) at an average rate of 30,000 dry metric tonnes per day. The model incorporates the following major mine components:

- Open Pit;
- Mill;
- TSF;
- Barren Rock and Mid-Grade Ore stored in the TSF (collectively referred to as Waste Rock);
- Reclaim Water Clarification Plant; and
- Water Treatment Plant (WTP).

The model is shown schematically on Figure 7.6.1 and descriptions of each flow path are provided in Table 7.6.1.

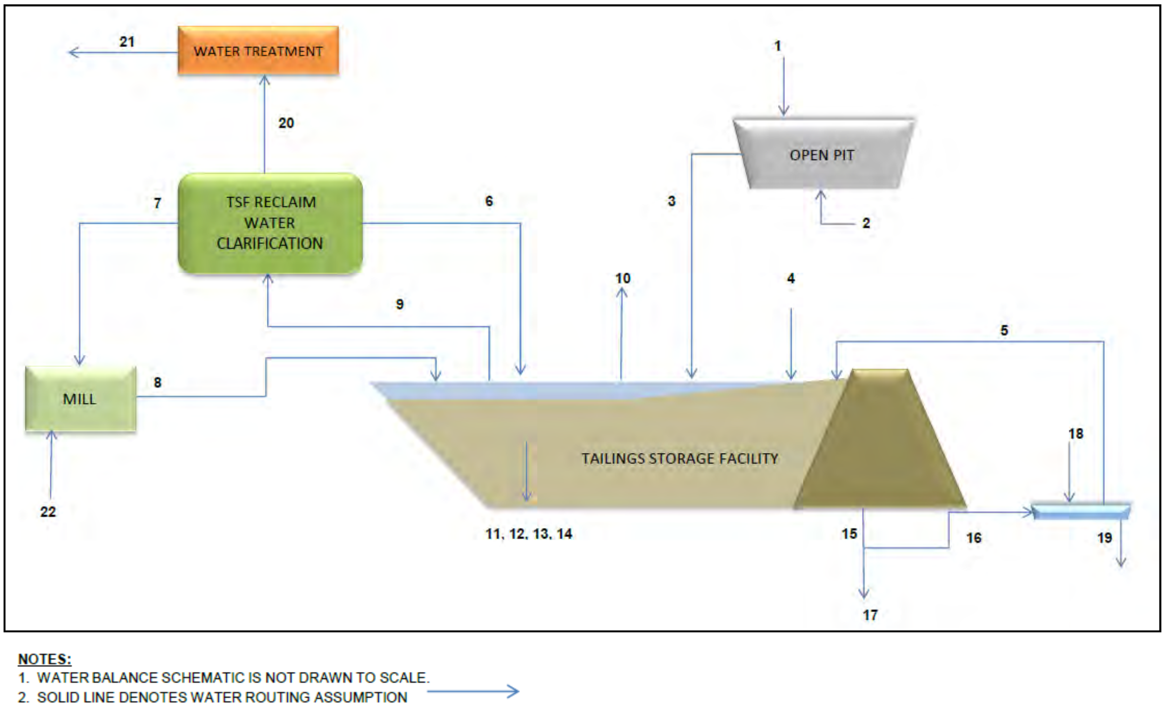


Figure 7.6.1 Operational Water Balance Model Schematic Flow Sheet (Operation phase)

Table 7.6.1 Operational Water Balance Flow Path Descriptions

Number	Description
1	Open Pit Direct Precipitation and Catchment Run-off
2	Open Pit Groundwater Inflows
3	Open Pit Dewatering to TSF
4	TSF Catchment & Beach Run-off, Direct Precipitation on Pond
5	Water Management Pond Recycle
6	Water from Clarification Plant to TSF Pond
7	Water From Clarification Plant to Mill
8	Water in Tailings to TSF
9	TSF Reclaim Water to Clarification Plant
10	TSF Pond Evaporation
11	Water Retained in Tailings Void Spaces
12	Water Retained in Clarification Slurry Void Spaces
13	Water Retained in Barren Rock Void Spaces
14	Water Retained Mid-Grade Stockpile Void Spaces
15	TSF Embankment Seepage – Total
16	TSF Embankment Seepage – Captured by Seepage Collection System/WMPs
17	TSF Embankment Seepage – Lost
18	Water Management Pond Embankment and Catchment Run-off
19	Water Management Pond Seepage
20	Excess Clarified Water to Treatment
21	Treated Water Discharge to Environment
22	Fresh Water Make-up to Mill

Model assumptions and parameters are discussed in the following sections, and additional details are presented in Samuel Engineering (2013).

7.6.2.2 Model Inputs and Assumptions

7.6.2.2.1 Climatic Conditions

The base case monthly operational water balance model was developed using the estimated monthly values shown in Table 7.6.2. The mean annual unit run-off (MAUR) for undisturbed basins in the Project area was estimated to be approximately 827 mm based on the long-term MAUR for the Project site station B-2 on Bird Brook at Napadogan. The mean annual precipitation (MAP) was estimated to be 1,350 mm, with 75% of the annual precipitation falling as rain and the remainder as snow. The annual average potential evapotranspiration (PET) for the Project site was estimated to be 500 mm. PET was assumed to equal lake evaporation and was applied to the TSF pond surface to estimate evaporation losses.

Table 7.6.2 Average Hydrometeorological Inputs

Parameter	Monthly Value (mm)												Annual (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Precipitation	115	83	107	96	111	114	127	122	119	117	116	123	1,350
Rainfall	34	21	45	70	110	114	127	122	119	114	85	51	1,012
Snowfall	81	62	62	26	1	0	0	0	0	3	31	72	338
Sublimation	15	15	15	15	0	0	0	0	0	0	0	15	75
Snowmelt	0	0	28	113	121	1	0	0	0	0	0	0	263
Available Precipitation	34	21	73	183	231	115	127	122	119	114	85	51	1275
Lake Evaporation	0	0	0	15	68	100	119	104	65	29	0	0	500
Available Run-off	41	28	65	213	138	49	33	26	25	54	82	73	827

Notes:
1) The precipitation values were estimated for Sisson climate station, which is at an approximate elevation of 305 m.
2) Surface run-off was estimated by multiplying the available precipitation values by the corresponding run-off coefficient for each Project area.
3) The lake evaporation values were applied to TSF pond area to estimate evaporative losses.
4) Available run-off values were applied to undisturbed areas within the mine footprint to estimate run-off.

7.6.2.2.1.1 Run-off Coefficients for Disturbed Areas

Natural run-off values are not directly applicable for mine site disturbed areas because of the substantial changes in run-off caused by altering the ground cover. Therefore, the quantities of water (run-off/infiltration) generated from the mine affected areas (open pit, TSF embankments, barren rock, mid-grade ore, and TSF beaches) and open water (TSF supernatant pond) were estimated by multiplying rainfall and snowmelt by the following assumed run-off coefficients:

- TSF Beaches: 0.7;
- TSF Embankments, Mid-Grade Ore, and Barren Rock: 0.8;
- TSF Pond: 1.0; and

- Open Pit Walls: 0.9.

7.6.2.2.1.2 Stochastic Inputs

The variability of climatic conditions was addressed using a stochastic version of the water balance model that included Monte Carlo-type simulation techniques. The monthly climate parameters were modeled as probability distributions rather than simply as mean values. The year-to-year variability of monthly run-off was quantified using coefficient of variation (C_v) values that were derived from regional datasets. The monthly mean and standard deviation values were used to develop monthly probability distributions that are required for a Monte Carlo simulation. The distributions of monthly precipitation were modelled assuming an underlying Gamma distribution.

7.6.2.2.1.3 TSF Embankment Drainage and Seepage Collection

Steady-state seepage analyses were completed using the finite element computer program SEEP/W to estimate the amount of seepage through the TSF embankments. It was assumed that a portion the embankment drainage and seepage will be captured by the embankment seepage collection system or intercepted and collected by groundwater pump-back wells downstream of the TSF. A small fraction of the total seepage was assumed to bypass the seepage collection systems and be lost to the environment downstream of the TSF.

It should be noted that a more conservative (higher) estimated TSF seepage values were used in the water quality modelling as compared to the Operational Water Balance Model that was carried out for engineering purposes. The estimated seepage losses from the TSF in each phase of the predictive water quality model are shown in Table 7.6.3 along with the estimated seepage capture rates of the water management ponds and the corresponding capture efficiencies.

Table 7.6.3 Estimated Seepage Rates by Project Phase

	Operation	Closure and Post-Closure
TSF Seepage (L/month)	2.8×10^8 (106 L/s)	6.3×10^7 (24 L/s)
Seepage Capture (L/month)	2.3×10^8 (87 L/)	4.2×10^7 (16 L/s)
Capture Efficiency (%)	82%	67%

7.6.2.2.1.4 TSF Reclaim Clarification Plant

Reclaim water pumped from the TSF will be sent to a clarification plant for removal of suspended solids prior to being pumped to the mill for use in the process. The settled solids produced from the clarification treatment system will include a lime underflow and calcium carbonate precipitate, both of which will be pumped back to the TSF as slurries.

7.6.2.2.1.5 Pumping to Water Treatment Plant

Water will be directed to a WTP from the TSF reclaim clarification plant at a rate of approximately 6 million m^3/a to maintain an acceptable operating pond volume in the TSF and to supplement the stream flow in the downstream environment. Pumping to treatment is assumed to commence as of approximately Year 8 and will continue until the end of Operation in Year 27, under average climatic conditions.

7.6.2.2.1.6 Mill Requirements

Water requirements at the mill were calculated based on the specified mill production rate and the expected solids content (% by weight) of the tailings. All of the process water will be supplied by the TSF reclaim system. The freshwater requirement for the mill is approximately 14 m^3/h. This fresh water requirement is assumed to be in addition to any process water make-up extracted from the TSF reclaim system.

7.6.2.2.1.7 Pit Dewatering System

The water pumped from the open pit by the dewatering system includes pit wall run-off, undisturbed pit catchment run-off entering the pit, and groundwater inflows. Groundwater inflows to the open pit were estimated to be approximately 40 L/s at the maximum extent of the pit. The inflow rate was assumed to increase linearly during the 27 years of Operation, from 0 L/s in Year 1, up to 40 L/s in Year 27. It was assumed that pit dewatering flows will be pumped to the TSF during Operation.

7.6.2.2.1.8 Water Retained in Voids in TSF

The amount of water retained in the tailings, clarification plant solids, barren rock and mid-grade ore stored in the TSF is a function of the production schedule and the dry density and specific gravity of the solids.

Approximately 209 million tonnes of barren rock and mid-grade ore will be stored in the TSF from Year 1 through to Year 20; from Year 21, the barren rock will be stored in the open pit and flooded during Closure along with the pit. Within the TSF, the mid-grade ore is assumed to be partially submerged by the supernatant pond starting in Year 15, with approximately 17 million tonnes submerged by Year 25. The barren rock will start to be submerged by the pond in Year 3, and will then be progressively saturated until Year 21.

7.6.2.2.1.9 Reclaim Water

The volume of water available for reclaim to the mill was estimated using the TSF water balance.

The primary TSF inflows are:

- water pumped to the TSF from the mill with the tailings slurry;
- water in the clarification plant slurries;
- direct precipitation and run-off to the TSF, which includes run-off from the exposed mid-grade ore stockpile, barren rock, and quarry; and
- embankment seepage recycle.

The primary TSF outflows are:

- pumping of excess water to the WTP;
- water retained in tailings and rock void spaces;
- evaporation; and
- embankment seepage.

The water available for process use is assumed to be 100% of the difference between these inflows and outflows.

7.6.2.3 Water Balance Results

The water balance model results were used to estimate the likelihood of having a surplus or deficit of water in the TSF. The TSF pond is predicted to be in a net surplus condition for the entire operating life of the mine, indicating that the system (including the TSF and contributing catchments) is able to supply more than enough water to meet the mill process water requirements, even under dry conditions. Surplus conditions mean that water either needs to be stored in the TSF or discharged.

The water balance model assumed that the TSF start-up pond is allowed to accumulate over one freshet season prior to the start of mine Operation and that the minimum operating pond volume is 3 million m^3. The TSF pond volume will then increase over the first eight years of Operation as the aerial extent of the TSF increases and surplus water is collected in the pond; no surface water discharge is expected until Year 8 under average climatic conditions. Approximately 6 million m^3/year of TSF pond water will be pumped to the WTP during Operation starting in Year 8 under average conditions. Surplus water in the TSF will be routed to the open pit after closure (starting in Year 28) to fill the pit lake more quickly. Water will be discharged from the pit lake through the WTP starting in Year 40. The model timeline is summarized below in Table 7.6.4.

Table 7.6.4 Summary of Water Balance Model Timeline

Mine/Model Year	Milestone
Year -1	Start-up – run-off collects in the TSF for initial operation of the mill up to approximately 3 million m^3.
Year 1 to Year 7	Operation – TSF pond grows as the facility expands.
Year 8 to Year 27	Operation – TSF pond reaches steady-state operating volume and discharge to the WTP begins.
Year 28 to Year 39	Closure – surplus water from the TSF is routed to the open pit to increase the rate of filling.
Year 40 Onward	Post-Closure – the open pit is full and water is discharged from the pit lake to a WTP.

7.6.3 Predictive Water Quality Model

7.6.3.1 Introduction and Modelling Objectives

The water quality predictions for the Project were modelled using GoldSim© from baseline through to Post-Closure, with average monthly outputs over a 100 year period. The model is generally based on the design and operating strategies employed in the Technical Report for the feasibility study (Samuel Engineering 2013). The results of the model were used in an iterative process to help optimize the

Project design and reduce the potential Project induced changes on downstream water quality. This optimization process resulted in several changes to the assumed design and Operation of the Project when compared to the feasibility study.

The objective of the predictive modelling was to quantitatively estimate the environmental effects of the Project on the water quality in the downstream environment including Napadogan Brook, McBean Brook, and their tributaries. The complete details of the methods and results are presented in the Predictive Water Quality Modelling report (Knight Piésold 2013c) and as updated in Knight Piésold (2014).

Water quality results were predicted for seven nodes along Napadogan Brook (NAP1, NAP2, NAP3, NAP5, NAP7, and NAP8), and one node along McBean Brook (MBB2). Water quality predictions have also been calculated for three unnamed tributaries (UT1, UT3, and UT4). The location of the model nodes are shown on Figure 7.6.2, and a close-up view of the mine site area is shown on Figure 7.6.3.

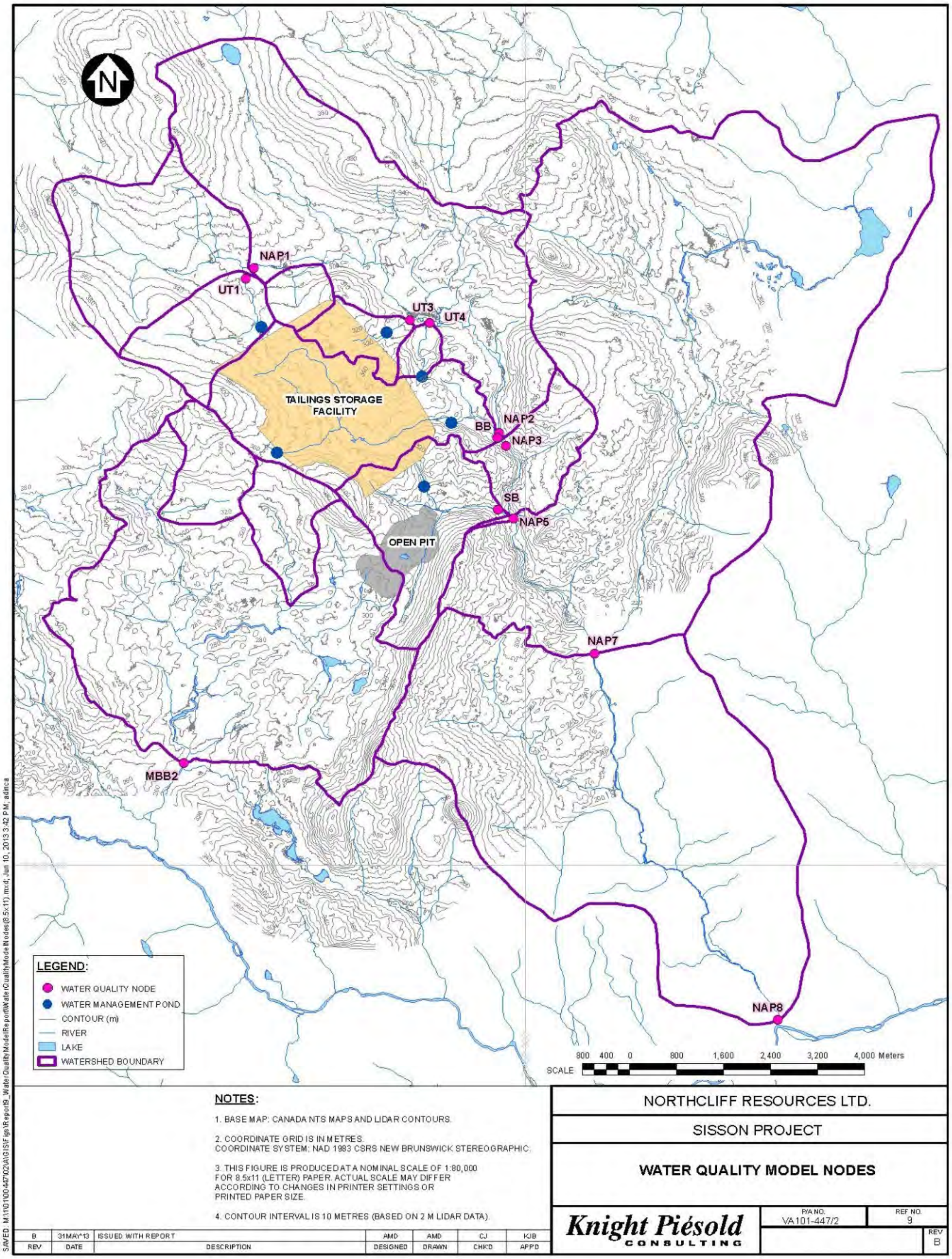


Figure 7.6.2 Water Quality Model Nodes

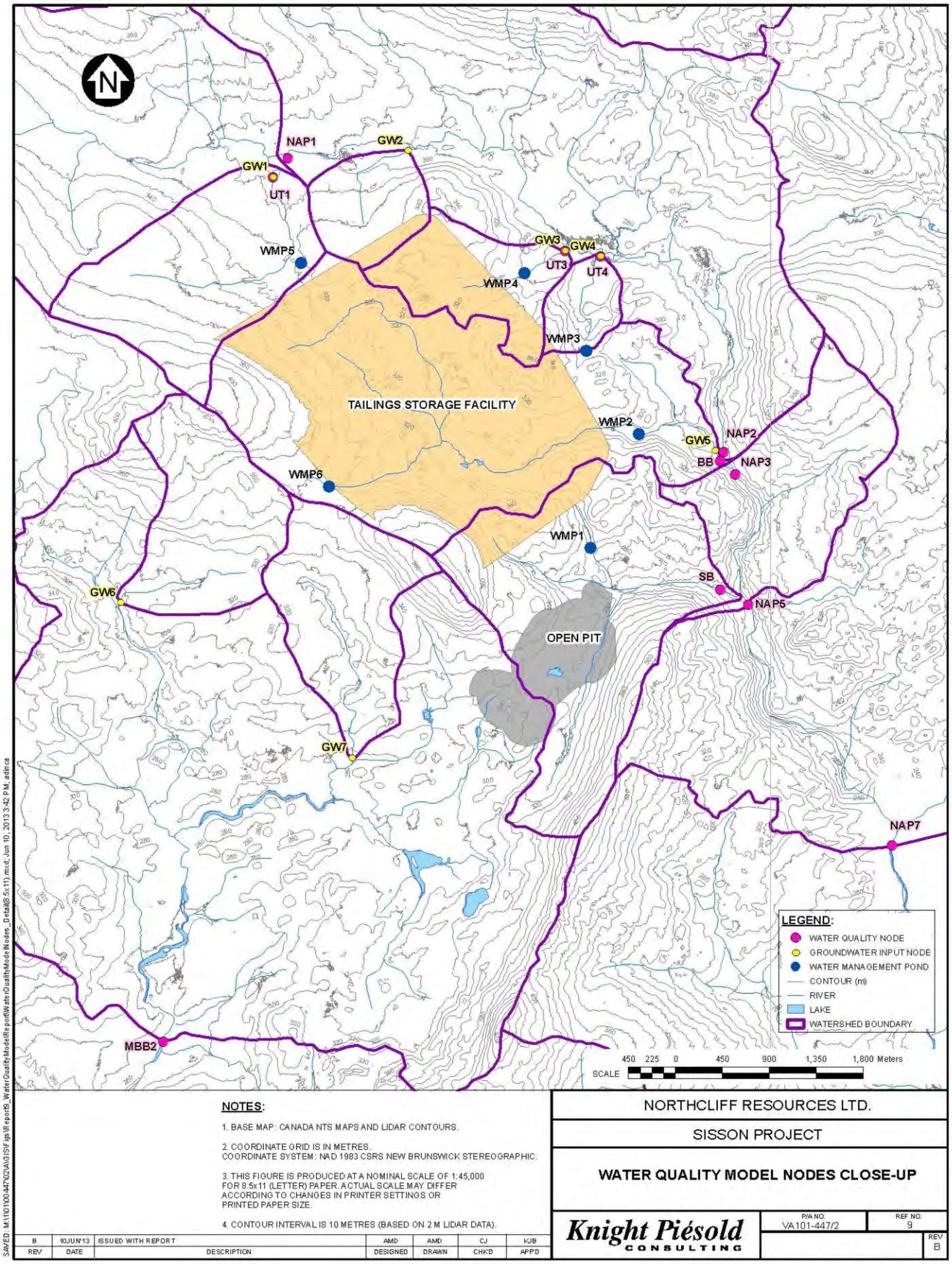


Figure 7.6.3 Water Quality Model Nodes Close-Up

7.6.3.2 Project Timeline

The model timeline encompasses all phases of the Project (Operation, Closure, and Post-Closure) as well as two years prior to Operation (*i.e.,* Construction, model Years -2 and -1), which represent baseline conditions at the downstream water quality nodes. Following the two baseline years, the model runs continuously from Year 1 (beginning of Operation) to Year 100 (the predicted water quality during Post-Closure is assumed to reach a steady state prior to Year 100). Predicted water quality changes are driven by the water management strategy in each of the following Project phases.

7.6.3.2.1 Operation (Years 1-27)

Operation begins with commissioning of the mill and ends when ore processing is complete, during which time the water management strategy includes the following.

- Diversion ditches are constructed around the open pit area to convey non-contact water from the upslope catchments to McBean Brook and Sisson Brook. This results in some water that would have naturally run-off to Sisson Brook being discharged to McBean Brook.
- Contact water and un-diverted non-contact water from within the TSF and open pit footprints report to the TSF and to the open pit, respectively.
- TSF embankment seepage is collected in the water management ponds (WMPs) and is continuously pumped back into the TSF. Water will not be stored in the WMPs under normal operating conditions.
- TSF basin seepage that bypasses the WMPs mixes with groundwater in the receiving environment and reports to the nearest creek after a five-year lag time.
- A seepage recovery system is modelled along the northern extent of the TSF downgradient of WMP 5 that is assumed to recover 30% of TSF basin seepage in that portion of the catchment.
- All contact and non-contact water collected in the open pit is pumped to the TSF.
- Beginning in Year 8, approximately 6 million m^3/a of excess water from the TSF is pumped to a water treatment plant (WTP) and discharged post-treatment to Napadogan Brook at the confluence with Sisson Brook. The WTP discharge rate is generally proportional to the baseline hydrograph of at the point of discharge. The discharge is further reduced during low flow months in late summer and mid-winter to minimize the impact on receiving water quality.
- Mill inputs (tailings deposition) to the TSF cease at the end of Year 27.

7.6.3.2.2 Closure (Years 28-39)

Closure begins when the mill shuts down and ends when the open pit has filled to the point where controlled discharge of excess water is required. During Closure, the water management strategy includes the following.

- Open pit dewatering ceases and the pit begins to fill with water.

- Pumping from the TSF to the WTP ceases and WTP effluent discharge to Sisson Brook stops; this causes a change in the predicted water quality in Napadogan Brook downstream of Sisson Brook.
- Inputs from the mill to the TSF cease at the end of Year 27 causing changes in water quality in the TSF starting in Year 28. Changes in predicted chemistry at the downstream nodes along Napadogan Brook are evident in Year 33; these nodes are affected by seepage from the TSF, which arrives with a five-year delay.
- Water collected in the TSF and quarry flows to the open pit through an engineered channel starting in Year 31.
- Water collected in the WMPs is continuously pumped back to the TSF.
- In Year 34, ferric sulphate batch treatment of the open pit water begins.

7.6.3.2.3 Post-Closure (Years 40 Onward)

Post-Closure begins when the open pit is full and discharge to the receiving environment begins.

- The open pit water is pumped to a WTP that discharges to Sisson Brook beginning in Year 40. The pit lake is maintained at an elevation that ensures it is a groundwater sink.
- Water collected in the WMPs is continuously pumped back to the TSF until water quality is suitable for discharge.

7.6.3.3 Mass Balance and Water Quality Model Description

7.6.3.3.1 Water Quality Calculations

The water quality model was developed using a mass balance calculation approach in GoldSim© to predict average monthly water chemistry at select locations within and downstream of the Project area. The mass balance method assumes that the incoming flows at any modelled node are thoroughly mixed at that point. The generalized mass balance equation for mixing points on natural streams is:

$$C_{New} = \frac{C_A \times Q_A + C_B \times Q_B}{(Q_A + Q_B)}$$

where:

C_{New} = mixed concentration (mg/L);

C_A = concentration of Stream A (mg/L);

Q_A = flow rate of Stream A (m^3/s);

C_B = concentration of Stream B (mg/L); and

Q_B = flow rate of Stream B (m^3/s).

A conservative approach was adopted for the prediction of water quality in the reservoir components of the model including the TSF, WMPs, and open pit. The monthly concentrations within each reservoir are equal to the sum of the stored load and input loads from the current time step (monthly loading), divided by the reservoir volume determined by the water balance model. Loads removed from each reservoir were determined using this concentration multiplied by the volume of water being removed from the reservoir in that time step.

The generalized mass balance equation for reservoirs is:

$$C_{New} = \frac{(C_A \times V_A) + (C_B \times V_B) - (C_A \times V_C)}{(V_A + P - E)}$$

where:

C_{New} = mixed concentration (mg/L)

C_A = concentration of reservoir A at the previous time step (mg/L);

V_A = volume of reservoir A (m^3);

C_B = concentration of stream B (mg/L);

V_B = monthly inflow volume of stream B (m^3);

V_C = monthly outflow volume of outlet stream C (m^3);

P = monthly precipitation (m^3); and

E = monthly evaporation (m^3).

7.6.3.3.2 Parameters

A total of 77 parameters were modelled, including hardness, alkalinity, organic carbon, major ions, and 33 metals (both total and dissolved). Several metals were reported as below the method detection limit (MDL) in both the source terms and the baseline data (beryllium, tellurium, and tin) and have therefore not been modelled. Metals were only modelled in the dissolved form within the proposed mine facilities, and in the total and dissolved form at downstream locations.

7.6.3.4 Inputs and Assumptions

7.6.3.4.1 General

The water quality modeling involved a series of studies and analyses including: a) characterizing the geochemical properties of waste materials (waste rock and tailings), open pit walls and borrow materials; b) based on these properties, generating geochemical source terms for these materials; c) developing the operational water balance model for the Project; and d) applying the source terms within the water balance model to predict consequent water quality characteristics at various nodes in the model. In each case, the analyses incorporated assumptions based on experience and best professional judgment. More conservative assumptions were used where the inputs to the analyses included higher uncertainty.

The model results are considered the best estimates based on the available information. It is expected that as more data are collected, the model inputs and assumptions will be refined, thereby reducing the level of conservativeness inherent in the results. It is expected that this will tend to result in lower predictions of chemical concentrations at each node in the model.

7.6.3.4.2 Climate, Hydrology, and Groundwater

Flow inputs for the mass balance water quality model were derived using the base case monthly operational mine site water balance that was previously developed for the feasibility study engineering using the GoldSim© software package. The original intent of this modelling was to estimate the magnitude and extent of any water surplus and/or deficit conditions in the TSF based on a range of possible climatic conditions. This model was modified to include the various contact water flow pathways defined between the Project and the downstream environment, and incorporated into the mass balance predictive water quality model.

The mean monthly hydrometeorological parameters were based on the values used in the operational water balance model. Catchment areas were calculated using the LiDAR topographic data where possible and National Topographic System (NTS) mapping where LiDAR data were not available (*e.g.,* in the upper reaches of East Branch Napadogan Brook).

Groundwater baseflow inputs were estimated based on the Bird Brook hydrologic data using a visual qualitative hydrograph separation approach. Flow data were estimated on a monthly basis using 40 years of data from which monthly averages were generated from the data set.

7.6.3.4.3 Geochemical Source Terms

Geochemical source terms were provided by SRK Consulting (Canada) Inc. (SRK) for the following:

- Open Pit Sump: mg/day;
- Milled Ore: mg/L (based on ~18.5 Mm3/y of process water);
- Process Reagents: mg/tonne of ore processed;
- Low-Grade Stockpile Run-off/Infiltration: mg/L;
- Barren Rock Run-off/Infiltration: mg/L;
- Barren Rock Flooding: mg/tonne of rock submerged;
- TSF Beach Run-off: mg/m^2/week;
- TSF Unsaturated Beach Infiltration: mg/L;

- TSF Embankment Run-off/Infiltration: mg/L;
- TSF Quarry Sump: mg/L;
- Pit Walls: mg/L; and
- Water Treatment Plant Effluent: mg/L.

Details regarding the development of the contact water source terms are provided in SRK (2013).

7.6.3.4.4 Water Treatment Plant

It was determined early in the predictive water quality modelling process that water treatment may be required to mitigate the effects of the Project on receiving waters. A water treatment plant (WTP) concept that could be incorporated into the mass balance model was subsequently developed by SRK. The estimated removal efficiency by the WTP for each parameter was applied to discharge from the TSF during Operation and from the open pit in Post-Closure. Estimated WTP discharge concentrations were provided by SRK (2013).

The WTP was represented in the mass balance model by limiting the maximum parameter concentrations in the discharge to estimated WTP discharge concentrations. It was assumed that the WTP would not remove constituents in the influent water when those concentrations were below the estimated WTP discharge concentrations. A water clarification system is also included in the Project design to pre-treat water recycled to the mill from the TSF. However, water quality improvements were not credited to this clarification plant, which is a conservative assumption. Additional test work and analysis is underway to better understand the potential contribution of the clarification system to water quality improvements. Additional water treatment has been applied to the model for the open pit, in the form of a batch treatment process that will be implemented in Closure (approximately Model Year 34).

7.6.3.4.5 Baseline Water Quality

7.6.3.4.5.1 Baseline Water Quality Data

The baseline water quality program for the Project began in 2007 with samples collected on a monthly or quarterly (seasonal) basis. The baseline surface water data collected until December 2011 were included for the development of monthly average background water quality inputs for the model, consistent with the baseline water quality. In cases where no data were available for a particular month or where data were collected seasonally and not monthly, parameter concentrations were assumed to equal the average concentrations of the previous month.

Groundwater quality data for samples collected between December 2011 and June 2012 were used to generate the background water quality for the mass balance model. Groundwater quality data were generally not applied to the model directly, but were used for comparison to low flow surface water quality data for nearby sites. Piper tri-linear diagrams were used to assess the similarity of geochemical facies for the groundwater to low flow surface water quality. The facies were similar and as a result the mid-winter water chemistry data for the nearby surface water sites were assumed to equal the groundwater chemistry. Many parameters are higher in groundwater than in nearby streams during low flow conditions, though it can be assumed that the majority of the flows are generated from groundwater inflows. Complex and simple geochemical processes can occur in the shallow groundwater/surface water environment which can result in some parameters precipitating out of solution. Assuming that low flow surface water chemistry is equivalent to new groundwater inflow chemistry accounts for these processes without the need for additional modelling. Parameter concentrations measured in all samples from each monitoring well location (shallow and deep wells) were averaged and used as baseline groundwater concentrations for each well location. Groundwater quality at nodes without groundwater monitoring wells was assumed to be the same as that of the closest groundwater monitoring site.

It should be noted that surface water and groundwater sample collection is ongoing, but the end dates specified above are the cut-off points for data used in the development of the baseline input terms for the model. The baseline conditions provided in this report refer to the average monthly data for each model node that were used as inputs to the model. These data under-represent the measured range for some of the parameters but are consistent with the model results, which are predicted monthly average concentrations.

7.6.3.4.5.2 Baseline Water Quality Calibration Model

Baseline water quality at the modelled nodes was assumed to be equal to the observed average monthly surface water quality at those points during the period of record. However, several key data inputs to the water quality model required further estimation and calculation. A calibration model was developed in GoldSim© to provide estimates for the following information that was not available in the baseline dataset:

- separation of the surface water and groundwater components of the resulting measured water quality;
- calculation of parameter concentrations in tributaries and modelled nodes for which no baseline data were available;
- estimation of parameter loads attenuated under baseline conditions when groundwater surfaces; and
- estimation of parameter loads attenuated under baseline conditions between modelled nodes for which baseline data are available.

Inputs to the calibration model included groundwater data from sites in close proximity to each node, groundwater flow data, averaged surface water data from sites in close proximity to each node, and surface water flow data.

Parameters that were predicted to decrease between the nodes in the calibration model shown on Figure 7.6.2, in at least one month each year under baseline conditions, include:

- NAP1 to NAP2: ammonia, nitrate, dissolved manganese, and total copper, lead, phosphorous, tin, vanadium, and zinc;

- BB to NAP3: nitrate, dissolved molybdenum, and total molybdenum;
- NAP3 to NAP4: hardness, alkalinity, ammonia, nitrate, phosphate, sulphate, chloride, fluoride, and dissolved and total aluminum, arsenic, boron, cadmium, calcium, copper, iron, lead, lithium, manganese, magnesium, mercury, molybdenum, phosphorous, potassium, rubidium, silicon, sodium, strontium, and tungsten;
- SB to NAP5: dissolved and total molybdenum; and
- NAP5 to NAP7: ammonia, phosphate, sulphate, dissolved aluminum, arsenic, cadmium, lead, molybdenum, phosphorous, silicon, uranium, and zinc, and total aluminum, antimony, arsenic, cadmium, chromium, cobalt, lead, lithium, molybdenum, phosphorous, silicon, tin, uranium, vanadium, and zinc.

The calibrated baseline model was used as basis for the predictive mass balance model for Operation, Closure, and Post-Closure.

7.6.3.5 Results

7.6.3.5.1 General

The following milestones in the model timeline strongly influence the model results and are key to interpreting the water chemistry predictions:

- water treatment has been applied to the model for mine site discharge to Sisson Brook during Operation and Post-Closure (Model Years 8 through 27 and Year 40 onward);
- TSF water quality is strongly affected by mill inputs (milled ore and process reagents) during Operation; and
- TSF seepage rates are lower in Closure and Post-Closure than during Operation.

Water chemistry changes at the downstream model nodes along Napadogan Brook are attributed to loading from contact water through two main pathways: (1) seepage from the TSF and Water Management Ponds, and (2) discharge of surplus treated water through the water treatment plant (WTP) in Operation and Post-Closure. The seasonality of the predicted changes is directly proportional to receiving water flow conditions, with higher modelled concentrations in response to lower surface water flow conditions.

Changes in predicted downstream chemistry that are driven by seepage chemistry are observed to increase from baseline concentrations at all of the modelled nodes that are located upstream of NAP5 (Napadogan Brook at the confluence with Sisson Brook) but downstream of the Project. Parameters that change as a result of treated water discharge from the Project are marked by an increase in concentration at NAP5 that coincides with WTP discharge in Model Year 8 and Post-Closure WTP discharge in Year 40. There are no additional Project-generated loads downstream of NAP5 and concentrations of all mine affected parameters subsequently decrease with distance downstream.

7.6.3.5.2 Guidelines for Comparison

Water quality predictions have been compared with the CCME Canadian Environmental Quality Guidelines for the Protection of Aquatic Life (Freshwater) (CCME FAL guidelines) and the Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ). The guidelines are presented in Table 7.6.5 along with the *Metal Mining Effluent Regulations* (*MMER*) for relevant metals. The predicted water quality was compared with the guidelines and regulations for the model nodes points along Napadogan Brook (NAP1, NAP2, NAP3, NAP5, NAP7, and NAP8), McBean Brook (MBB2) and an unnamed tributary (UT1). Water quality in other areas of the Project was also modelled, but is not compared with the guidelines. These areas include the Tailings Storage Facility (TSF), Open Pit, Water Treatment Plant (WTP), three unnamed tributaries (UT3, and UT4), Bird Brook, and Sisson Brook.

While water quality predictions are compared to these guidelines below, it must be noted that consequent risks to human, ecological or fish health cannot be directly inferred from any guideline exceedances. These risks are assessed in Chapter 8 of this EIA Report as they relate to the consideration of specific Valued Environmental Components. The results presented below do not, in and of themselves, necessarily infer the deterioration or protection of environmental quality. The results are meant to provide an indication of the issues that would require further study and confirmation as the Project advances.

Table 7.6.5 Applicable Water Quality Guidelines and Regulations

Parameter	Guidelines		Regulations
	CCME FAL Guidelines (mg/L)	GCDWQ (mg/L)	*MMER* - Column 2 (mg/L)
pH	pH 6.5 to 9	pH 6.5 to 8.5	
Ammonia	0.499 [a]		
Nitrate	3	10	
Sulphate		500	
Bromide (Br)		0.01	
Chloride (Cl)	640		
Fluoride (F)	0.12	1.5	
Aluminum (Al)	0.005 to 0.1 [b]	0.2*	
Antimony (Sn)		0.006	
Arsenic (As)	0.005	0.01	0.50
Barium (Ba)		1	
Boron (B)		5	
Cadmium (Cd)	$10^{(0.86*(\log(H)-3.2)}$/1000 to 0.000055 [c]	0.005	
Chromium (Cr)	0.0089	0.05	
Copper (Cu)	$e^{(0.8545*\ln(H)-1.465)}$ 0.2/1000 to 0.004 [c]	1	0.30
Iron (Fe)	0.3	0.3	
Lead (Pb)	$e^{((1.273*\ln(H)-4.705))}$ /1000 to 0.007 [c]	0.01	0.20
Manganese (Mn)		0.05	
Mercury (Hg)	0.000026	0.001	
Molybdenum (Mo)	0.073		
Nickel (Ni)	$e^{((0.76*\ln(H)+1.06))}$ /1000 to 0.15 [c]		0.50
Phosphorous (P)	Narrative		
Selenium (Se)	0.001	0.01	
Silver (Ag)	0.0001		

Table 7.6.5 Applicable Water Quality Guidelines and Regulations

Parameter	Guidelines		Regulations
	CCME FAL Guidelines (mg/L)	GCDWQ (mg/L)	*MMER* - Column 2 (mg/L)
Sodium (Na)		200	
Thallium (Tl)	0.0008		
Uranium (U)	0.015	0.02	
Zinc (Zn)	0.03	5	0.50

Notes:
1) Units are in mg/L unless otherwise specified.
2) Metals guidelines were applied to both total and dissolved concentrations generated in the model.
[a] CCME FAL guidelines for ammonia ranges from 0.017 to 192 mg/l; the guideline is inversely proportional to both pH and temperature. The guideline value used for comparison was based on the 90th percentile baseline pH and temperature.
[b] CCME FAL guidelines for Al are pH dependent; guideline is 0.005 mg/L for pH < 6.5 and 0.1 mg/L for pH > 6.5.
[c] Hardness (H) dependent guidelines; guidelines are calculated using predicted hardness. Maximum hardness specified is generally based upon an assumed hardness of 180 mg/L $CaCO_3$.
* The GCDWQ guideline for aluminum is an “operational guidance value” established for operational considerations in drinking water treatment, and therefore is not applicable for the water quality in Napadogan Brook or its tributaries

7.6.3.5.3 Results

Predicted water quality is discussed in this section for the nodes along Napadogan Brook (NAP1 through NAP8), McBean Brook (MBB2), and the unnamed tributary immediately upstream of NAP1 (UT1).

Since completion of the Draft EIA Report in July 2013, geochemical ML/ARD testing of site materials continued. In particular, further humidity cell testing of quarry rock by SRK demonstrated the need to revise the water quality modelling source terms for embankment runoff and infiltration. A correction was also made to the treatment levels that can be conservatively assumed for chromium in the water treatment plant discharge at the current stage of Project planning. The previous model results were based on the incorrect assumption of water treatment for chromium to 0.001 mg/L and the new results are based upon the corrected assumption of 0.01 mg/L. All other assumptions, background data and source terms used in the previous modelling remain valid and have not been updated. The results of the updated predictive water quality modelling are presented below. The most notable change from the previous model results is the significant reduction in predicted copper concentrations at modelled nodes.

While the results for the modelled location on the unnamed tributary to Napadogan Brook (UT1) are presented in the graphs along with results for nodes on Napadogan and McBean brooks, the degree of uncertainty for the UT1 results is greater than for the other nodes due to a lack of baseline water quality, hydrological, and hydrogeological information in this area. It is important to note that the UT1 results are indicative only and do not have the same level of accuracy or confidence as the results at other nodes. They represent a conservative assumption that all modelled seepage that bypasses the TSF water management systems becomes surface water before it enters Napadogan Brook and is accounted for at the NAP1 node, when some of it may well enter the brook as groundwater.

The focus of the discussion for the predicted Project surface water chemistry is on those parameters that are predicted to increase to levels that exceed one or both of the CCME FAL guidelines or GCDWQ at model nodes in Napadogan Brook. Predicted effluent discharge from the WTP does not exceed the *MMER* for any parameter. The discussion pertains to the dissolved concentrations for these parameters, as only solutes are modelled for the Project facilities. The results for the receiving water quality nodes include predicted total metals concentrations, but these only change from baseline concentrations with the addition of the dissolved loads from the mine site seepage and discharge. The seasonality of the predicted data is summarized for each key parameter along with the duration (or time frame) over which the elevated concentrations are predicted to occur and how the concentrations vary with distance from the source. The parameters of interest have been determined based upon the predicted results exceeding one or more of the guidelines for any of the mine phases; these parameters are sodium (Na), manganese (Mn), fluoride (F), aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), and selenium (Se).[1] For brevity, parameters that did not exceed either the CCME FAL guidelines or GCDWQ are not discussed here; only those parameters that exceeded either or both of these guidelines are discussed.

All of the key parameter concentration changes are affected by seepage. Concentrations of Na, F, Cd, and Se are also influenced by discharge of excess treated water from the TSF and the open pit. Some similarities are evident in the seasonality of the model results for these parameters that are driven by changes in receiving water flow conditions. Seepage rates from the TSF and WMPs are constant set rates for each year in the model and do not follow a seasonal pattern within each year; as a result, concentrations at the downstream surface water quality nodes are predicted to increase in response to seasonal low surface water flow conditions. The mean annual hydrograph for the Project area is bi-modal with the lowest stream flows observed in February, August, and September. The majority of the parameters remain below guidelines for the remainder of the year, but rise to levels that exceed guidelines during these months due to the influence of seepage.

The changes in chemistry that result from treated water discharge are also predicted to follow the same seasonal trend as seepage affected changes. However, there are a few parameters (Al, As, Cd, Cr, Cu, and Mn) for which water treatment is applied and this seasonal trend is not as pronounced.

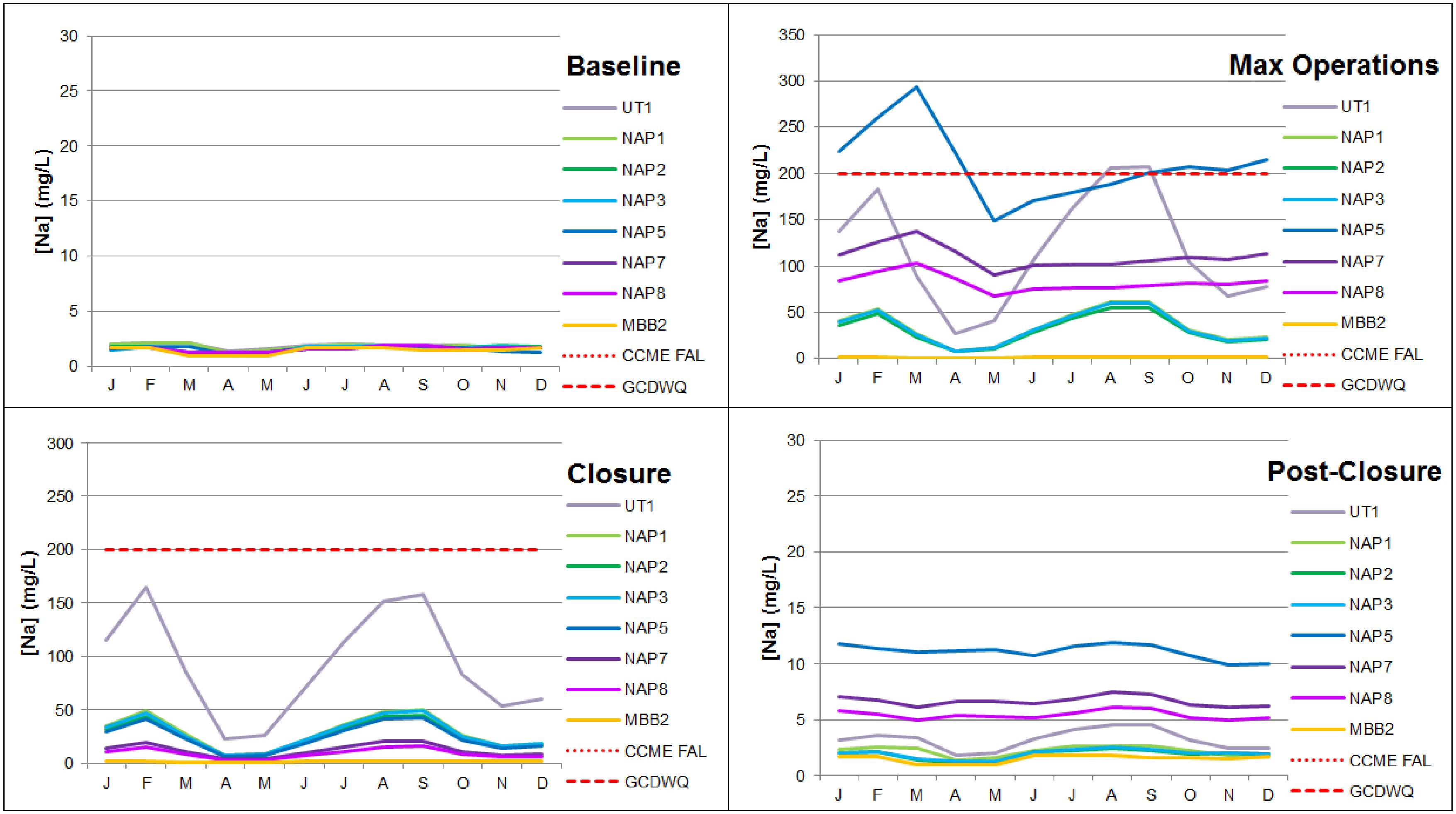
The predicted McBean Brook water chemistry is not altered by mine seepage; however, changes are modelled as a result of water diverted around the open pit from the Sisson Brook catchment to McBean Brook. Surface water diversion structures will route run-off that would naturally have drained through Sisson Brook into the McBean Brook catchment. The modelled data for McBean Brook have been included herein, but a detailed discussion of the results has not been provided since no parameters were noted to increase to a point where guidelines were encroached upon, except for those that were observed to exceed guidelines in the baseline data.

7.6.3.5.3.1 Sodium (Na)

The annual distribution of predicted sodium concentrations for one year in each Project phase are provided on Figure 7.6.4. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

[1] The EIA Report of July 2013 showed lead concentrations in excess of lead guidelines at UT1, while the updated model results do not. Thus, lead is not discussed in this section.

Sodium concentrations are predicted to exceed the GCDWQ 200 mg/L aesthetic objective at NAP5 and at UT1 only during Operation; there is no CCME FAL guideline for this parameter. Sodium is used as a mill reagent, which is the primary loading source for this parameter; therefore, concentrations of sodium in the TSF and at the modelled nodes in the receiving environment decrease at the beginning of Closure, when mill inputs no longer contribute to the system. The objective exceedance at NAP5 is a result of treated water discharge from the TSF to Sisson Brook during Operation (Years 8 through 27); concentrations are predicted to decrease below the objectives at the next model node (NAP7). Sodium is predicted to exceed the GCDWQ objective at NAP5 year-round from Years 8 through 14 (Operation) and then seasonally in association with lower receiving water flow conditions from Years 15 through 27 (generally from September through April). The maximum sodium concentration of 293 mg/L is predicted at NAP5 in Model Year 17 (Operation). The predicted chemistry at UT1 is primarily affected by seepage water from the TSF. At this location sodium concentrations are highest during Operation. Concentrations decrease below the objective at the next model node (NAP1). Sodium exceeds the GCDWQ objective seasonally from Years 10 through 15 (generally in August and September). The maximum sodium concentration of 207 mg/L is predicted at UT1 in Model Year 14 (Operation).



Notes:

1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Maximum Operations" refers to the year for which sodium reaches its maximum value (Year 14 for NAP1, NAP2, NAP3, and MBB2; Year 16 for NAP5, NAP7, and NAP8).
3. ***There is no CCME FAL Guideline for sodium.***
4. The GCDWQ for sodium is an aesthetic guideline based on taste and is not within the scale of the baseline and Post-Closure graphs.
5. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
6. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

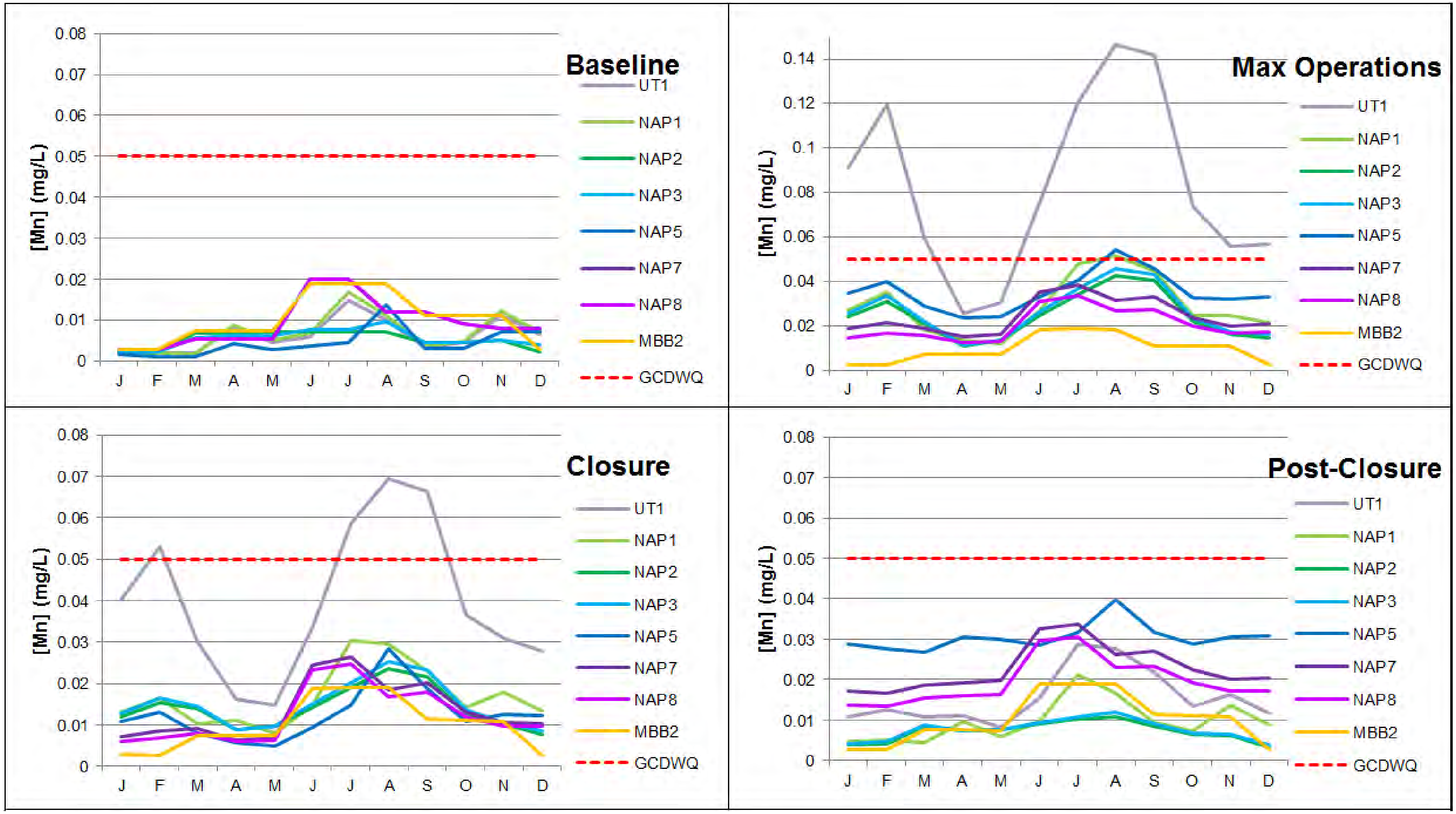
Figure 7.6.4 Predicted Sodium Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.2 Manganese (Mn)

The annual distribution of predicted manganese concentrations for one year in each Project phase are provided on Figure 7.6.5. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

Manganese concentrations are predicted to exceed the GCDWQ 0.05 mg/L aesthetic objective on a seasonal basis at UT1, NAP1, and NAP5 during Operation and at UT1 during Closure; there is no CCME FAL guideline for manganese. Maximum annual concentrations occur in August in association with low surface water flows; predicted concentrations remain below the objective for the remainder of the year with few exceptions. Maximum annual concentrations are predicted to exceed the objective during Operation in Years 10 through 25 at NAP5, and in Years 13 through 19 at NAP1; however, average annual concentrations at these sites remain below the objective. Maximum annual concentrations are predicted to exceed the objective at UT1 during Operation and Closure in Years 7 through 33; the annual average concentrations are predicted to exceed this objective at UT1 during Operation in Years 9 through 26.

The highest predicted value downstream of UT1 is 0.055 mg/L for NAP5 in Model Year 16 (Operation), followed by 0.052 mg/L for NAP1 in Model Year 14 (Operation). At UT1, the highest predicted value is 0.147 mg/L, occurring in Year 16 (Operation). Changes in manganese concentrations at NAP5 and downstream result from TSF seepage, embankment runoff, and WTP discharge, though WTP discharge does not result in a notable change at NAP5 compared to the upstream nodes affected by seepage and embankment runoff. Concentrations decrease below the guideline at the next downstream model node from both NAP1 and NAP5 (NAP2 and NAP7, respectively). It is noted that the seasonal distribution of manganese concentrations is slightly different at NAP7 and NAP8 compared to NAP5 due to manganese loading from background sources downstream of the Project area.



Notes:

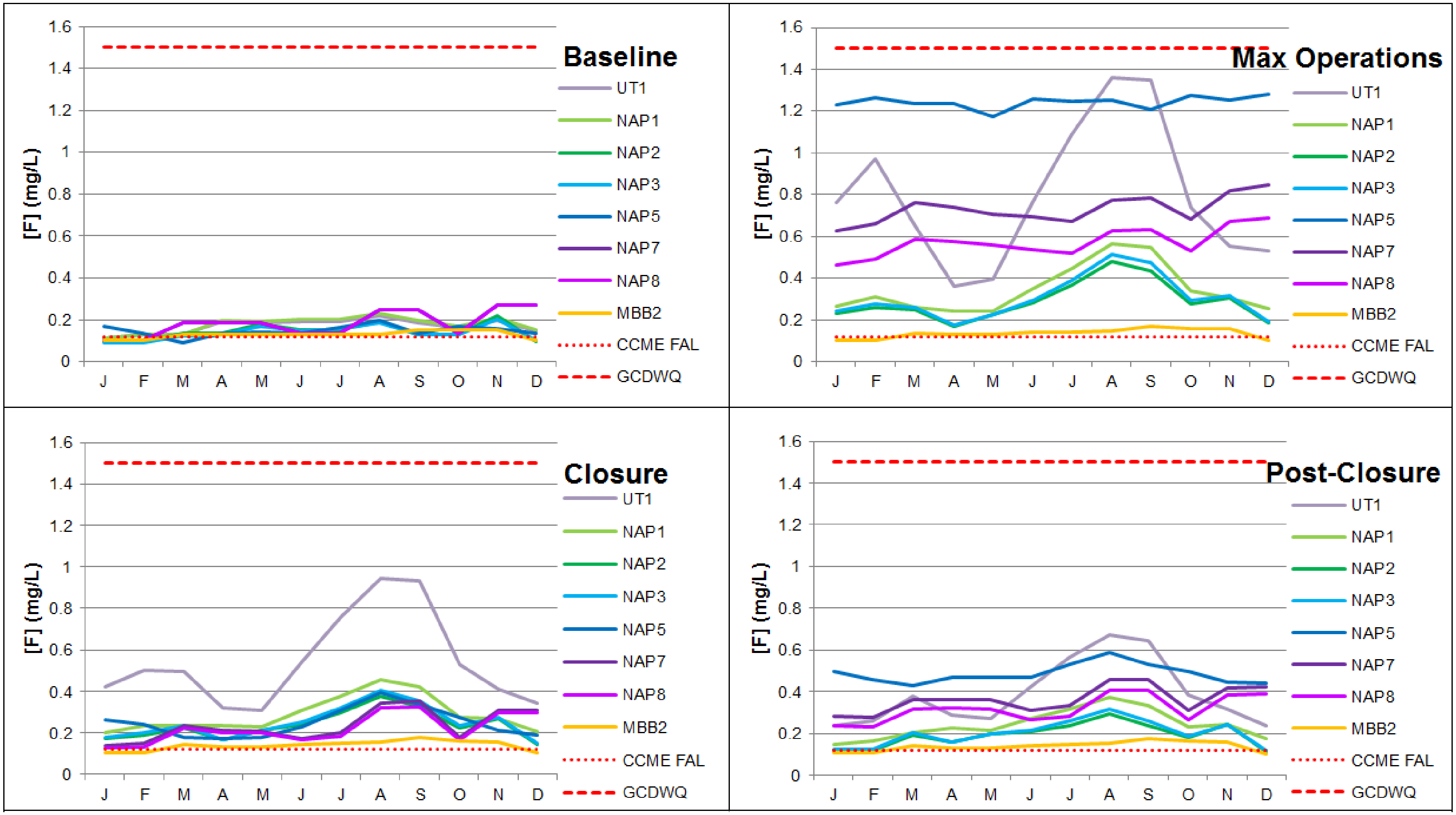
1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. " Max Operations" refers to the year for which manganese reaches its maximum value (Year 14 for all nodes).
3. ***There is no CCME FAL guideline for manganese.***
4. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.5 Predicted Manganese Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.3 Fluoride (F)

The annual distribution of predicted fluoride concentrations for one year in each Project phase are provided on Figure 7.6.6. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

Fluoride concentrations are not predicted to exceed the 1.5 mg/L GCDWQ, but are predicted to exceed the 0.12 mg/L CCME FAL guideline at each node for the duration of the modelled Project life. Baseline fluoride concentrations are elevated throughout the Project area and average levels generally exceeded the CCME FAL guideline. Changes in fluoride concentrations are predicted as a result of seepage and point source discharge from the WTP. The greatest increase is noted at UT1 due to seepage from the TSF and Water Management Pond 5 (WMP5), reaching a maximum concentration of 1.4 mg/L in Year 17 (Operation). Peak concentrations decrease at NAP 1 (maximum concentration of 0.57 mg/L in Year 17) and continue to decrease downstream along Napadogan Brook, upstream of the discharge point for the WTP effluent in Sisson Brook. The predicted variability at each of these nodes is seasonal with the highest concentrations in the lower flow months in late-summer. Peak concentrations of fluoride increase at NAP5 when compared to the upstream nodes (maximum concentration of 1.3 mg/L in Year 12) due to the treated water discharge from the WTP during Operation, and to a lesser degree in Post-Closure. The concentration of fluoride in the WTP effluent is higher during Operation than in Post-Closure because ore processing, which is the main loading source for fluoride, ceases at the end of Operation.



Notes:

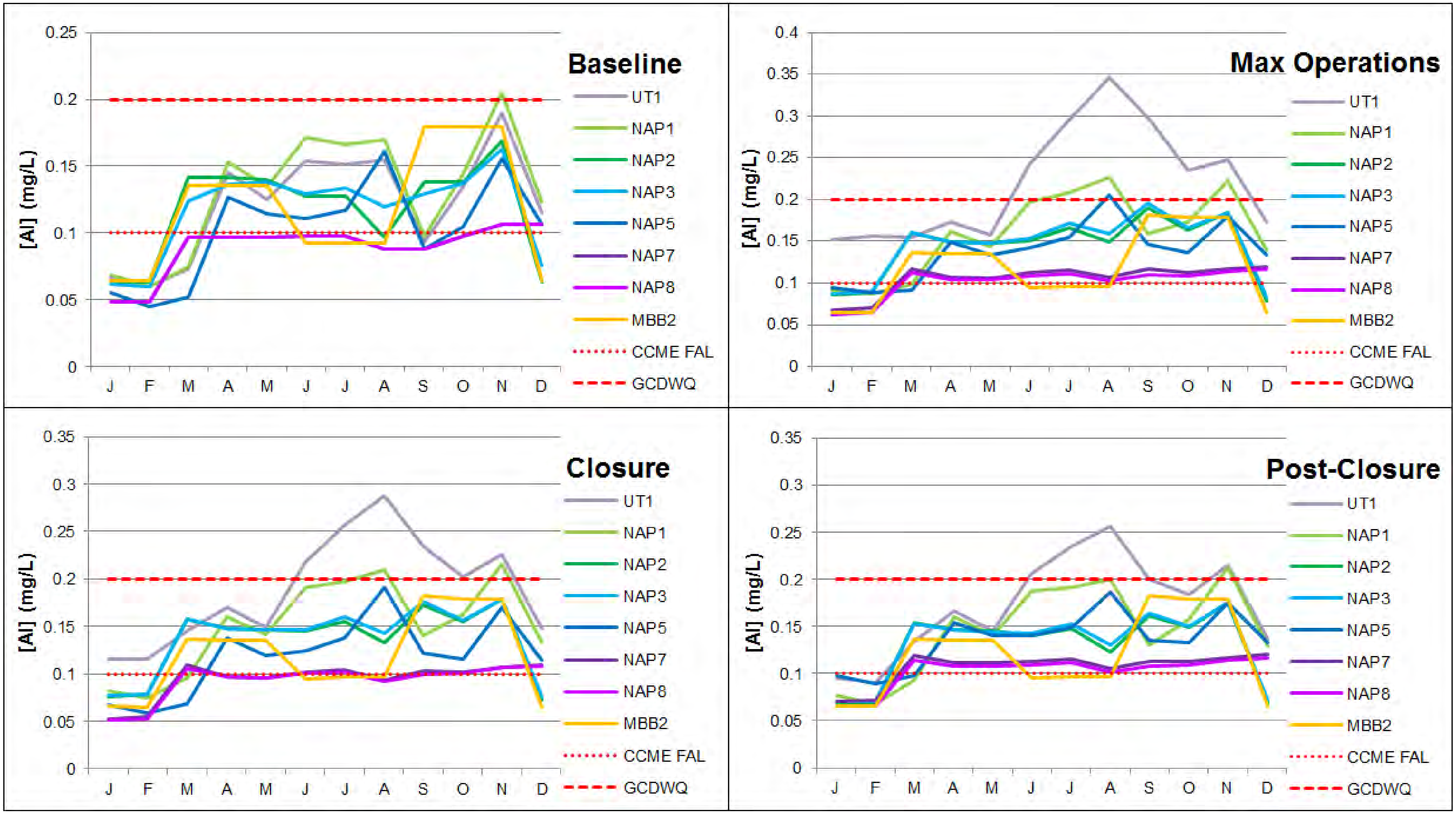
1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which fluoride reaches its maximum value (Year 24 for NAP1, NAP2, NAP3, and MBB2; Year 11 for NAP5, NAP7, and NAP8).
3. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
4. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.6 Predicted Fluoride Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.4 Aluminum (Al)

The annual distribution of predicted dissolved aluminum concentrations for one year in each Project phase are provided on Figure 7.6.7. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

Aluminum concentrations are naturally elevated in the Project area, particularly in samples collected from the upper portion of the Napadogan Brook watershed, decreasing with distance downstream. Average baseline dissolved aluminum concentrations exceeded the CCME FAL guideline at all sites except in lower Napadogan Brook and seasonally exceeded the GCDWQ at NAP1, UT1 and NAP5 (baseline values are from the average monthly dataset used for the model inputs for each of the nodes and measured maximum and minimum concentrations are under-represented). The GCDWQ guideline for aluminum is an operational guidance value for water treatment plants and is therefore not directly applicable to potential water quality effects on human health; reference to the guideline has been included in this assessment for completeness (Mackie, J. Personal communication, October 27, 2014). The predicted aluminum concentrations resulting from the Project are slightly higher than the baseline concentrations, but follow the same seasonal distribution. Aluminum concentrations are predicted to exceed the 0.1 mg/L CCME FAL guideline (pH > 6.5) on a regular basis at all modelled nodes for the duration of the model and are predicted to exceed the 0.2 mg/L GCDWQ operational guidance value on occasion, but only at NAP1, UT1, and NAP5 (maximum concentrations of 0.227 mg/L, 0.346 mg/L, and 0.206 mg/L respectively). Maximum concentrations are predicted to occur in Model Year 24 (Operation) for all nodes in Napadogan Brook.



Notes:

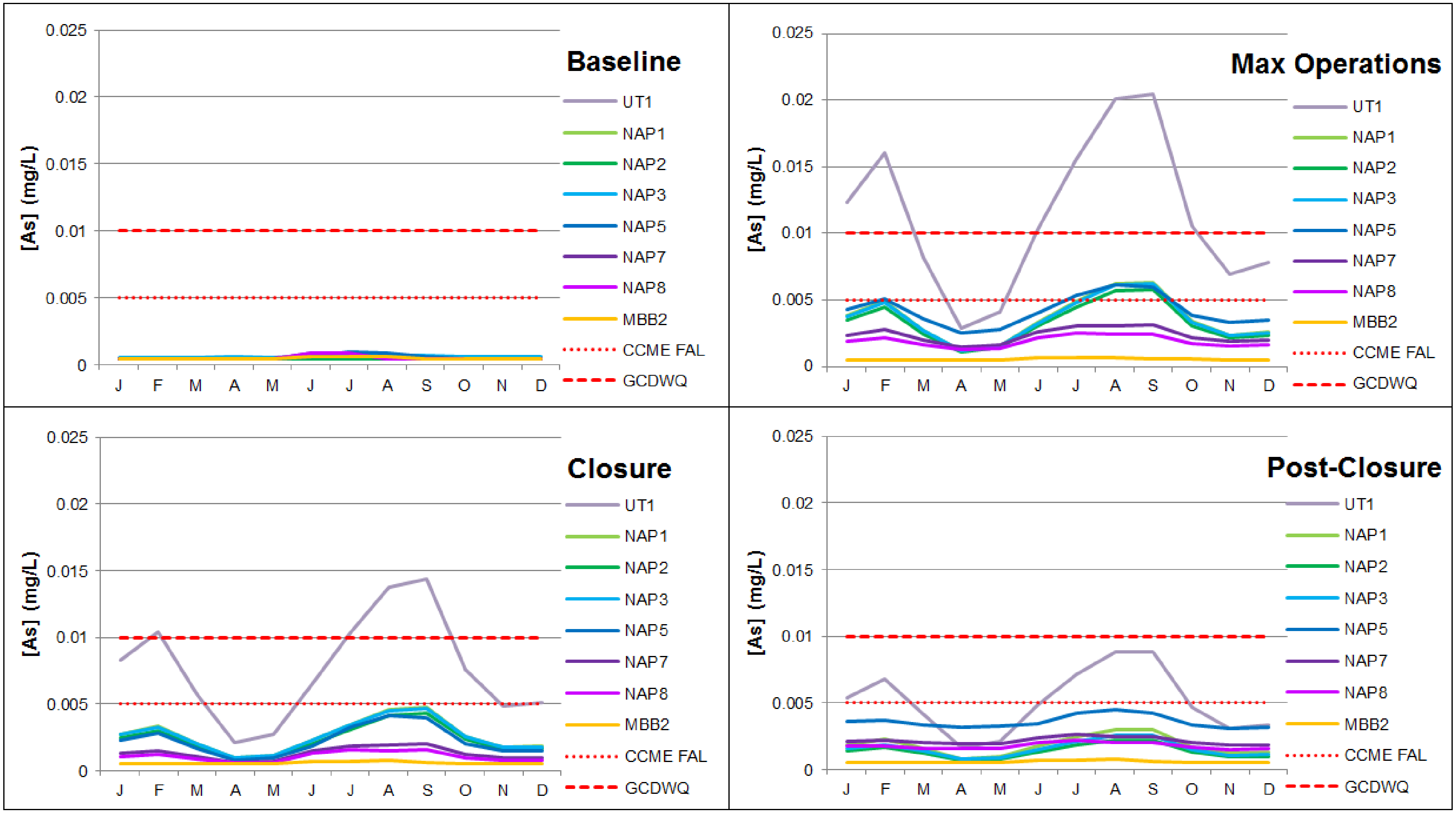
1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which aluminum reaches its maximum value (Year 24 for all nodes).
3. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
4. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.7 Predicted Aluminum Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.5 Arsenic (As)

The annual distribution of predicted dissolved arsenic concentrations for one year in each Project phase is provided on Figure 7.6.8. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

Arsenic concentrations are predicted to increase during Operation and seasonally exceed guidelines at several nodes. These guideline exceedances are driven mainly by seepage from the TSF, with minor increases in concentrations due to WTP effluent, and are predicted to decrease below guidelines at all nodes along Napadogan Brook at the start of Closure. Arsenic is predicted to exceed the 0.01 mg/L GCDWQ and the 0.005 mg/L CCME FAL guideline at UT1 on a seasonal basis from Year 10 to Year 13 (during Operation). After which arsenic seasonally exceeds the CCME FAL guideline for the duration of the model. Annual average concentrations at UT1 also exceed the GCDWQ guideline from Year 13 to 16 (Operation) and exceed the CCME FAL guideline from Year 10 onward. The predicted concentrations are highest at UT1; however, the results for this node have a lesser degree of certainty than those for other nodes. Downstream from UT1, arsenic is predicted to exceed the CCME FAL guidelines on a seasonal basis at NAP1 through NAP5 during Operation only. The predicted concentrations do not exceed the CCME FAL guidelines at the nodes downstream of NAP5 (NAP7 and NAP8). Changes in arsenic concentrations upstream of NAP5 are related to seepage from the TSF and Water Management Ponds (WMPs) as well as runoff from the embankment. The changes at NAP5 are also affected by WTP effluent during Operation and in Post-Closure. The predicted arsenic concentrations are higher under low flow conditions and are highest in the summer months (July, August, and September). Predicted arsenic concentrations peak at all sites in Model Year 14 (Operation) with a maximum concentration of 0.020 mg/L predicted at UT1. The next highest predicted concentration of arsenic downstream of UT1 is 0.0063 mg/L at NAP1.



Notes:

1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which arsenic reaches its maximum value (Year 14 for all nodes).
3. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
4. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

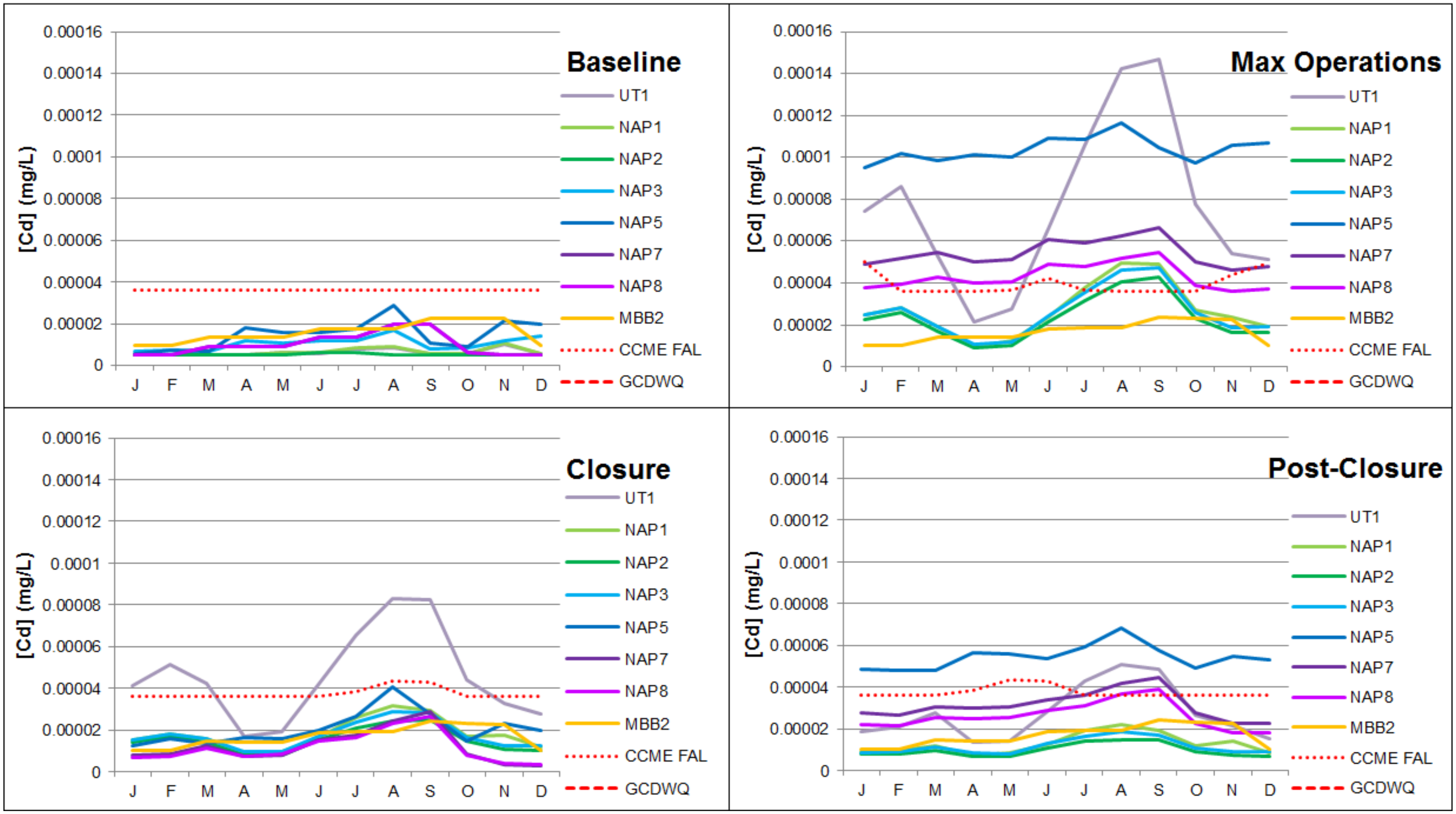
Figure 7.6.8 Predicted Arsenic Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.6 Cadmium (Cd)

The annual distribution of predicted dissolved cadmium concentrations for one year in each Project phase is provided on Figure 7.6.9. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

It is noted that baseline cadmium concentrations are elevated and generally exceeded the hardness-dependent CCME FAL guideline throughout the Project area.

The predicted cadmium concentrations do not exceed the short-term cadmium CCME FAL guideline at any node, but several exceedances of the long-term guideline have been noted. Annual minimum, average, and maximum concentrations predicted at NAP5 during Operation and Post-Closure exceed the long-term guideline (the baseline annual maximum concentration also exceeds this guideline). At NAP7, cadmium concentrations exceed the guideline year-round during Operation and the annual maximum exceeds the guideline during Post-Closure. Upstream from NAP5, cadmium concentrations are predicted to exceed the guideline seasonally during Operation, Closure, and Post-Closure at UT1 and during Operation only at NAP1 and NAP3. Changes in cadmium concentrations upstream of NAP5 are related to seepage from the TSF and WMPs as well as runoff from the embankment. The changes at NAP5 are also affected by WTP effluent during Operation and in Post-Closure. The predicted cadmium concentrations are higher under low flow conditions and are highest in the summer months (July, August, and September).



Notes:

1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which cadmium reaches its maximum value (Year 24 for NAP1, NAP2, NAP3, and MBB2; year 20 for NAP5, NAP7, and NAP8).
3. The CCME FAL guideline is hardness-dependent; the guideline shown is for long-term exposure and is calculated for hardness at NAP1; the CCME FAL guideline for short-term exposure is above the scale of these graphs.
4. ***The GCDWQ guideline of 0.005 mg/l is not shown on these graphs.***
5. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
6. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.9 Predicted Cadmium Concentrations at Downstream Nodes by Project Phase

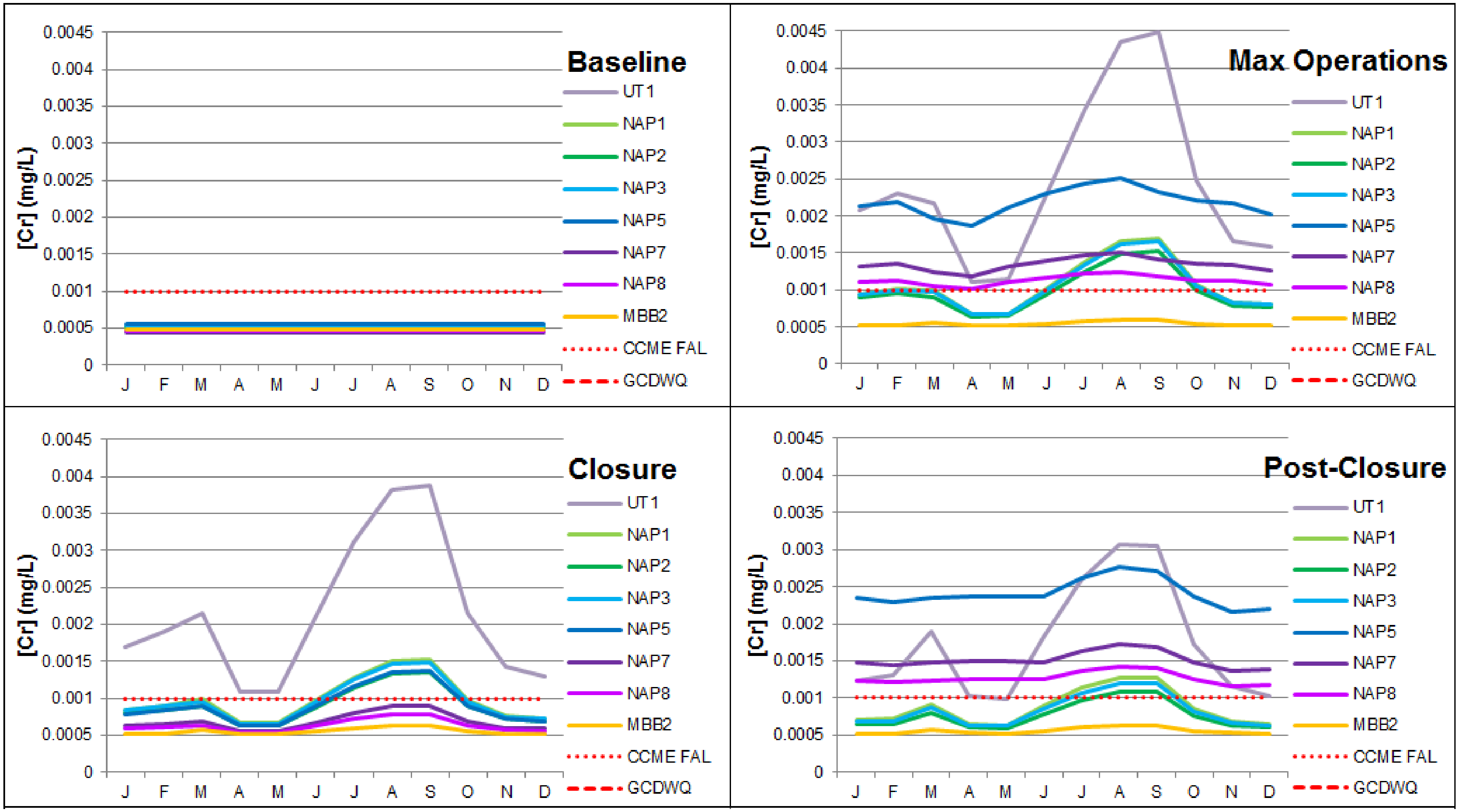
7.6.3.5.3.7 Chromium (Cr)

The annual distribution of predicted dissolved chromium concentration for one year in each Project phase is provided on Figure 7.6.10. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

The hexavalent chromium (Cr VI) guideline has been used for comparison instead of the trivalent chromium guideline (CCME FAL guideline of 0.0089 mg/L), as Cr VI is the principal species found in surface waters (CCME 1999). Chromium concentrations are predicted to be equal to or greater than the 0.001 mg/L CCME FAL guideline for Cr VI year-round at UT1 from Year 6 of Operation, though Closure and Post-Closure. The predicted chromium concentrations exceed this guideline on a seasonal basis, concurrent with lower receiving water stream flow, at all model nodes from NAP1 to upstream of NAP5. The same seasonal variability is predicted at NAP5 for Closure, with similar seasonal exceedances of the CCME FAL. Chromium concentrations are predicted to decrease below the guideline at NAP7, and downstream, during Closure. Chromium concentrations are predicted to increase at NAP5, NAP7, and NAP8 during Operation and Post-Closure as a result of discharge from the WTP. Prior to Year 8 of Operation, the chromium concentrations are predicted to exceed the CCME FAL seasonally at NAP5 and are the result of seepage from the TSF. However, chromium is predicted to continuously exceed the CCME FAL for the remainder of Operation and in Post-Closure. The WTP influent chromium concentrations are below the water treatment threshold of 0.01 mg/L during Closure, and as a result, there is no removal of this parameter in the model for this phase; this is a conservative assumption. Chromium concentrations decrease downstream of NAP5 (at nodes NAP7 and NAP8), though they are predicted to remain above the CCME FAL during Operation (after Year 8), and through Post-Closure.

The changes upstream of NAP5 are predominantly driven by seepage and runoff from the embankment which results in season influences on downstream water quality, with higher concentrations occurring during periods of lower stream flow. These lower flow periods are from June through October, and a second lower peak is also evident in February. These seasonal influences continue to affect predicted water quality at NAP5 and downstream, but the predicted concentrations are more consistent throughout the year due to continuous discharge (seasonally variable) from the WTP in Operation and Post-Closure. Chromium concentrations are predicted to be highest during Operation at UT1 (0.0045 mg/L); seasonal peak concentrations are also predicted to be higher at this node for Closure and Post-Closure that the other model nodes. The maximum predicted concentrations for NAP5 and downstream are occur in Post-Closure under steady-state conditions (after model Year 50). The predicted concentrations in Post-Closure range from 0.0021 mg/L to 0.0028 mg/L with an average of 0.0023 mg/L.

Predicted concentrations remain well below the 0.05 mg/L GCDWQ at all nodes.



Notes:

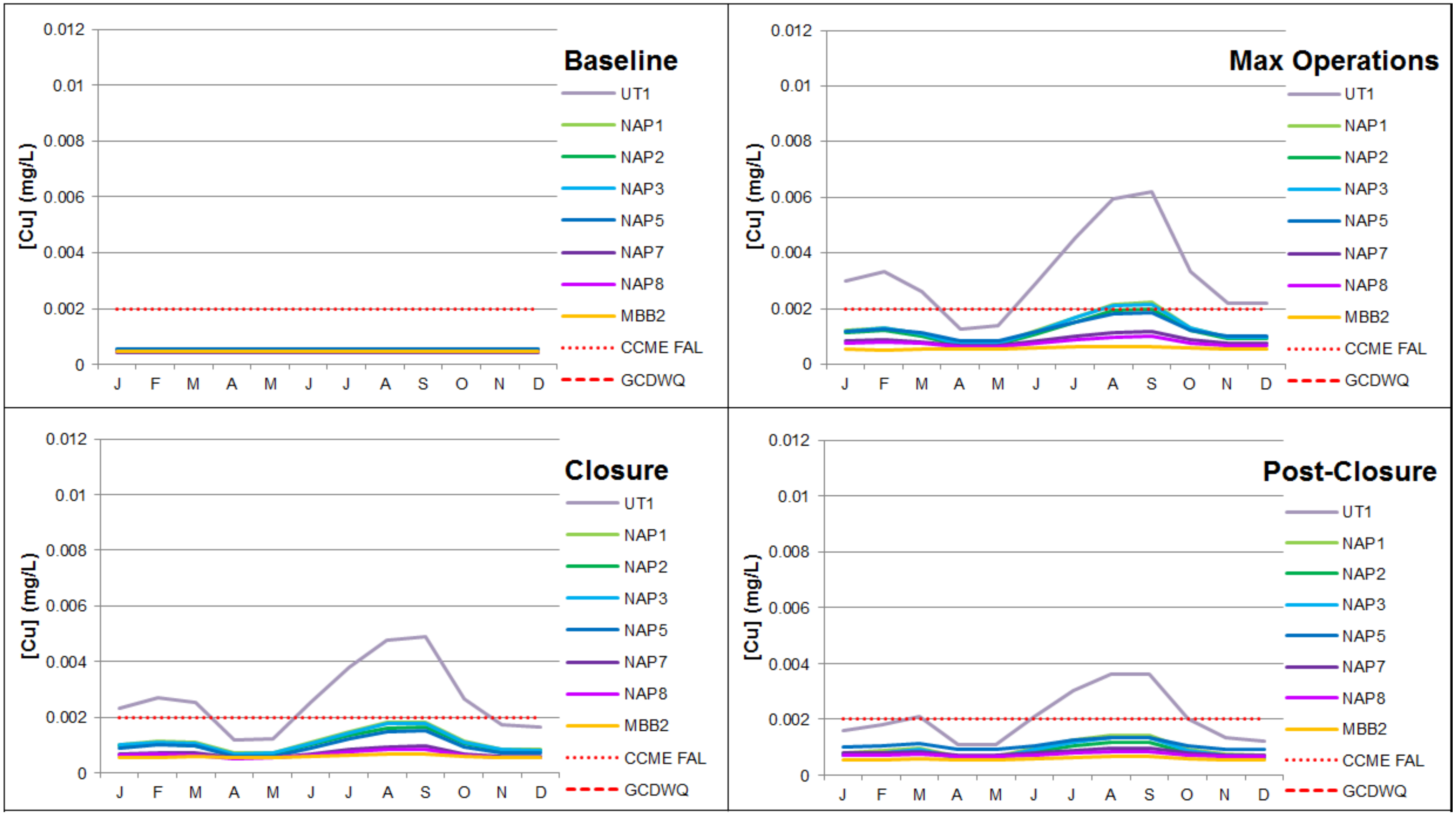
1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which chromium reaches its maximum value (Year 26 for all nodes).
3. The CCME FAL guideline for trivalent chromium is 0.0089 mg/l; the CCME FAL guideline for hexavalent chromium is 0.001 mg/l.
4. ***The GCDWQ guideline of 0.05 mg/l is not shown on these graphs.***
5. The current conditions indicate that chromium is below the method detection limit at all nodes.
6. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
7. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.10 Predicted Chromium Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.8 Copper (Cu)

Annual distributions of predicted dissolved copper concentrations for one year in each Project phase are provided on Figure 7.6.11. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

Maximum copper concentrations are predicted to exceed the hardness dependent CCME FAL guideline at UT1, and marginally at NAP1 and NAP3. Average annual concentrations exceed the guideline only at UT1. The applicable guideline for all model nodes is 0.002 mg/L for hardness of < 83 mg/L $CaCO_3$. Predicted concentrations remain well below the 1 mg/L GCDWQ at all nodes. Copper concentrations are influenced by seepage and by WTP effluent (effluent discharge limit of 0.002 mg/L); however, the point source effluent does not affect the trend to lower predicted concentrations moving from UT1 and NAP1 downstream. The predicted changes to copper concentrations for all sites are predominantly driven by seepage and embankment runoff and are therefore seasonal, with higher concentrations occurring in during periods of lower stream flow. Concentrations at UT1 are predicted to exceed the CCME FAL guideline from June through November, and again from January to March during Operation and Closure. During Post-Closure, concentrations of copper are predicted to exceed the CCME FAL guideline at UT1 from June to October and again in March. Seasonal fluctuations follow the same trends at the nodes downstream from UT1, but maximum concentrations (during August and September) are predicted to marginally exceed the CCME FAL guideline only during Operation at NAP1 and NAP3. Maximum copper concentrations are reached in late-Operation and early-Closure with a predicted peak concentration of 0.0062 mg/L at UT1. The next highest concentration is predicted at NAP1, with a maximum (rather than annual average) concentration of 0.0022 mg/L. Predicted copper concentrations decrease to levels at or below the CCME FAL guidelines in lower Napadogan Brook (NAP5 to NAP8) during all project Phases.



Notes:

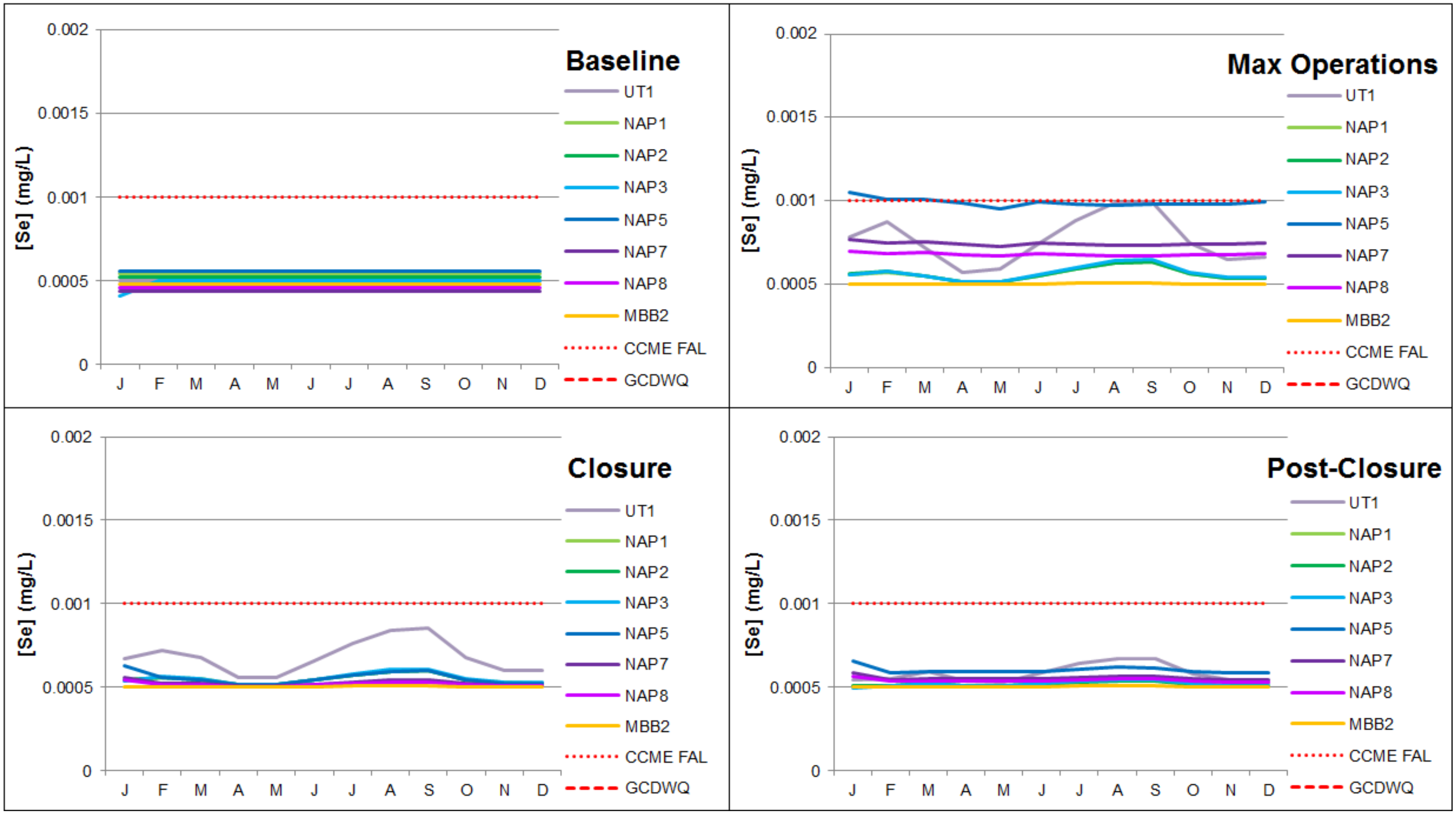
1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which copper reaches its maximum value (Year 26 for all nodes).
3. ***The GCDWQ guideline is 1.0 mg/l and is not within the scale of these graphs.***
4. CCME FAL guideline is hardness-dependent, with a minimum of 0.002 mg/l for hardness <83 mg/l.
5. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
6. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.11 Predicted Copper Concentrations at Downstream Nodes by Project Phase

7.6.3.5.3.9 Selenium (Se)

The annual distribution of predicted dissolved selenium concentrations for one year in each Project phase is provided on Figure 7.6.12. The use and interpretation of these predictions in considering the consequent risks to human, ecological or aquatic environment health are found in the HHERA (Section 7.7), Aquatic Environment (Section 8.5), and Public Health and Safety (Section 8.9).

Selenium concentrations are predicted to fluctuate seasonally around the CCME FAL guideline at NAP5 during Operation as a result of WTP effluent being discharged via Sisson Brook, starting in Model Year 8 (Operation). Concentrations at this node are predicted to remain well below the 0.01 mg/L GCDWQ and to drop below the CCME FAL guideline by Year 17 (Operation phase). The predicted concentrations at NAP5 during Operation are effectively at the guideline (range of 0.00097 mg/L to 0.00105 mg/L).



Notes:

1. "Baseline" refers to Model Years -1 and -2; "Closure" refers to Year 30; "Post-Closure" refers to Year 50.
2. "Max Operations" refers to the year for which selenium reaches its maximum value (Year 24 for NAP1, NAP2, NAP3, and MBB2; Year 11 for NAP5, NAP7, and NAP8).
3. ***The GCDWQ guideline is 0.01 mg/l and is not within the scale of these graphs.***
4. The current conditions indicate that selenium is below the method detection limit at all nodes.
5. CCME FAL refers to the CCME Canadian Environmental Quality Guidelines for the Protection of Freshwater Aquatic Life.
6. GCDWQ refers to the Health Canada Guidelines for Canadian Drinking Water Quality.

Figure 7.6.12 Predicted Selenium Concentrations at Downstream Nodes by Project Phase

7.7 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT (HHERA)

As outlined in Sections 3.4.1.6 and 3.4.2.5, activities being carried out during the Construction, Operation, Decommissioning, Reclamation and Closure phases will release contaminants of potential concern (COPCs) to which humans and ecological receptors may potentially be exposed. Specifically:

- emissions of criteria air contaminants (CACs) from Project activities have the potential to affect human health through inhalation;
- deposition of COPCs in dust from extraction and transport of the ore has the potential to affect soil quality, thereby also affecting vegetation, wildlife, and consumers of country foods; and
- treated surplus water release from the water treatment plant, and release of seepage from the TSF, may release COPCs into groundwater or surface water which may affect water quality in nearby streams and thereby affect drinking water, aquatic life, and consumers of fish or aquatic plants.

A Human Health and Ecological Risk Assessment (HHERA) is the most appropriate mechanism to quantify the potential risks to human and ecological health that could result from Project activities. An HHERA consists of two main components: a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (ERA). An HHRA is an assessment of the potential toxicological risks on human receptors. An ERA is an assessment of the potential ecotoxicological risks on ecological receptors. Section 4.13 of the Final Guidelines (NBENV 2009) and Section 4.8 of the Terms of Reference (Stantec 2012a) require that an HHERA of the Project be conducted as part of the environmental impact assessment (EIA) of the Project.

All chemicals, whether from human-made or natural sources, have an inherent toxicity and thus can result in a potential to cause a toxicological health risk to living organisms. The nature and magnitude of the health risk associated with a chemical depends upon:

- the type of receptor being exposed (*e.g*., human or wildlife);
- the duration and route of exposure (*e.g*., acute versus chronic exposure; with dermal, inhalation or ingestion routes of exposure); and
- the hazard represented by the chemical (*i.e*., its inherent toxicity).

If all three components (*i.e.,* receptor, exposure, and hazard) are present, then the possibility exists that a health risk may result (Figure 7.7.1). If, however, one or more of these three components is not present, then there is no risk. For example, a human or ecological receptor could be exposed to a contaminant, but if that contaminant has a very low toxicity or is present at very low levels, then no unacceptable risk would be expected. Alternatively, a contaminant present or released into the environment may be very toxic, but if there is no route of exposure by which a receptor could be exposed to the contaminant, again there is no risk to the receptor.

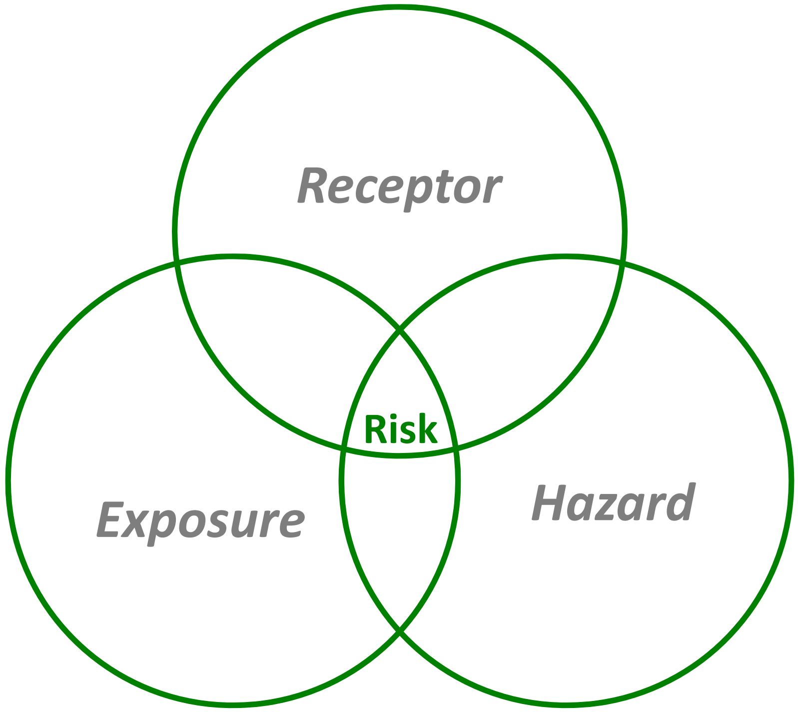


Figure 7.7.1 Health Risk Components

7.7.1 Human Health and Ecological Risk Assessment Methodology

This assessment of risks to human and ecological health was conducted according to widely-accepted risk assessment methodologies and follows guidance published and endorsed by regulatory agencies, including the following publications:

- "Federal Contaminated Sites Risk Assessment in Canada, Part I: Guidance on Human Health Risk Preliminary Quantitative Risk Assessment (PQRA), Version 2.0" (Health Canada 2010a);
- "Federal Contaminated Sites Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors Version 2.0" (Health Canada 2010b);
- "Federal Contaminated Sites Risk Assessment in Canada, Part V: Guidance on Complex Human Health Detailed Quantitative Risk Assessment For Chemicals ($DQRA_{CHEM}$)" (Health Canada 2010c); and
- "A Framework for Ecological Risk Assessment—Canadian Council of Ministers of the Environment" (CCME 1996).

The HHERA framework (Figure 7.7.2) is composed of the following major components, which are the same for the characterization of risks to both human and ecological receptors.

- **Project Site Characterization and Modelled Predictions:** This component includes a review and compilation of existing information including the Project components and related activities, and biophysical and land use studies completed in support of this EIA.
- **Problem Formulation:** Problem formulation includes the identification of the potential Project-related environmental hazards that may pose a health risk (*i.e.*, COPC), potential receptors (human and ecological), and relevant exposure pathways (*e.g.*, inhalation of COPC in air). The problem formulation component ensures that the HHERA focuses on the key areas and issues of concern.
- **Hazard (Toxicity) Assessment**: The hazard (toxicity) assessment includes the identification of published, scientifically-reviewed toxicity information for each COPC, against which the receptor exposures can be compared.
- **Exposure Assessment:** The exposure assessment is the qualitative or quantitative evaluation of the degree to which the receptors will be exposed to the COPC, generally expressed as a dose (*e.g.*, mg of COPC per kg body weight per day). Generally, human and ecological receptors can be exposed to these contaminants by directly inhaling them, coming into dermal contact with them, or ingesting them along with food and water.
- **Risk Characterization**: Risk characterization is a qualitative or quantitative assessment of the health risk of each COPC to each receptor, based on the degree of exposure. The potential for Project activities to affect the health of a receptor can then be assessed based on the magnitude of the predicted risk.
- **Uncertainty Assessment:** A review of the assumptions and uncertainties associated with the risk estimation is completed. If, upon review, one or more of the assumptions used to estimate the exposure (and risk) is found to be unreliable, the assumption may be revised and the risk calculations repeated until the results are considered to be reliable, but not unduly conservative in its approach. A conservative assessment or assumption is one that is likely to over-state the actual risk or consequence, rather than under-stating it.
- **Recommendations:** If required, recommendations are provided for mitigation and/or monitoring that would reduce the potential risk.

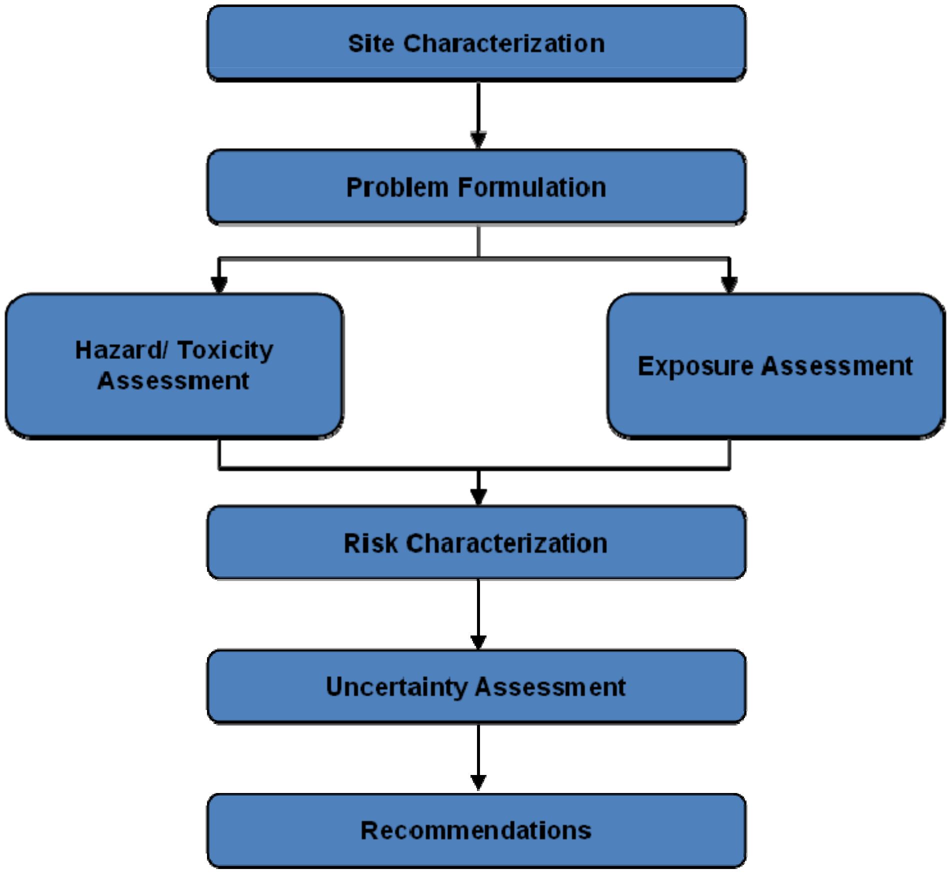


Figure 7.7.2 Human Health and Ecological Risk Assessment Framework

To assess the potential human and ecological health risks, the HHERA considered how the Project activities may result in the release of contaminants to the environment. Details of the activities associated with each of the Project phases of Construction (the time during which the Project would be constructed), Operation (the time period after the Construction phase during which the mine would operate), and Decommissioning, Reclamation and Closure (*i.e.,* the time following the completion of Operation of the Project) are provided in Section 3.4. The HHERA considered the potential risks from the Project alone and in the context of the existing environmental conditions as follows.

- The "Baseline Case" evaluates potential health risks presently existing at and near the Project site, and is based upon measured data for COPC concentrations in air, soil, plants, water, soil invertebrates, small mammals, and fish. COPC concentrations for wild game (*e.g.*, moose) were estimated based upon measured concentrations of COPCs in other media.

- The "Project Alone Case" evaluates potential future health risks arising from changes in air quality and the burden of metal deposition to soils and vegetation caused by dust fall near the Project site, and changes to water quality in downstream watercourses (*i.e.,* Napadogan Brook) caused by the Project.

- As implied by the name, the “Project + Baseline Case” evaluates the health risks associated with the predicted environmental concentrations, which incorporate both the health risks potentially arising from existing conditions and those from predicted changes in the environment that may be caused by Project activities.

7.7.2 Project Site Characterization and Environmental Quality Model Predictions

In order to complete the HHERA, it was necessary to understand the area within which Project-related environmental effects can be predicted or measured with a reasonable degree of accuracy and confidence. For the HHERA, this includes an area of 20 x 20 km centred on the Project Development Area (PDA, defined as the physical footprint of Project components; see Figure 1.2.1). Referred to herein as the HHERA Study Area, this 20 km x 20 km area encompasses the open pit; the ore processing plant; storage areas; the TSF; and the quarry and areas directly adjacent to the PDA (Figure 7.7.3).

The area of the Project straddles a topographical divide that separates the headwaters of the McBean Brook and Napadogan Brook watersheds. Both brooks drain to the Nashwaak River, which enters the St. John River at Fredericton. The majority of the Project facilities lie within the small Bird and Sisson brook tributary watersheds to West Branch Napadogan Brook, which drains via Napadogan Brook to the Nashwaak River. The southwestern portion of the open pit does, however, partially intersect small headwater tributaries to McBean Brook. These watersheds support both warm and cold water fish species. The main aquatic species of interest in Napadogan Brook and the headwaters of the Nashwaak River are Atlantic salmon, American eel, and brook trout. A detailed description of water quality, and fish and fish habitat is provided in Sections 7.6, 8.4, and 8.5.

Most of the Project is located near the southwestern border of the Central Uplands Ecoregion within the Beadle Ecodistrict, a lake-filled region of rolling hills separated by broad valleys. This area is typically well-drained, forested upland, separated by rolling valleys. The HHERA Study Area includes tolerant hardwood forest at higher elevations, transitioning to black spruce/balsam fir dominated forest in the valley bottoms. As will be discussed in Section 8.7.2 (Vegetated Environment), over 400 vascular plant species were identified in the HHERA Study Area, including an S2/sensitive species (Nodding ladies’-tresses, *Spiranthes cernua*) at one location outside the PDA. Further information on existing vegetation communities in the PDA and parts of the HHERA Study Area are presented in Section 8.7.

As will be discussed in Section 8.6.2 (Terrestrial Environment), wildlife within the PDA and parts of the HHERA Study Area consists of up to 22 mammalian species, approximately 146 songbird species that use every type of habitat in the area, and 11 herpetile (reptiles and amphibian) species. A total of 13 Species at Risk (SAR) may potentially be present in the region including: Canada lynx, Tricolored Bat, Northern Myotis, Little Myotis, Wood turtle, Bald Eagle, Common Nighthawk, Chimney Swift, Olive-sided Flycatcher, Eastern Wood-pewee, Barn Swallow, Canada Warbler, and Rusty Blackbird. More details regarding wildlife and wildlife habitats in the PDA and parts of the HHERA Study Area are provided on Section 8.6.

Like much of central New Brunswick, the general area of the Project is sparsely populated but supports a variety of land uses including hunting, fishing, ATV, snowmobile, and commercial forestry. There is a long history of active commercial logging, and thus there are many forestry roads, in the general area of the Project. A number of active recreational campsite leases (some containing privately-owned cabins) are located near the PDA. The closest of these recreational campsites is approximately 1.5 km to the east of the open pit location (Figure 7.7.3). There are no permanent residences located in the immediate vicinity of the Project; the closest permanent residences are located in Napadogan, a small community on Highway 107, approximately 9 km to the northeast of the Project site (Figure 7.7.3).

An Indigenous Knowledge Study (Moccasin Flower Consulting 2013) (IKS) was conducted by the St. Mary's First Nation (SMFN), Woodstock First Nation (WFN), and Madawaska Maliseet First Nation (MMFN). The IKS identified a number of plant and animal species of importance to First Nations in the general area of the Project, including berries, nuts (*e.g.,* butternuts, hazelnuts), fiddleheads, moose and deer, muskrat, beaver, rabbit, grouse, and fish including Atlantic salmon. The IKS also provided information on specific areas of traditional land use (*e.g.,* areas where vegetation is collected for food and medicinal uses, drinking water springs, and fishing and hunting areas).

7.7.2.1 Contaminants of Potential Concern (COPCs)

As noted previously, sources of contaminants from Project activities include emissions of criteria air contaminants (CACs, *i.e.,* SO_2, NO_2, CO, PM, PM_{10}, and $PM_{2.5}$) from combustion sources, emissions of non-criteria air contaminants (non-CACs) from fugitive ore dust during extraction and transport, and release of treated surplus water or seepage containing trace metals into groundwater and surface water in the receiving environment. For brevity, these contaminants are referred to below as contaminants of potential concern, or COPCs. Environmental media potentially directly affected by these releases include air, soil, and surface water. Changes in COPC concentrations in soil and surface water may also result in changes in COPC concentrations in plants, game, and fish.

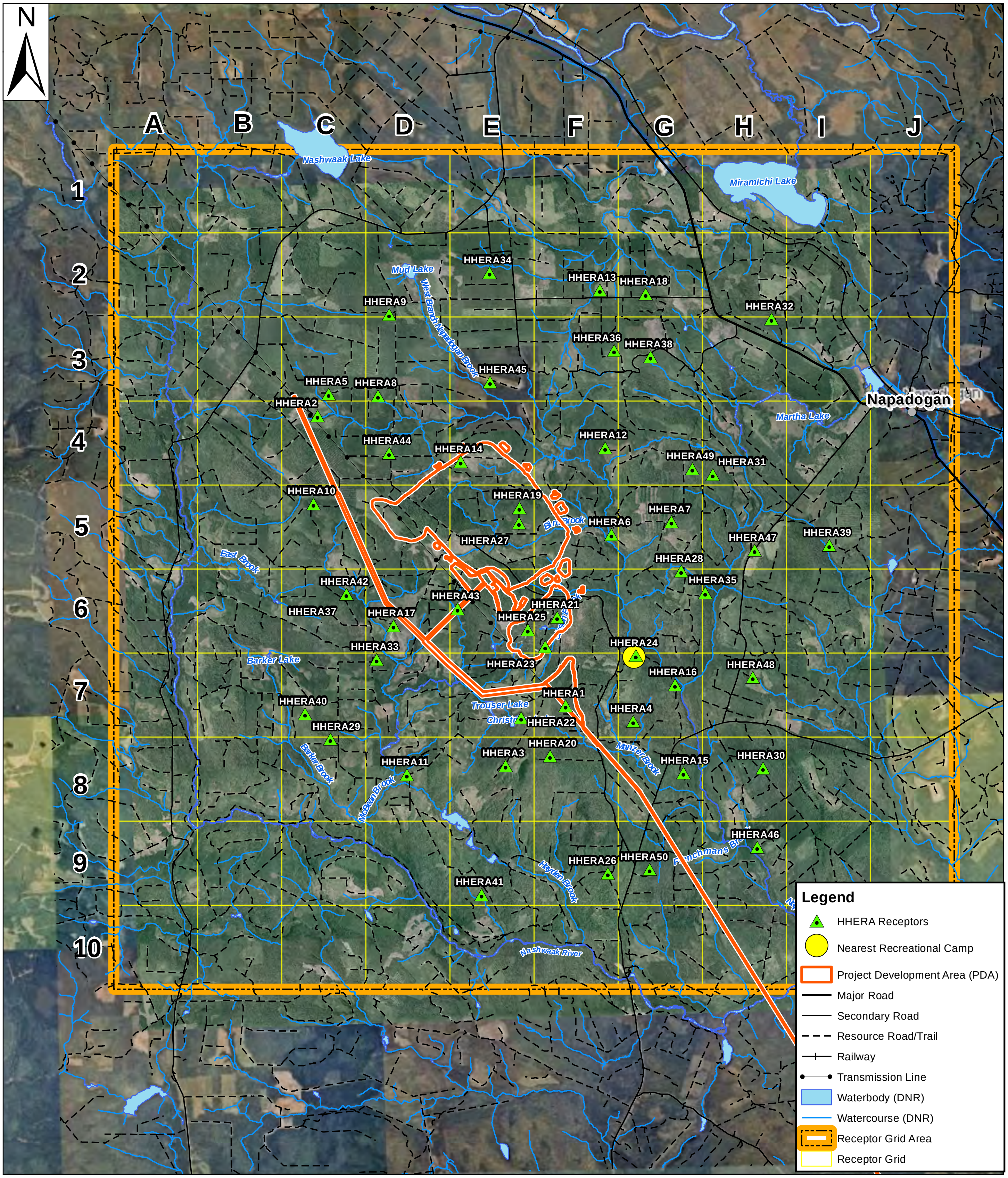
Exposure point concentration (EPC) values are concentrations of COPCs in relevant environmental media that are selected to represent the conditions to which human and ecological receptors may be exposed.

7.7.2.1.1 COPC Identification

A multi-step screening process was used to identify the COPCs for the HHERA. For air, the CACs identified in Section 7.1 (*i.e.,* SO_2, NO_2, CO, PM, PM_{10}, and $PM_{2.5}$) were carried forward as COPCs in the HHERA.

For terrestrial and aquatic environments, the trace metals contained in the ore (shown in Table 3.4.33) were identified as possible COPCs; however, a screening process was applied to select which of these metals should be carried forward as COPCs. For terrestrial (soil related) exposures, the screening considered: whether the contaminant was already present in the environment at concentrations above guidelines, the toxic potential of the metal constituents in the ore dust, and the potential for levels of metals in dust to be lower than the existing soil conditions.

For aquatic (surface water related) exposures, the selection of COPCs considered the model-predicted concentrations of various trace metals in surface water associated with Operation and Decommissioning, Reclamation and Closure phases (Section 7.6) screened against drinking water guidelines and guidelines for the protection of freshwater aquatic life.



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC PROJECT AND SHOULD NOT BE USED FOR OTHER PURPOSES.

Receptor Grid for HHERA Sisson Project: Environmental Impact Assessment (EIA) Report, Napadogan, N.B.	Scale: NTS 0 0.5 1 1.5 Kilometres	Project No.: 121810356	Data Sources: NBDNR, SNB Imagery Provided By: NBDNR	Fig. No.: 7.7.3	Stantec
	Date: (dd/mm/yyyy) 12/07/2013	Dwn. By: JAB Appd. By: DLM			
Client: Sisson Mines Ltd.					

7.7.2.1.2 COPC Screening Based on Soil Quality Guidelines

For soil, if existing concentrations of a contaminant in soil (as measured in the baseline sampling program, Stantec 2012h) were higher than existing regulatory guidelines, the contaminant was carried forward as a COPC, for further evaluation. The measured baseline soil data obtained as part of the baseline sampling program (Stantec 2012h) were compared to applicable environmental quality standards or guidelines for soil. The soil data were sufficient to determine a 95 percent upper confidence limit of the mean (95 percent UCLM). The use of a 95 percent UCLM for comparing site concentrations to clean-up standards or establishing background levels is recommended by the USEPA (2002). Where the 95 percent UCLM soil concentrations exceeded the screening level guidelines, the contaminant was carried forward as a COPC. The 95 percent UCLM of arsenic, manganese, and selenium in measured soil data were higher than the applicable human health and ecological screening guideline values found in:

- Canadian Council of Ministers of the Environment (CCME) "Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health 1999, updated 2011" (CCME 1999);
- Ontario Ministry of the Environment (OMOE) "Table 3 Site Condition Standards of Soil, Groundwater and Sediment Standards for Use Under Part XV.1 of the *Environment Protection Act*, 2009" (OMOE 2009); and
- United States Environmental Protection Agency (USEPA) "Ecological Soil Screening Levels, 2007" (USEPA 2007).

7.7.2.1.3 COPC Screening Based on Relative Toxic Potential of Ore

Following the initial identification of potential COPCs described above, the total metal concentration of each COPC was then assessed based on the relative toxic potential (RTP) to human health, mammals, birds, and plant and soil invertebrates (Alberta Health and Wellness 2011). To evaluate the potential for ore dust to affect environmental quality through air dispersion and subsequent deposition onto soil, the RTP was calculated by dividing the concentration of each metal in the ore (as shown in Table 3.4.31), by the appropriate toxicity reference value (TRV, mg/kg body weight-day for oral ingestion for humans, mammals and birds; mg/kg for direct contact for plants and soil invertebrates). Consistent with USEPA (1989) guidance, parameters accounting for more than one percent of the RTP were selected as COPCs that would be further evaluated in the HHERA.

Parameters accounting for more than one percent of the relative toxic potential included: aluminum, arsenic, boron, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, thallium, titanium, uranium, vanadium, and zinc; these COPCs were carried forward in the HHERA. Very limited toxicological data are available for a number of metals (*e.g.*, bismuth, calcium, iron, magnesium, potassium, rubidium, sodium, sulphur, and titanium), and thus these metals were omitted from the HHERA. Although the soil and tap water guidelines for lithium from the USEPA Regional Screening Tables were developed using a provisional peer reviewed toxicity value (PPRTV) developed for a Superfund site, the PPRTV number provides very little information about the adverse environmental effects of a contaminant, or the quality of evidence on which the toxicity assessment was based (USEPA 2012). A literature review (Aral and Vecchio-Sadus 2008) has indicated that lithium is not expected to bioaccumulate and its human and environmental toxicity are low. Based on the results of the literature review, it was concluded that neither lithium intake from food and water nor from occupational exposure presents a toxicological hazard (Aral and Vecchio-Sadus 2008).. As none of the Health Canada (2010a) recommended resources have developed a toxicological reference value for lithium, and given the findings of the published literature review, lithium was not carried forward as a COPC.

A third step, consisting of comparison of concentrations of metals in the ore to the background soil concentrations (based on the median of soil sample results), was completed. Parameters for which ore concentrations were less than or equal to the background soil concentrations were not carried forward for further analysis, since ore deposition would not increase the existing background soil total metal concentrations. This sub-set includes selenium.

7.7.2.1.4 COPC Screening Based on Water Quality Guidelines

Existing (measured) and predicted future metal concentrations in surface water were screened by comparison to provincial and federal guidelines for the protection of aquatic life, and for drinking water, as found in:

- CCME Water Quality Guidelines for the Protection of Aquatic Life (Freshwater) (CCME 1999 and updates);
- British Columbia approved water quality guidelines (BC Ministry of Environment 2010b); and
- Health Canada "Guidelines for Canadian Drinking Water Quality" (GCDWQ; Health Canada 2012b).

7.7.2.1.5 Summary of COPC Screening

The non-CAC COPC selection process therefore includes screening of trace elements in a series of steps (Table 7.7.1), as follows.

- In Step 1, it is determined whether measured concentrations in soil exceed guidelines.
- In Step 2, the toxic potential of trace elements in the ore for human and ecological receptors is considered.
- In Step 3, trace element concentrations in the ore are higher than local soil background values is confirmed.
- In Step 4, water is screened against guidelines for drinking water and aquatic life. Elements that are flagged as COPCs in this step get added to the list derived by screening soils.

In addition, mercury was added to the list of COPCs as being inherently of interest. Also, sodium was screened out as it was flagged by aesthetic objectives for drinking water quality, not by health-based guidelines.

Table 7.7.1 Summary of Non-CAC Contaminant of Potential Concern Screening

Parameter	Step 1	Step 2 - Toxic Potential by Receptor				Step 3		Step 4 - Screening Water			
	Guideline Exceedance	HH	Bird	Small Animal Prey	Plant/Soil Invertebrates	Is ore concentration higher than background?	List of Soil-based COPCs	Drinking Water Guideline Screening	Freshwater Aquatic Life Screening	Final List of HHRA COPCs	Final List of ERA COPCs
Aluminum		X		X			Aluminum			Aluminum	Aluminum
Antimony											
Arsenic	X	X		X	X		Arsenic			Arsenic	Arsenic
Barium											
Bismuth											
Boron					X		Boron		X	Boron	Boron
Cadmium											
Calcium											
Chromium		X	X	X			Chromium			Chromium	Chromium
Cobalt			X		X		Cobalt			Cobalt	Cobalt
Copper			X	X	X		Copper			Copper	Copper
Iron											
Lead		X					Lead			Lead	Lead
Lithium											
Magnesium											
Manganese	X	X		X	X		Manganese			Manganese	Manganese
Mercury						no				Mercury (IOI)	Mercury (IOI)
Molybdenum		X	X	X	X		Molybdenum			Molybdenum	Molybdenum
Nickel				X			Nickel			Nickel	Nickel
Phosphorus											
Potassium											
Rubidium											
Selenium	X					no					
Silver											
Sodium								X			
Strontium											
Sulphur											
Thallium		X			X		Thallium	X	X	Thallium	Thallium

Table 7.7.1 Summary of Non-CAC Contaminant of Potential Concern Screening

Parameter	Step 1	Step 2 - Toxic Potential by Receptor				Step 3		Step 4 - Screening Water			
	Guideline Exceedance	HH	Bird	Small Animal Prey	Plant/Soil Invertebrates	Is ore concentration higher than background?	List of Soil-based COPCs	Drinking Water Guideline Screening	Freshwater Aquatic Life Screening	Final List of HHRA COPCs	Final List of ERA COPCs
Titanium					X		Titanium			Not measured in baseline and will thus only be assessed for plants exposed to soil dusted for 27 years; baseline soil is assumed to have zero concentration.	
Tungsten	X						Tungsten		X	Tungsten	Tungsten
Uranium		X			X		Uranium		X	Uranium	Uranium
Vanadium		X	X	X	X		Vanadium	X	X	Vanadium	Vanadium
Zinc					X		Zinc			Zinc	Zinc

Notes:
Iron and manganese are omitted from the COPC list since their guideline is based on aesthetic objectives and not health effects.

Legend:
IOI Inherently of Interest
HH Human Health
COPC contaminant of potential concern
HHRA Human Health Risk Assessment
ERA Ecological Risk Assessment

The final list of non-CAC COPCs for the HHRA and ERA includes (Table 7.7.1):

- Aluminum (Al);
- Arsenic (As);
- Boron (B);
- Chromium (Cr);
- Cobalt(Co);
- Copper
- Lead (Pb);
- Manganese (Mn);
- Mercury (Hg);
- Molybdenum (Mo);
- Nickel (Ni);
- Thallium (Tl);
- Tungsten (W);
- Uranium (U);
- Vanadium (V); and
- Zinc (Zn).

In addition, CACs (*i.e.,* SO_2, NO_2, CO, PM, PM_{10}, and $PM_{2.5}$) were carried forward as COPCs for the HHRA.

7.7.2.2 Existing and Predicted Future Contaminant Concentrations in the Environment

In order to evaluate the potential health risks associated with COPCs from the Project, the HHERA relied on the results of the predictive air dispersion and deposition modelling (Section 7.1) and the predictive water quality modelling (Section 7.6). These predictive models provide estimates of COPCs in air and surface water under future conditions (*i.e*., Project + Baseline Case). Future COPC concentrations in vegetation, soil invertebrates, and small mammals were estimated based upon future (*i.e*., Project + Baseline Case) soil concentrations as predicted by the air dispersion and deposition modelling. Future COPC concentrations for fish, benthic invertebrates, and sediment were estimated using predicted future (*i.e*., Project + Baseline Case) COPC concentrations in surface water as predicted by the predictive water quality modelling.

The equation used to calculate a COPC concentration in a biological tissue from a soil or water concentration (hereinafter referred to as the "generalized equation") is as follows:

$$EPC_j = EPC_i \times UP_{ij}$$

where:

EPC_j = Exposure point concentration in target biotic tissue *j* (*e.g*., plants or fish, mg/kg wet weight);

EPC_i = Exposure point concentration in measured media *i* (*e.g*., soil and surface water, in mg/kg dry weight or in mg/L); and

UP_{ij} = Uptake Factor from environmental medium *i* to target biota tissue *j* (environmental medium and biotic tissue dependent).

However, another important aspect of the HHERA is to assess the risk from the Project in the context of existing or background exposures. Given the importance of existing concentrations to both the prediction of future concentrations and for providing context for the health risk estimates, both the existing contaminant concentrations in the environment (*i.e.*, the concentrations that are present currently, prior to any Project activities) are presented along with the predicted future (*i.e.*, Project + Baseline) contaminant concentrations.

Where measured baseline data were available for biological tissues, these values are considered to be more reliable than a model-estimated value would be. However, for Project + Baseline Case predictions, it is always necessary to rely upon model-estimated values. In order to reconcile measured and model-estimated values, the following approach was taken.

The expected magnitude of change introduced by the project was estimated by calculating both Baseline Case and Project + Baseline Case predictions for metal concentrations in biological tissues. The ratio of the two predictions (*i.e.*, (predicted Project + Baseline Case) / (predicted Baseline Case)) was calculated to provide an estimate of the expected magnitude of change to be introduced as a result of the Project going forward. The measured baseline tissue concentrations were then multiplied by this ratio in order to estimate the expected future concentration in tissues.

As a more concrete example of this approach, the 95 percent UCLM value for arsenic in brook trout fillet that would be consumed by humans was measured and found to be 0.89 mg/kg wet weight for the fish carcass in West Branch Napadogan Brook for the Baseline Case. Williams *et al.* (2006) provided a review of arsenic bioaccumulation by a variety of fish species, and gave an equation relating the bioaccumulation factor for arsenic in fish tissue to the arsenic concentration in water. Using the equation of Williams *et al.* (2006), the expected ratio of Project + Baseline Case to Baseline Case arsenic concentrations in fish tissue was estimated using measured and predicted future case arsenic concentrations in the water for each of the assessment locations on West Branch Napadogan Brook and McBean Brook. The baseline fish tissue arsenic concentration was then multiplied by these site-specific ratio values to estimate future fish tissue arsenic concentrations.

The same process was applied, using appropriate bioaccumulation models or uptake factors for each of the COPCs, and for each of the biological tissue types used as a potential food source by humans or ecological receptors (*i.e.*, fish tissue, benthic invertebrates, plant tissues, soil invertebrates, animal prey tissues, *etc.*), to predict Project + Baseline Case tissue metal concentrations where measured baseline data were available. In the absence of measured baseline tissue data, then both Baseline Case and Project + Baseline Case tissue metal concentrations were simply predicted from measured or expected metal concentrations in water, soil or sediment, using published uptake factors or bioaccumulation models.

HHERA receptor locations were established within 2 km x 2 km grids within the larger 20 km x 20 km HHERA Study Area, in order to assess potential exposures within each grid square. These HHERA locations generally correspond to the baseline soil sample locations (Stantec 2012h), of which ten represented biota sampling locations where vegetation, soil invertebrates, and small game samples were also collected. These locations were selected to provide appropriate coverage of the HHERA Study Area, thereby incorporating the expected locations of sensitive human and ecological receptors into the assessment. In the event that multiple samples (or HHERA receptor locations) were collected within the same grid, the maximum value was carried forward for assessment. Figure 7.7.3 shows the HHERA receptor locations and grid squares considered in the assessment.

Additional details regarding the COPC concentrations used in the HHERA are provided below.

7.7.2.2.1 Air

Air COPCs are detailed in Section 7.1 and Section 8.2, and include the following CACs: particulate matter (PM) (including $PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). Non-CAC concentrations in air were also assessed.

To characterize baseline concentrations of COPCs in ambient air, as discussed in Section 8.2.2, Northcliff conducted an ambient air quality monitoring program at the Project site over a six month period to cover three seasons (summer, fall and winter). The monitoring was carried out from August 2011 to February 2012, at a site in Napadogan that was selected because it is the nearest residential area to the Project. Additional air quality data collected by the Province of New Brunswick was used to further describe the ambient air quality generally found in central New Brunswick

Particulate matter (dustfall) concentrations in air were measured at Napadogan as part of the ambient air quality monitoring. The average particulate matter concentration measured was 17.0 $\mu g/m^3$, with concentrations ranging from a low of 7.1 $\mu g/m^3$ in February 2012 to a high of 35.3 $\mu g/m^3$ in August 2011. These levels were assumed to represent existing conditions for the Baseline Case.

Predicted CAC concentrations for the Project + Baseline Case were provided in Table 7.1.8. Note that these CAC concentrations represent the maximum overall ground-level concentrations (GLCs) during Operation. As indicated in Section 8.2, maximum GLCs of CAC during Construction were lower than those during Operation, and emissions of CAC during Decommissioning, Reclamation and Closure are expected to be similar to or less than those during Construction.

Maximum metals concentrations in air were determined using the results of chemical analysis of the ore and the air dispersion model results for PM_{10} emitted during Project activities that are associated with the ore dust generation. Details of how the concentrations of metals from the ore samples (provided in Table 3.4.31) were determined, and how dust emissions from ore and overburden were estimated, are provided in Section 3.4.1.5 (Construction) and 3.4.2.5 (Operation). A summary of the air deposition modelling is provided in Section 7.1. The resulting maximum predicted GLCs of metals from air dispersion during Operation are provided in Tables 7.7.2 to 7.7.4.

Table 7.7.2 Maximum 1-hour COPC Concentrations in Ambient Air (mg/m^3)

COPC	Maximum Ground-level 1-h Air Exposure Point Concentrations (EPCs) (mg/m³)	
	Baseline Case	Project + Baseline Case
Aluminum (Al)	7.00E-04	1.13E-01
Arsenic (As)	5.99E-06	2.72E-04
Boron (B)	6.08E-06	6.37E-06
Chromium (Cr)	2.52E-06	4.44E-04
Cobalt (Co)	2.00E-06	8.18E-05
Copper (Cu)	6.57E-04	1.19E-03
Lead (Pb)	6.62E-06	2.98E-04
Manganese (Mn)	2.56E-05	8.63E-03
Mercury (Hg)	1.95E-08	2.53E-07
Molybdenum (Mo)	3.04E-06	9.74E-05
Nickel (Ni)	2.99E-06	1.33E-04
Thallium (Tl)	1.01E-05	6.11E-06
Tungsten (W)	3.67E-06	1.72E-04

Table 7.7.2 Maximum 1-hour COPC Concentrations in Ambient Air (mg/m^3)

COPC	Maximum Ground-level 1-h Air Exposure Point Concentrations (EPCs) (mg/m^3)	
	Baseline Case	Project + Baseline Case
Uranium (U)	6.46E-05	1.76E-05
Vanadium (V)	2.01E-06	5.04E-04
Zinc (Zn)	5.72E-05	9.94E-04

Table 7.7.3 Maximum 24-hour COPC Concentrations in Ambient Air (mg/m^3)

COPC	Maximum Ground-level 24-h Air Exposure Point Concentrations (EPCs) (mg/m^3)	
	Baseline Case	Project + Baseline Case
Aluminum (Al)	2.88E-04	4.75E-03
Arsenic (As)	2.46E-06	1.14E-05
Boron (B)	2.50E-06	1.29E-06
Chromium (Cr)	1.03E-06	1.86E-05
Cobalt (Co)	8.20E-07	3.43E-06
Copper (Cu)	2.70E-04	5.00E-05
Lead (Pb)	2.72E-06	1.25E-05
Manganese (Mn)	1.05E-05	3.61E-04
Mercury (Hg)	8.01E-09	6.24E-08
Molybdenum (Mo)	1.25E-06	1.97E-05
Nickel (Ni)	1.23E-06	5.55E-06
Thallium (Tl)	4.16E-06	2.56E-07
Tungsten (W)	1.51E-06	3.48E-05
Uranium (W)	2.65E-05	7.39E-07
Vanadium (V)	8.27E-07	2.11E-05
Zinc (Zn)	2.35E-05	4.17E-05

Table 7.7.4 Maximum Annual Average COPC Concentrations in Ambient Air (mg/m^3)

COPC	Annual Average Air Exposure Point Concentrations (EPC) at Grid G8 (mg/m^3)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	1.64E-04	1.51E-04	3.16E-04
Arsenic (As)	2.16E-06	3.51E-07	2.51E-06
Boron (B)	2.47E-06	1.59E-07	2.63E-06
Chromium (Cr)	8.13E-07	5.66E-07	1.38E-06
Cobalt (Co)	7.19E-07	1.08E-07	8.27E-07
Copper (Cu)	1.93E-04	1.55E-06	1.94E-04
Lead (Pb)	1.75E-06	3.83E-07	2.13E-06
Manganese (Mn)	6.53E-06	6.78E-06	1.33E-05
Mercury (Hg)	6.95E-09	5.87E-09	1.28E-08
Molybdenum (Mo)	1.24E-06	2.40E-06	3.64E-06
Nickel (Ni)	1.10E-06	1.68E-07	1.27E-06
Thallium (Tl)	4.12E-06	8.12E-09	4.13E-06
Tungsten (W)	1.45E-06	4.25E-06	5.70E-06
Uranium (U)	2.28E-05	2.33E-08	2.28E-05
Vanadium (V)	7.59E-07	6.69E-07	1.43E-06
Zinc (Zn)	1.52E-05	1.27E-06	1.65E-05

7.7.2.2.2 Soil

As reported in Stantec (2012h), soil samples were collected from the HHERA receptor locations identified in Figure 7.7.3. To predict the future soil concentrations (*i.e.*, Project + Baseline Case), the mass loading associated with deposition of ore dust during Operation as predicted by the air deposition modelling was added to the measured existing metal concentrations in soil at each of the HHERA receptor locations. During the Construction and Decommissioning, Reclamation and Closure phases, the mine would not be producing, processing, or handling ore, and hence there would not be atmospheric deposition of ore dust.

Ore dust deposition rates were obtained on a site-specific basis as annual average values from the air dispersion and deposition model (Section 7.1). To estimate the deposition of ore dust on soil concentration, it was assumed that 100 percent of the deposited ore dust and associated COPCs are incorporated into the surface layer of soil (*i.e.,* the top 10 cm) within the HHERA receptor grid. For example, for the soil concentrations at grid location G8 (see Figure 7.7.3), the concentrations in soil for the Baseline Case are the measured concentrations in the soil sample from location HHERA15, the Project Alone Case concentrations are based on the results of deposition modelling for HHERA15, and the Project + Baseline Case is the sum of the measured soil concentration and the modelled deposition. As an example, the results for Grid G8 are shown in Table 7.7.5, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.5 Concentrations in Soil at HHERA Grid G8 (mg/kg dry weight)

COPC	Soil Exposure Point Concentrations (EPC) at Grid G8 (mg/kg dry weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	6.24E+03	1.24E-04	6.24E+03
Arsenic (As)	1.00E+01	3.34E-07	1.00E+01
Boron (B)	2.00E+00	7.36E-08	2.00E+00
Chromium (Cr)	7.00E+00	5.37E-07	7.00E+00
Cobalt (Co)	1.10E+00	9.04E-08	1.10E+00
Copper (Cu)	5.00E+00	1.45E-06	5.00E+00
Lead (Pb)	1.16E+01	3.73E-07	1.16E+01
Manganese (Mn)	4.80E+01	1.32E-05	4.80E+01
Mercury (Hg)	6.00E-02	5.20E-09	6.00E-02
Molybdenum (M0)	2.00E-01	1.11E-06	2.00E-01
Nickel (Ni)	3.00E+00	1.63E-07	3.00E+00
Thallium (Tl)	5.00E-02	6.70E-09	5.00E-02
Tungsten (W)	2.00E-01	1.96E-06	2.00E-01
Uranium (U)	5.00E-01	1.93E-08	5.00E-01
Vanadium (V)	3.20E+01	5.53E-07	3.20E+01
Zinc (Zn)	1.40E+01	1.20E-06	1.40E+01

7.7.2.2.3 Surface Water

For the HHERA, exposure to surface water for the existing (Baseline Case) conditions was based on annual average metal concentrations in surface water samples from the Napadogan River watershed collected between the June 2007 and April 2012 (Section 8.4 and Knight Piésold 2012e). Samples were variously collected by Rescan between 2007 and 2008 and by Northcliff between 2009 and 2012.

Water quality modelling (Section 7.6) was used to predict surface water quality during the Construction, Operation, and Decommissioning, Reclamation and Closure phases at seven locations along Napadogan Brook (NAP1, NAP2, NAP3, NAP5, NAP7, and NAP8), and one location along McBean Brook (MBB2), as shown in Figure 7.6.2. The modelling also predicted surface water quality at locations in three unnamed tributaries to Napadogan Brook (UT1, UT3, and UT4), though with reduced levels of confidence. For the purposes of establishing surface water concentrations for the Project + Baseline Case to be used in the HHERA, the maximum annual average COPC concentration during any of the phases was selected for the Project + Baseline Case, and thus represents a conservative estimate of water quality in consideration of all Project phases and activities. Project Alone concentrations were estimated as the Project + Baseline Case concentration minus the Baseline Case concentration.

For those HHERA receptor grids that contained one of the above-noted watercourses, the results of surface water quality monitoring and water quality modelling that best represented that particular reach of watercourse was applied to the grid. For example, for Grid G8 (see Figure 7.7.3), the results at NAP5 best represents the Napadogan Brook in this area. As an example, the water quality data for Baseline, Project Alone, and Project + Baseline Cases for Grid G8 are provided in Table 7.7.6, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3. Note that if a grid square did not contain a watercourse, no surface water (or fish) exposures were assigned to that grid location.

Table 7.7.6 Concentrations in Surface Water at HHERA Grid G8 (mg/L)

COPC	Surface Water Exposure Point Concentrations (EPC) at Grid G8 (mg/L)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	1.34E-01	1.39E-01	2.73E-01
Arsenic (As)	6.90E-04	3.86E-03	4.55E-03
Boron (B)	1.69E-03	2.15E-01	2.16E-01
Chromium (Cr)	5.42E-04	5.17E-04	1.06E-03
Cobalt (Co)	6.02E-05	1.26E-03	1.32E-03
Copper (Cu)	5.00E-04	1.40E-03	1.90E-03
Lead (Pb)	1.30E-04	1.67E-04	2.97E-04
Manganese (Mn)	8.64E-03	3.22E-02	4.08E-02
Mercury (Hg)	1.31E-05	3.88E-07	1.35E-05
Molybdenum (Mo)	2.08E-04	1.40E-02	1.43E-02
Nickel (Ni)	5.00E-04	1.99E-03	2.49E-03
Thallium (Tl)	5.00E-05	1.63E-04	2.13E-04
Tungsten (W)	2.19E-03	1.79E-02	2.01E-02
Uranium (U)	1.96E-04	1.91E-03	2.10E-03
Vanadium (V)	6.37E-04	1.20E-02	1.27E-02
Zinc (Zn)	1.56E-03	1.11E-02	1.26E-02

7.7.2.2.4 Groundwater

Human and ecological receptors are not expected to be directly exposed to potential increases in the identified COPCs in groundwater. Several recreational campsites (some including cabins) are believed to collect water flowing from springs (this will be confirmed prior to Construction); these springs were also identified as drinking water sources by First Nations. As shown on Figure 8.4.11, the recreational campsites are located no closer than 1.5 km from the eastern edge open pit, and any springs or wells that might be present at the camps are not expected to be affected by pit dewatering (see Section 8.4). The closest known well users identified through NBDELG are in the community of Napadogan, more than 9 km from the Project, and would not be affected by seepage from the Project (Section 8.4). Although a series of groundwater wells will be installed to supply fresh water during Operation, they will be sited to avoid migration of potential contaminants from the TSF to the well (Section 8.4). As result, further assessment of groundwater is not considered in the HHERA.

7.7.2.2.5 Vegetation

Because metals are ubiquitous in the environment, a determination of existing concentrations of metals in vegetation is required to evaluate current exposures to COPC in vegetation. As described in Stantec (2012h), a total of 16 vegetation samples, including shrubs (8 samples, referred to below as "browse") and grasses (8 samples, referred to below as "forage"), and 9 wild berry samples (referred to below as "berries") were collected from key sampling locations shown on Figure 7.7.3. These data were used to estimate 95 percent UCLM for leafy vegetation and berries, which were then used as exposure concentrations for ingestion of vegetation for the Baseline Case (*i.e.*, prior to Project activities).

Concentrations of COPCs in plant tissues for the future Project + Baseline Case were estimated based upon the predicted concentrations of COPCs in soil for Project + Baseline Case, using the generalized equation relating elemental concentrations in vegetation to soil concentrations, and using published uptake factors (Baes *et al*. 1984; Bechtel Jacobs 1998; Bechtel Jacobs 1998 in USEPA 2007; CSA 1987; Davis *et al*. 1993; EcoMatters *et al*. 2004; Garn *et al*. 2001; Hamilton *et al*. 2002; Haus *et al.* 2007; Holdway *et al.* 1983; IAEA 1994; Koutsospyros *et al.* 2006; Lijzen *et al.* 2001; McGeer *et al.* 2003; ORNL 1998; Sample *et al.* 1998a; Sample *et al.* 1998b; Sheppard and Evenden 1988; Sheppard and Evenden 1990; Sheppard *et al.* 2010; Strigul *et al.* 2010; Torres and Johnson 2001; USEPA 2007; Williams *et al.* 2006; Zach *et al.* 1998). Project Alone Case concentrations in vegetation were estimated as the difference between the Project + Baseline Case concentrations and the Baseline Case concentrations. As an example, the COPC concentrations in browse, forage, and berries for Grid G8 are provided in Tables 7.7.7 to 7.7.9, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.7 Concentrations in Browse at HHERA Grid G8 (mg/kg wet weight)

COPC	Browse Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	2.43E+01	4.83E-07	2.43E+01
Arsenic (As)	3.71E-02	1.24E-09	3.71E-02
Boron (B)	1.14E+01	4.19E-07	1.14E+01
Chromium (Cr)	8.88E-02	6.81E-09	8.88E-02
Cobalt (Co)	2.24E+00	1.84E-07	2.24E+00
Copper (CU)	3.71E+00	4.24E-07	3.71E+00
Lead (Pb)	2.18E-01	3.93E-09	2.18E-01
Manganese (Mn)	9.63E+02	2.64E-04	9.63E+02
Mercury (Hg)	2.35E-02	1.11E-09	2.35E-02
Molybdenum (Mo)	5.01E-02	2.78E-07	5.01E-02
Nickel (Ni)	2.23E+00	9.06E-08	2.23E+00
Thallium (Tl)	6.25E-03	8.37E-10	6.25E-03
Tungsten (W)	1.48E-01	5.47E-07	1.48E-01

Table 7.7.7 Concentrations in Browse at HHERA Grid G8 (mg/kg wet weight)

COPC	Browse Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Uranium (U)	2.00E-03	2.87E-11	2.00E-03
Vanadium (V)	7.00E-02	1.21E-09	7.00E-02
Zinc (Zn)	1.76E+02	8.37E-06	1.76E+02

Table 7.7.8 Concentrations in Forage at HHERA Grid G8 (mg/kg wet weight)

COPC	Forage Exposure Point Concentrations at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	5.24E+01	1.04E-06	5.24E+01
Arsenic (As)	5.13E-02	1.71E-09	5.13E-02
Boron (B)	1.81E+00	6.65E-08	1.81E+00
Chromium (Cr)	3.10E-01	2.38E-08	3.10E-01
Cobalt (Co)	1.27E-01	1.04E-08	1.27E-01
Copper (Cu)	3.33E+00	3.80E-07	3.33E+00
Lead (Pb)	6.61E-01	1.19E-08	6.61E-01
Manganese (Mn)	6.56E+02	1.80E-04	6.56E+02
Mercury (Hg)	2.72E-02	1.28E-09	2.72E-02
Molybdenum (Mo)	5.79E-01	3.21E-06	5.79E-01
Nickel (Ni)	6.09E-01	2.48E-08	6.09E-01
Thallium (Tl)	8.50E-03	1.14E-09	8.50E-03
Tungsten (W)	5.50E-02	2.03E-07	5.50E-02
Uranium (U)	4.00E-03	5.74E-11	4.00E-03
Vanadium (V)	1.35E-01	2.33E-09	1.35E-01
Zinc (Zn)	2.17E+01	1.03E-06	2.17E+01

Table 7.7.9 Concentrations in Berries at HHERA Grid G8 (mg/kg wet weight)

COPC	Berries Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	3.50E+01	6.96E-07	3.50E+01
Arsenic (As)	6.00E-03	2.00E-10	6.00E-03
Boron (B)	1.76E+00	6.49E-08	1.76E+00
Chromium (Cr)	6.55E-02	5.03E-09	6.55E-02
Cobalt (Co)	1.35E-02	1.11E-09	1.35E-02
Copper (Cu)	7.66E-01	8.75E-08	7.66E-01
Lead (Pb)	7.90E-02	1.42E-09	7.90E-02
Manganese (Mn)	1.70E+02	4.66E-05	1.70E+02
Mercury (Hg)	5.00E-03	2.36E-10	5.00E-03
Molybdenum (Mo)	5.00E-02	2.77E-07	5.00E-02
Nickel (Ni)	2.27E-01	9.24E-09	2.27E-01
Thallium (Tl)	4.00E-03	5.36E-10	4.00E-03
Tungsten (W)	5.00E-03	1.85E-08	5.00E-03
Uranium (U)	2.00E-03	2.87E-11	2.00E-03
Vanadium (V)	1.10E-01	1.90E-09	1.10E-01
Zinc (Zn)	5.84E+00	2.77E-07	5.84E+00

7.7.2.2.6 Soil Invertebrates

Soil invertebrates represent an important food source for many small mammals and birds. Because soil invertebrates accumulate COPCs from their environment, a determination of existing concentrations of metals in soil invertebrates is important to the evaluation of health risks to wildlife. As reported in Stantec (2012h), concentrations of metals in soil invertebrate tissues were analysed in nine samples (*i.e.,* seven slug samples and two earth worm samples) collected from selected HHERA receptor locations shown on Figure 7.7.3. The soil invertebrate concentration for the Baseline Case is an average of the existing slug concentration (based on a 95 percent UCLM of the seven slug samples) and the existing worm concentrations (based on an average of the two earthworm samples). These concentrations were then used as representative exposure concentrations for ingestion of metals by wildlife for the Baseline Case (*i.e.*, prior to Project activities).

Concentrations of COPCs in soil invertebrates for the Project + Baseline Case were estimated based upon the predicted concentrations of COPCs in soil for Project + Baseline Case, using the generalized equation relating elemental concentrations in biota to soil concentrations and using published uptake factors (Baes *et al*. 1984; Bechtel Jacobs 1998; Bechtel Jacobs 1998 in USEPA 2007; CSA 1987; Davis *et al*. 1993; EcoMatters *et al*. 2004; Garn *et al*. 2001; Hamilton *et al*. 2002; Haus *et al.* 2007; Holdway *et al.* 1983; IAEA 1994; Koutsospyros *et al.* 2006; Lijzen *et al.* 2001; McGeer *et al.* 2003; ORNL 1998; Sample *et al.* 1998a; Sample *et al.* 1998b; Sheppard and Evenden 1988; Sheppard and Evenden 1990; Sheppard *et al.* 2010; Strigul *et al.* 2010; Torres and Johnson 2001; USEPA 2007; Williams *et al.* 2006; Zach *et al.* 1998). Project Alone Case concentrations in soil invertebrates were estimated as the difference between the Project + Baseline Case concentrations and the Baseline Case concentrations. As an example, the COPC concentrations in soil invertebrates for Grid G8 are provided in Table 7.7.10, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.10 Concentrations in Soil Invertebrates at HHERA Grid G8 (mg/kg wet weight)

COPC	Terrestrial Invertebrates Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	2.22E+02	4.41E-06	2.22E+02
Arsenic (As)	1.22E+00	2.87E-08	1.22E+00
Boron (B)	1.75E+00	6.45E-08	1.75E+00
Chromium (Cr)	4.28E-01	3.28E-08	4.28E-01
Cobalt (Co)	7.93E-01	6.52E-08	7.93E-01
Copper (Cu)	7.68E+00	5.87E-07	7.68E+00
Lead (Pb)	6.14E+00	1.59E-07	6.14E+00
Manganese (Mn)	1.71E+03	4.69E-04	1.71E+03
Mercury (Hg)	7.51E-02	6.50E-09	7.51E-02
Molybdenum (Mo)	1.85E-01	1.03E-06	1.85E-01
Nickel (Ni)	3.93E-01	2.14E-08	3.93E-01
Thallium (Tl)	3.24E-02	4.33E-09	3.24E-02
Tungsten (W)	2.30E-02	2.26E-07	2.30E-02
Uranium (U)	2.85E-02	1.10E-09	2.85E-02
Vanadium (V)	5.48E-01	9.46E-09	5.48E-01
Zinc (Zn)	1.45E+02	4.06E-06	1.45E+02

7.7.2.2.7 Small Mammals

Small mammals are consumed as prey by other wildlife receptors. As reported in Stantec (2012h), a total of 30 small mammal samples were collected at selected HHERA receptor locations (Figure 7.7.3). These data were used to estimate 95 percent UCLM, considered to represent existing concentrations of metals in small mammals prior to any Project activities, which were then used as the Baseline Case exposure concentrations for ingestion of metals in small mammals by wildlife.

Concentrations of COPCs in small mammals for the Project + Baseline Case were estimated based upon the predicted concentrations of COPCs in soil for Project + Baseline Case, using the generalized equation relating elemental concentrations in biota to soil concentrations and using published uptake factors (Baes *et al*. 1984; Bechtel Jacobs 1998; Bechtel Jacobs 1998 in USEPA 2007; Davis *et al*. 1993; EcoMatters *et al*. 2004; IAEA 1994; Koutsospyros *et al.* 2006; Sheppard and Evenden 1988; Torres and Johnson 2001; USEPA 2007; Zach *et al.* 1998). Project Alone Case concentrations in small mammals were estimated as the difference between the Project + Baseline Case concentrations and the Baseline Case concentrations. As an example, the COPC concentrations in small mammals for Grid G8 are provided in Table 7.7.11, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.11 Concentrations in Small Mammals at HHERA Grid G8 (mg/kg wet weight)

COPC	Small Animal Prey Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	8.36E+00	1.66E-07	8.36E+00
Arsenic (As)	4.90E-02	1.34E-09	4.90E-02
Boron (B)	7.24E-01	2.66E-08	7.24E-01
Chromium (Cr)	3.11E-01	2.39E-08	3.11E-01
Cobalt (Co)	3.52E-02	2.89E-09	3.52E-02
Copper (Cu)	3.82E+00	1.11E-06	3.82E+00
Lead (Pb)	1.82E-01	2.59E-09	1.82E-01
Manganese (Mn)	3.32E+01	9.10E-06	3.32E+01
Mercury (Hg)	1.88E-02	1.63E-09	1.88E-02
Molybdenum (Mo)	1.47E-01	8.15E-07	1.47E-01
Nickel (Ni)	2.11E-01	5.35E-09	2.11E-01
Thallium (Tl)	2.33E-02	3.12E-09	2.33E-02
Tungsten (W)	9.48E-03	9.30E-08	9.48E-03
Uranium (U)	1.00E-03	3.87E-11	1.00E-03
Vanadium (V)	2.43E-02	4.20E-10	2.43E-02
Zinc (Zn)	3.15E+01	1.99E-07	3.15E+01

7.7.2.2.8 Game

Consumption of wild game is considered an important pathway for human exposures, and consumption of moose was a specific concern of First Nations. As moose tissue samples were not available for analysis, concentrations of COPCs in wild game for both the Baseline and Project + Baseline cases were estimated. Wild game (*i.e.*, moose) is assumed to consume vegetation as both forage and browse, and to consume incidental COPC-affected soil as well as COPC-affected surface water. The generalized equation used to calculate moose tissue concentrations for human health consumption is as follows:

$$C_{game} = [(F_V \times Q_{V(game)} \times C_V) + (B_S \times Q_{S(game)} \times C_S) + (F_W \times Q_{W(water)} \times C_W)] \times Ba_{(game)} \times MF$$

where:

C_{game} = Concentration of COPC in wild game tissue (mg/kg wet weight);

F_V = Fraction of vegetation from site (conservatively set at 100%; unitless);

$Q_{V(game)}$ = Quantity of vegetation ingested by wild game (kg dry weight/day);

C_V = Concentration of COPC in vegetation (mg/kg dry weight);

B_S = Fraction of soil from site (conservatively set at 100%; unitless);

$Q_{S(game)}$ = Quantity of soil ingested by wild game (kg dry weight/day);

C_S = Concentration of COPC in soil (mg/kg dry weight);

F_W = Fraction of water from site (conservatively set at 100%; unitless);

$Q_{W(game)}$ = Quantity of water ingested by wild game (L/day);

C_W = Concentration of COPC in surface water (mg/L);

$B_{a(game)}$ = COPC-specific bio-transfer factor for wild game (day/kg wet weight); and

MF = Metabolic factor (set at 1.0; unitless).

Wild game are conservatively assumed to spend an entire lifetime in the vicinity of the Project, within the grid locations shown in Figure 7.7.3, and not range into other areas that would be subject to different regimes of deposition. As such, fractions of vegetation, soil and water from the site are set at 100%. It is also conservatively assumed that all COPC are 100% bioavailable to wild game and not metabolized (*i.e.*, metabolic factor of 1.0). Vegetation eaten by wild game (*i.e.*, moose) was estimated to be 2.8 kg/dry weight of vegetation per day and assumed to comprise 80% browse and 20% forage. As aquatic vegetation is not generally available in the vicinity of the Project, the vegetation diet of wild game was assumed to be made up entirely of terrestrial vegetation. Primary literature uptake factors for predicting animal tissue concentrations are available for beef. In accordance with USEPA (2005) guidance, to predict the uptake of COPC into wild game, the beef uptake factor is adjusted based on the relative lipid content of the game animal (assumed 10% fat content for the moose, in contrast to 19% for the beef as per Shultz *et al.* (1994); Stephenson (2003); and Knott *et al.* (2005)). As an example, the COPC concentrations in wild game for Grid G8 are provided in Table 7.7.12, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.12 Concentrations in Wild Game at HHERA Grid G8 (mg/kg wet weight)

COPC	Wild Game Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	2.79E+00	2.47E-03	2.80E+00
Arsenic (As)	4.55E-03	2.64E-04	4.81E-03
Boron (B)	7.43E-02	1.10E-03	7.54E-02
Chromium (Cr)	2.26E-02	1.16E-04	2.27E-02
Cobalt (Co)	6.88E-01	2.00E-04	6.88E-01
Copper (Cu)	6.87E-01	5.99E-04	6.88E-01
Lead (Pb)	2.42E-03	1.95E-06	2.42E-03
Manganese (Mn)	6.73E+00	4.04E-04	6.73E+00
Mercury (Hg)	2.43E-03	1.02E-06	2.43E-03
Molybdenum (Mo)	1.86E-02	9.90E-04	1.96E-02
Nickel (Ni)	2.19E-01	1.04E-04	2.19E-01
Thallium (Tl)	5.71E-03	7.34E-05	5.79E-03
Tungsten (W)	5.99E-02	5.54E-03	6.54E-02
Uranium (U)	2.06E-05	1.76E-06	2.24E-05
Vanadium (V)	1.45E-02	3.18E-04	1.48E-02
Zinc (Zn)	2.44E-01	1.10E-05	2.44E-01

7.7.2.2.9 Fish Tissue

Fish tissue samples were collected from brook trout greater than 9 cm in length from Sisson Brook, Bird Brook, McBean Brook, and the West Branch Napadogan Brook (see Section 8.5). Samples were collected from nine locations (two in Bird Brook, two in Sisson Brook, one in McBean Brook, and three in the West Branch Napadogan Brook). These results were used to determine 95 percent UCLMs for detected contaminants. For COPC that were not detected in the tissue samples, the EPCs were assumed to be at one half of the reported detection limit. The measured fish tissue concentrations were incorporated into the assessment as site-specific existing data for the assessment of fish ingestion exposure pathways for humans and for ecological receptors for the Baseline Case; whole fish concentrations were used for the assessment of ecological receptors, while only the concentrations in the carcass (*i.e.*, cleaned fish – head and entrails removed) were used to assess human exposures. These fish concentrations, used in the Baseline Case, represent the current or existing conditions, prior to any of the Project activities.

For each HHERA receptor grid locations, concentrations of COPCs in fish tissue for the future (Project + Baseline Case) were estimated based upon the modelled future (Project + Baseline Case) concentrations of COPCs in water for that grid location, as described in Section 7.7.2.2.3, and the generalized equation for estimating fish tissue concentrations from surface water concentrations. Uptake factors for surface water to fish were obtained from CSA (1987); Davis *et al*. (1993); Holdway *et al.* (1983); Lijzen *et al.* (2001); McGeer *et al.* (2003); Sheppard *et al.* (2010); Strigul *et al.* (2010); and Williams *et al.* (2006). Project Alone Case concentrations in fish tissues were estimated as the difference between the Project + Baseline Case concentrations and the Baseline Case concentrations. As an example, the COPC concentrations in whole fish tissues and fish carcass for Grid G8 are provided in Tables 7.7.13 and 7.7.14, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.13 Concentrations in Whole Fish Tissues at HHERA Grid G8 (mg/kg wet weight)

COPC	Fish Tissue Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	2.59E+01	2.68E+01	5.28E+01
Arsenic (As)	7.24E-01	5.04E-01	1.23E+00
Boron (B)	2.66E-02	3.38E+00	3.41E+00
Chromium (Cr)	1.09E-01	1.04E-01	2.13E-01
Cobalt (Co)	7.86E-02	1.64E+00	1.72E+00
Copper (Cu)	8.00E-01	6.02E-01	1.40E+00
Lead (Pb)	4.94E-02	1.66E-02	6.60E-02
Manganese (Mn)	7.11E+00	2.65E+01	3.36E+01
Mercury (Hg)	1.13E-01	3.36E-03	1.16E-01
Molybdenum (Mo)	1.56E-02	1.05E+00	1.07E+00
Nickel (Ni)	4.66E-02	7.15E-02	1.18E-01
Thallium (Tl)	1.68E-02	5.48E-02	7.16E-02
Tungsten (W)	7.19E-03	5.86E-02	6.57E-02
Uranium (U)	8.94E-03	8.68E-02	9.58E-02
Vanadium (V)	4.76E-02	9.01E-01	9.49E-01
Zinc (Zn)	2.58E+01	4.70E+00	3.05E+01

Table 7.7.14 Concentrations in Fish Carcass Tissues at HHERA Grid G8 (mg/kg wet weight)

COPC	Fish Carcass Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	3.16E+00	3.27E+00	6.43E+00
Arsenic (As)	8.90E-01	6.19E-01	1.51E+00
Boron (B)	2.50E-02	3.18E+00	3.20E+00
Chromium (Cr)	3.48E-02	3.32E-02	6.80E-02
Cobalt (Co)	4.01E-02	8.39E-01	8.79E-01
Copper (Cu)	4.06E-01	3.05E-01	7.11E-01
Lead (Pb)	2.40E-02	8.05E-03	3.20E-02
Manganese (Mn)	2.82E+00	1.05E+01	1.33E+01
Mercury (Hg)	1.28E-01	3.80E-03	1.32E-01
Molybdenum (Mo)	6.36E-03	4.29E-01	4.35E-01
Nickel (Ni)	2.85E-02	4.37E-02	7.22E-02
Thallium (Tl)	1.41E-02	4.60E-02	6.01E-02
Tungsten (W)	3.54E-03	2.88E-02	3.24E-02
Uranium (U)	2.95E-03	2.87E-02	3.16E-02
Vanadium (V)	2.50E-02	4.73E-01	4.98E-01
Zinc (Zn)	1.64E+01	2.99E+00	1.94E+01

7.7.2.2.10 Sediment

As part of the qualitative and quantitative baseline surveys, sediment samples were collected from Sisson Brook, Bird Brook, McBean Brook, and West Branch Napadogan Brook. Eight samples were collected from McBean Brook and eleven samples were collected from West Branch Napadogan Brook.

These results were used to determine 95 percent UCLMs for detected contaminants. For COPC that were not detected in the sediment samples, the EPCs were assumed to be at one half of the reported detection limit. These sediment concentrations, used in the Baseline Case, represent the current or existing conditions, prior to any of the Project activities.

For each HHERA receptor grid locations, concentrations of COPCs in sediment for the future (Project + Baseline Case) were estimated based upon the modelled future (Project + Baseline Case) concentrations of COPCs in water for that grid location, as described in Section 7.7.2.2.3, and the generalized equation for estimating fish tissue concentrations from surface water concentrations. Where available, uptake factors for water-to-sediment were based on concentration ratios from Sheppard *et al.* (2010) which were adjusted to consider site-specific sediment characteristics (*e.g.,* organic carbon and grain size) and provide the quantity of the available and mineralized metal content in the sediment. For the Project Alone Case, increases in sediment concentrations for the non-mineralized portion of the sediment were calculated as the product of the increases in water concentrations and the adjusted site-specific concentration ratios. For the Project + Baseline Case, metal sediment concentrations were calculated as the sum of the measured Baseline sediment concentrations and their corresponding predicted increase. For metals not covered by Sheppard *et al.* (2010), sediment-to-water partition coefficients were obtained from other sources as follows: boron from Lemarchand (2005), mercury from CSA (2011 update), and tungsten from Clausen *et al.* (2010). As an example, the COPC concentrations in sediment for Grid G8 are provided in Table 7.7.15, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.15 Concentrations in Sediment at HHERA Grid G8 (mg/kg dry weight)

COPC	Sediment Exposure Point Concentrations (EPC) at Grid G8 (mg/kg dry weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	7.87E+03	1.01E+04	1.80E+04
Arsenic (As)	3.25E+01	8.82E-01	3.34E+01
Boron (B)	2.00E+00	8.58E+00	1.06E+01
Chromium (Cr)	9.86E+00	1.43E-01	1.00E+01
Cobalt (Co)	1.19E+01	9.05E+00	2.10E+01
Copper (Cu)	1.93E+01	1.19E+00	2.05E+01
Lead (Pb)	2.94E+01	1.31E+00	3.07E+01
Manganese (Mn)	1.82E+03	2.78E+01	1.85E+03
Mercury (Hg)	7.59E-02	6.22E-05	7.60E-02
Molybdenum (Mo)	4.70E+00	3.44E+00	8.14E+00
Nickel (Ni)	1.64E+01	4.22E+00	2.06E+01
Thallium (Tl)	3.09E-01	1.07E+00	1.37E+00
Tungsten (W)	2.50E+00	8.04E+00	1.05E+01
Uranium (U)	5.11E+00	3.42E+00	8.53E+00
Vanadium (V)	2.03E+01	1.08E+01	3.12E+01
Zinc (Zn)	6.30E+01	1.81E+00	6.48E+01

7.7.2.2.11 Benthic Invertebrates

Benthic invertebrates represent an important food source for many small mammals and birds. Because soil invertebrates accumulate COPCs from their environment, a determination of existing concentrations of metals in benthic invertebrates is important to the evaluation of health risks to wildlife.

Benthic invertebrate samples were not analyzed for COPCs; however, concentrations of COPCs in benthic invertebrates for both the Baseline Case and the Project + Baseline Case were estimated.

Concentrations of COPCs in benthic invertebrates for the Project + Baseline Case were estimated based upon the predicted concentrations of COPCs in soil for the Project + Baseline Case, using the generalized equation relating elemental concentrations in biota to sediment concentrations and using published uptake factors (Garn *et al*. 2001; Hamilton *et al*. 2002; Haus *et al.* 2007; ORNL 1998). The Project Alone Case concentrations in benthic invertebrates were estimated as the difference between the Project + Baseline Case concentrations and the Baseline Case concentrations. As an example, the COPC concentrations in benthic invertebrates for Grid G8 are provided in Table 7.7.16, for illustrative purposes. This same process was repeated at each of the receptor grid squares in Figure 7.7.3.

Table 7.7.16 Concentrations in Benthic Invertebrates at HHERA Grid G8 (mg/kg wet weight)

COPC	Benthic Invertebrates Exposure Point Concentrations (EPC) at Grid G8 (mg/kg wet weight)		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	3.59E+02	4.61E+02	8.20E+02
Arsenic (As)	7.78E-02	4.35E-01	5.13E-01
Boron (B)	4.58E-01	1.97E+00	2.42E+00
Chromium (Cr)	5.50E-02	5.25E-02	1.08E-01
Cobalt (Co)	1.04E-03	2.17E-02	2.28E-02
Copper (Cu)	2.09E+00	5.87E+00	7.96E+00
Lead (Pb)	1.16E-01	1.49E-01	2.66E-01
Manganese (Mn)	1.13E+00	4.22E+00	5.36E+00
Mercury (Hg)	9.32E-03	7.64E-06	9.33E-03
Molybdenum (Mo)	2.66E-02	1.79E+00	1.82E+00
Nickel (Ni)	1.50E-01	5.97E-01	7.47E-01
Thallium (Tl)	1.86E-02	1.22E-01	1.40E-01
Tungsten (W)	9.12E-02	2.93E-01	3.84E-01
Uranium (U)	5.92E-03	5.75E-02	6.35E-02
Vanadium (V)	1.03E-02	1.96E-01	2.06E-01
Zinc (Zn)	2.24E+00	1.59E+01	1.82E+01

7.7.3 Human Health Risk Assessment (HHRA)

A human health risk assessment (HHRA) is a scientific study that estimates the nature and magnitude of potential adverse health risks in humans following exposure to contaminants released by a project. The scope of the HHRA is to assess interactions between predicted or measured levels of COPC in environmental media (*i.e*., air, soil, water, and food items) that may occur as a result of Project-related emissions or releases, and the potential for these interactions to result in adverse health risks to human receptors exposed to these media.

7.7.3.1 Problem Formulation

The problem formulation step defines the nature and scope of the work to be conducted, permits practical boundaries to be placed on the overall scope of work, and focuses the assessment on the key areas and issues of concern. As the relevant receptor locations for the HHERA have been identified elsewhere, as have the relevant COPCs for the assessment, the key tasks that comprise the problem formulation step of this HHRA include the following:

- receptor identification and characterization; namely the identification of "receptors of concern", which includes those persons with the greatest probability of exposure to contaminants and/or those that have the greatest sensitivity to these contaminants; and
- identification of exposure pathways and routes.

7.7.3.1.1 Receptor Identification and Characterization

A human receptor is a hypothetical person, inclusive of all life stages (*i.e.*, an infant, toddler, child, adolescent, adult) who is potentially exposed to the COPC while in the HHERA Study Area. General physical and behavioural characteristics specific to the receptor type (*e.g.*, body weight, breathing rate, food consumption rate) are used to obtain an amount of contaminant exposure (*i.e.,* dose) received by each receptor. The HHRA must be sufficiently comprehensive to ensure inclusion of those receptors with the greatest potential for exposure to COPC, and those who have the greatest sensitivity, or potential for developing adverse health outcomes from these exposures.

Based on current and anticipated future land use, the human receptors considered for the assessment include traditional, recreational, or commercial users of the land surrounding the Project. Health Canada (2009; 2010a) has provided food ingestion characteristics for fish and game that are specific to Canadian Aboriginal populations, and higher than the fish ingestion characteristics for the general Canadian population as shown in Table 7.7.17 (Health Canada does not provide wild game ingestion rates for the Canadian general population). As indicated in Health Canada (2010a), all other characteristics (e.g., soil ingestion, body weight) should be assumed to be equivalent to the general population. For this HHRA, the physical characteristics for each of the human receptor life stages (infant, toddler, child, teen, adult) were obtained from Health Canada (2010a), with the exception of fish ingestion rates, which were obtained from Health Canada (2009).

A First Nations receptor, inclusive of all life stages, was selected for the assessment, as all other receptors (*e.g.,* recreational, commercial) were considered to have potentially lesser exposures than members of local Aboriginal communities who may use the land or resources in or near the PDA for traditional uses such as fishing, hunting, and collecting plants for food and medicinal use. Although consumption rates for local plants are not known, it has been conservatively assumed that a First Nations receptor would consume vegetation that they collected from natural areas in an amount equivalent to the total vegetable consumption rate of the Canadian general population. It was conservatively assumed that the First Nations receptor would be present in the HHERA Study Area, on average, two days per week, every week, each year. This is considered conservative, and reflects comments made by a member of local First Nations who indicated that he would spend about 10% of his time (*i.e*., less than 1 day per week) in the general area of the PDA for hunting (Polchies, P. Personal communication, September 26, 2012).

In accordance with Health Canada guidance, carcinogenic and non-carcinogenic COPCs are evaluated differently. Non-carcinogenic COPCs are assumed to act via a threshold mechanism and exposures are assessed within specific life stages. The toddler life stage is defined as six months to four years (3.5 years total life stage) (Health Canada 2010a). As determined by Health Canada, toddlers are generally more susceptible to oral exposures than other age groups due to their generally higher ratio of ingestion rate to body weight. If the toddler assessment finds acceptable risk levels, then by default the risks to people in other life stages are also assumed to be acceptable. Both a First Nations adult and a First Nations toddler life stage were considered in the HHRA for non-carcinogenic COPCs; however, as the health risk estimates for the toddler were confirmed to be higher than the adult, only the results for a toddler are reported herein.

Carcinogenic COPCs are assumed to act via a non-threshold mechanism and exposures are assessed over a lifetime. Carcinogenic risks from COPC exposures were assessed assuming a composite (or lifetime) receptor.

Table 7.7.17 Human Receptor Characteristics

Assumed Characteristic	Receptor Values			Units for Lifetime
	Toddler	Adult	Lifetime	
Canadian General Population				
Body weight (kg)	16.5	70.7	--	--
Incidental soil ingestion rate (kg/d)	0.08	0.02	0.047	g soil-a/kg bw-d
Inhalation rate (m^3/d)	8.3	16.6	21.7	m^3 air-a/kg bw-d
Water ingestion rate (L/d)	0.6	1.5	1.76	L water-a/kg bw-d
Vegetable ingestion (kg/d)	0.172	0.325	0.4	kg vegetation-a/kg bw-d
Fish ingestion (kg/d) *	0.056	0.111		kg fish-a/kg bw-d
Canadian Aboriginal Populations (First Nations)				
Fish ingestion (kg/d)	0.095	0.22	0.276	kg fish-a/kg bw-d
Wild game ingestion (kg/d)	0.085	0.27	0.302	kg game meat-a/kg bw-d

Notes:
"--" lifetime body weight is not used; body weight in accounted for in the adjusted lifetime ingestion rates.
" * " Fish ingestion rate of Canadian general population not used in the HHRA (HHRA used First Nations consumption rates for fish).

Legend:

kg	kilogram	bw	body weight
a	annum (*i.e.*, year)	d	day
L	litre	m^3	cubic metre

Source: Health Canada (2009) (fish ingestion rates only) and Health Canada (2010a).

The fraction of fish originating from the HHERA Study Area was assumed to represent 20% of the total fish consumption shown in Table 7.7.17. This assumption was made in consideration of the annual fish ingestion for a family of four that is considered representative of Canadian Aboriginal populations (Health Canada 2009) and the fish stream productivity within the HHERA Study Area. Based on fish ingestion rates presented in Health Canada (2009), a total of 230 kilograms of fish would be required on an annual basis to meet the dietary fish requirements of a family of four (two adults and two toddlers). Based on the measured average weight of fish of length 15 cm and greater from the HHERA Study Area (as measured during field studies, Section 8.5.2), this would represent approximately 4,580 fish. However, based on fish density observations from sampling programs carried out for the Aquatic Environment (see Section 8.5.2), neither McBean nor West Branch Napadogan brooks have the capacity to supply these many fish. In addition, the variety of species that are usually assumed to be included in the fish ingestion category (including both finfish and shellfish) is far greater than that found in the HHERA Study Area. For example, the Indigenous Knowledge Study (IKS) noted that many participants fish for salmon in the Southwest Miramichi River. As such, a realistic, yet still conservative exposure scenario for fish ingestion, based on 20% of the fish originating from the HHERA Study Area, was selected.

The fraction of vegetation originating from the HHERA Study Area was assumed to represent 10% of the total vegetation consumption by a human receptor. This assumption was made in consideration of the estimated time spent in the HHERA Study Area as well as the realistic assumption that a variety of species stemming from various locations would be included within the vegetation ingestion pathway.

For game ingestion, it was assumed that 100% of the game would originate from the HHERA Study Area. This assumption was made in consideration that one large game animal (*i.e.*, a moose) could represent a large portion of a family's game consumption for a one-year period, and also considers that individuals tend to return of hunting areas year after year. This same one-year period would represent a substantive portion of the toddler life stage. As such, the assumption of 100% of game being obtained from the HHERA Study Area is considered a conservative but potentially realistic scenario for the First Nation receptor.

7.7.3.1.2 Exposure Pathway Screening and Conceptual Site Model

Relevant receptor locations for the HHERA and the relevant COPCs for the assessment were identified in Section 7.7.2. It remains to identify the key linkages or exposure pathways through which human receptors might be significantly exposed to COPCs under the Baseline and future (Project + Baseline) cases.

In the exposure assessment, the likelihood that human receptors may come into contact with a COPC is evaluated by examining the potential pathway for the movement of a COPC from its source to the eventual point of intake (exposure) by the receptor. For the purpose of this assessment, the exposure media and pathways are:

- inhalation of COPCs from air contaminant emissions released by the Project;
- direct contact with soil, including incidental ingestion of soil, inhalation of dust from soil and dermal contact with soil;
- ingestion of plants, fish, and game that have accumulated contaminants from the soil and other media; and
- ingestion of water.

A summary of potential exposure media for human receptors and a pathway-specific rationale for inclusion or exclusion from this HHRA is shown in Table 7.7.18.

Table 7.7.18 Rationale for Exposure Pathway Inclusion in the HHRA

Exposure Pathway	Included in HHRA?	Rationale
Inhalation of COPCs from air emissions	Yes	COPCs will be released from the Operation of the Project. Potential environmental effects on local air quality have been raised by stakeholders. This pathway was carried through the assessment.
Dermal contact with soil	Yes	Dermal absorption of COPC through contact with soil was assessed, as dispersed ore dust from activities at the PDA may affect soil quality and since the current soil concentrations in the HHERA Study Area (Figure 7.7.3) already exceed the soil quality guidelines for some COPCs. This pathway was carried through the assessment.
Incidental ingestion and inhalation of soil	Yes	Through the activity of traditional plant and vegetation collection, there exists a potential for the incidental ingestion of soil, and inhalation of particulate matter from soil. For this reason, this pathway was carried through the assessment.
Surface Water Ingestion	Yes	Water bodies may receive COPC input via transport from terrestrial media. Although surface water has not been identified as a potable water source, human receptors may be exposed to COPC concentrations in surface water if they drink from these sources. This pathway was carried through the assessment.
Ingestion of Country Foods (vegetation, game and fish)	Yes	Potential accumulation of COPC in country foods is a concern for First Nations. Deposition of dust and metals on soils, and subsequent accumulation in country foods (vegetation and game), may occur from Project activities. Similarly, changes in local water quality due to Project activities may result in higher concentrations of COPCs in fish tissues. This pathway was carried through the assessment.
Groundwater Ingestion or Contact	No	The closest known well users identified through NBDELG are in the community of Napadogan, more than 9 km from the Project, and would not be affected by seepage or releases from the Project. Although a series of groundwater wells will be installed to supply fresh water during Operation, these wells will be sited to avoid migration of potential contaminants from the TSF to the wells. This pathway was not carried through the assessment.

Beginning with the source media (*e.g.*, air, soil, water), the key exposure pathways through which potential dietary items can accumulate COPCs, and human receptors can become exposed to COPCs, are summarized the conceptual HHRA model shown in Figure 7.7.4.

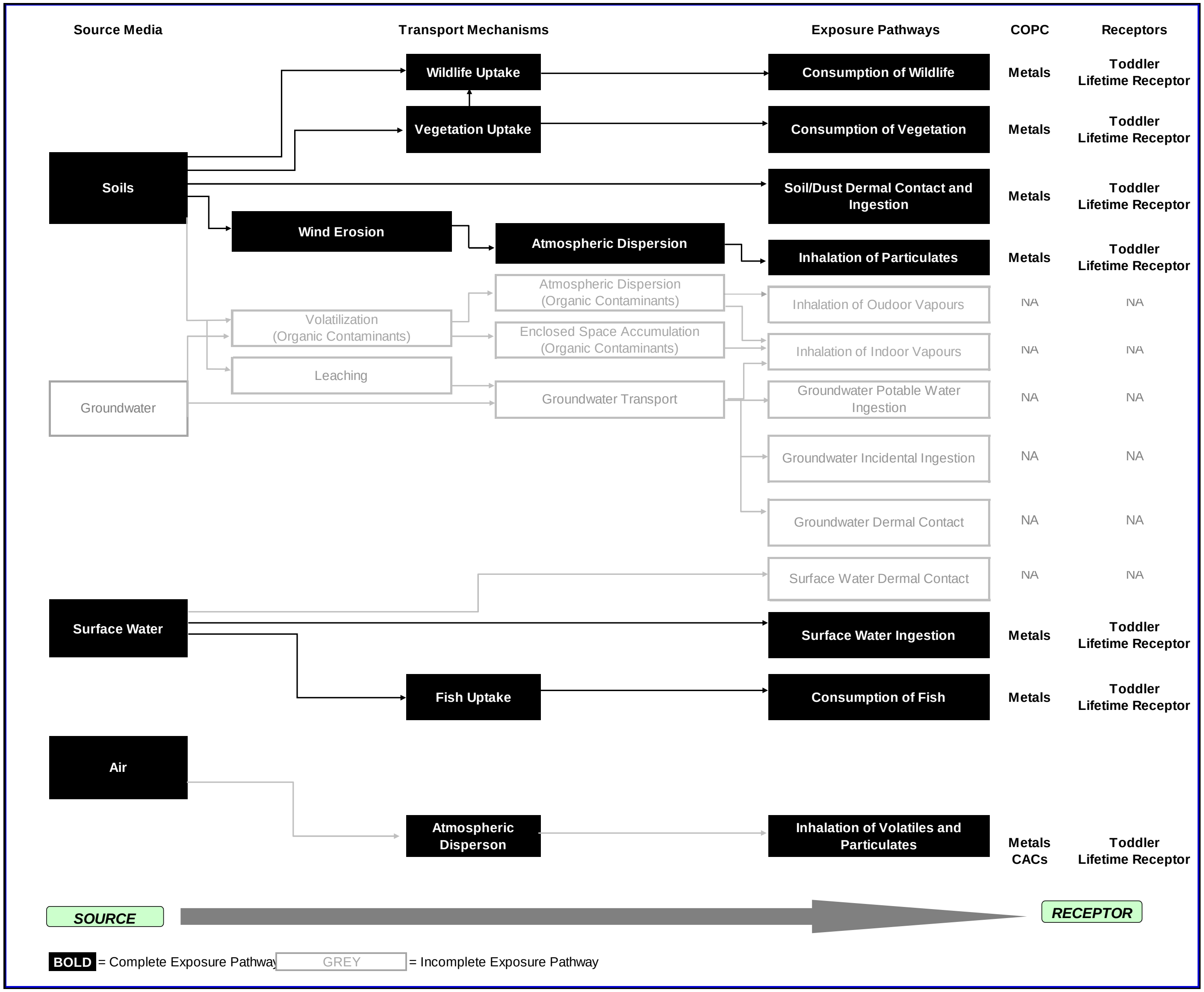


Figure 7.7.4 Conceptual Site Model for Human Health Receptors

7.7.3.2 Hazard Assessment

The hazard assessment (also known as a toxicity assessment) involves the selection of toxicological reference values (TRVs), also referred to as exposure limits, for each contaminant. Toxicity is the potential for a contaminant to produce any type of damage (whether permanent or temporary) to the structure or functioning of any part of the receptor's body. The toxicity of a contaminant depends on the amount taken into the body (referred to as the "dose") and the duration of exposure (*i.e.*, the length of time the receptor is exposed to the contaminant). For each contaminant, there is a specific dose and duration of exposure necessary to produce a toxic environmental effect in a given receptor. This is referred to as the "dose-response relationship" of a contaminant. The toxic potency of a contaminant (*i.e.*, its ability to produce any type of damage to the structure or function of any part of the body) is dependent on the inherent properties of the contaminant itself (*i.e.*, its ability to cause a biochemical or physiological response at the site of action within the receptor's body) as well as the ability of the contaminant to reach the site of action. This dose-response principle is central to the risk assessment methodology.

7.7.3.2.1 Toxicological Reference Values (TRVs)

Two basic categories of contaminants are commonly recognized by regulatory agencies (depending on the contaminant's mode of toxic action) and applied when estimating TRVs for human health (USEPA 1989). These are the "threshold" approach (typically used to evaluate non-carcinogens) and the "non-threshold" approach (typically used for carcinogenic compounds).

In the case of threshold contaminants, a threshold level must be exceeded for toxicity to occur. A no observable adverse effect level (NOAEL) can be identified for threshold contaminants, which is the dose or amount of the contaminant that results in no obvious response in the most sensitive test species and test endpoint. The application of uncertainty factors to the NOAEL provides an added level of protection, allowing for derivation of a TRV that is expected to be safe to the general public following exposure for a prescribed period of time. Generic nomenclature for TRVs for threshold contaminants includes Reference Concentration (RfC), which refers to the acceptable concentration of an airborne contaminant for which the primary route of exposure is inhalation, and Reference Dose (RfD), which refers to the acceptable dose of a contaminant and is most commonly expressed in terms of the total intake of the contaminant per unit of body weight per day (mg/kg-day).

Non-threshold contaminants are capable of producing cancer by altering genetic material. Regulatory agencies such as Health Canada and the USEPA assume that any level of long-term exposure to carcinogenic contaminants is associated with some "hypothetical cancer risk". As a result, regulatory agencies have typically employed acceptable Incremental Lifetime Cancer Risk (ILCR) levels (*i.e.*, levels over and above those that one would expect to be exposed to from background sources other than related to the Project). Generic nomenclature for TRVs for non-threshold contaminants includes Unit Risk (UR), defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a unit concentration of 1 µg/L in water, or 1 $\mu g/m^3$ in air (USEPA 1989), and cancer Slope Factor (SF), which is generally defined as the upper-bound increased cancer risk from a lifetime exposure to an agent usually expressed in units of proportion (of a population) affected per mg/kg-day (USEPA 1989).

7.7.3.2.2 Selection of TRVs

An essential part of the risk assessment process is the identification of toxicity reference values (TRV) against which exposures can be compared. These values are based on scientifically reviewed, published toxicological assessments from Canadian and American sources. TRVs have been established by several regulatory agencies including Health Canada, the United States Environmental Protection Agency (US EPA), the World Health Organization (WHO), Canadian Council of Ministers of the Environment (CCME), the Netherlands National Institute for Public Health and Environment (RIVM), and the Agency for Toxic Substances and Disease Registry (ATSDR). In the selection of toxicity values, Health Canada guidance was followed. Specifically, as per Health Canada (2010a), preference was given to the Health Canada values and, for substances with no Health Canada TRVs, alternative TRVs were obtained from the following agencies, in order of preference:

- Other Health Canada TRVs;
- US EPA Integrated Risk Information System (IRIS);
- World Health Organization (WHO);
- Netherlands National Institute of Public Health and the Environment (RIVM);
- Agency for Toxic Substances and Disease Registry (ATSDR); and
- California Environmental Protection Agency (Cal EPA).

The toxicity reference values and oral slope factors used in this HHRA for non-carcinogen and carcinogen oral exposure are summarized in Table 7.7.19, Table 7.7.20, and Table 7.7.21.

Table 7.7.19 Acute Inhalation Toxicological Reference Values

COPC	Toxicological Reference Value (TRV) (mg/m^3)	Health Endpoint	Source
1-hour Acute Exposure			
Sulphur dioxide (SO_2)	0.90	not available	GNB (1997), CCME (1996)
Nitrogen oxides (NO_x as NO_2)	0.40	not available	GNB (1997), Health Canada (2006)
Carbon monoxide (CO)	35	not available	GNB (1997), CCME (1996)
Total particulate matter (PM)	--	--	--
Particulate matter less than 2.5 microns ($PM_{2.5}$)	--	--	--
Particulate matter less than 10 microns (PM_{10})	--	--	--
Aluminum (Al)	0.05	health	TCEQ (2013)
Arsenic (As)	0.0001	not available	AENV (2013)
Boron (B)	0.05	health	TCEQ (2013)
Chromium (Cr)	0.001	health (total chromium)	AENV (2011)
Cobalt (Co)	0.0002	health	TCEQ (2013)
Copper (Cu)	0.10	respiratory system	Cal EPA (2012)
Lead (Pb)	0.0015	not available	AENV (2011)
Manganese (Mn)	0.002	not available	AENV (2011)

Table 7.7.19 Acute Inhalation Toxicological Reference Values

COPC	Toxicological Reference Value (TRV) (mg/m^3)	Health Endpoint	Source
Mercury (Hg) - total	--	--	--
Molybdenum (Mo)	0.03	health	TCEQ (2013)
Nickel (Ni)	0.006	not available	AENV (2011)
Thallium (Tl)	0.001	health	TCEQ (2013)
Tungsten (W)	0.01	health	TCEQ (2013)
Uranium (U)	0.0005	health	TCEQ (2013)
Vanadium (V)	--	--	--
Zinc (Zn)	--	--	--
24-hour Acute Exposure			
Sulphur dioxide (SO_2)	0.30	not available	GNB (1997), Health Canada (2006)
Nitrogen oxides (NO_x as NO_2)	0.20	not available	GNB (1997), Health Canada (2006)
Carbon monoxide (CO)	--	--	--
Total particulate matter (PM)	0.12	not available	GNB (1997)
Particulate matter less than 2.5 microns ($PM_{2.5}$)	0.03	health	OMOE (2012)
Particulate matter less than 10 microns (PM_{10})	0.05	interim value provided as guide	OMOE (2012)
Aluminum (Al)	--	--	--
Arsenic (As)	0.0003	health	OMOE (2012)
Boron (B)	0.12	particulate	OMOE (2012)
Chromium (Cr)	0.0005	health	OMOE (2012)
Cobalt (Co)	0.0001	health	OMOE (2012)
Copper (Cu)	0.05	health	OMOE (2012)
Lead (Pb)	0.0005	health	OMOE (2012)
Manganese (Mn)	0.0002	health	OMOE (2012)
Mercury (Hg) - total	0.003	health	OMOE (2012)
Molybdenum (Mo)	0.12	particulate	OMOE (2012)
Nickel (Ni)	0.0001	particulate	OMOE (2012)
Thallium (Tl)	--	--	--
Tungsten (W)	--	--	--
Uranium (U)	0.0001	particulate	OMOE (2012)
Vanadium (V)	0.002	health	OMOE (2012)
Zinc (Zn)	0.12	particulate	OMOE (2012)
Notes: "--" indicates that TRV is not available			

Table 7.7.20 Chronic Inhalation Toxicological Reference Values (Non-Carcinogens)

COPC	Toddler Toxicological Reference Value (TRV) (mg/m^3)	Adult Toxicological Reference Value (TRV) (mg/m^3)	Health Endpoint	Source
Inhalation (mg/m^3)				
Aluminum (Al)	1.99	1.99	provisional	ATSDR (2008)
Arsenic (As)	Not applicable	Not applicable	assessed as a carcinogen	Health Canada (2010b)

Table 7.7.20 Chronic Inhalation Toxicological Reference Values (Non-Carcinogens)

COPC	Toddler Toxicological Reference Value (TRV) (mg/m^3)	Adult Toxicological Reference Value (TRV) (mg/m^3)	Health Endpoint	Source
Boron (B)	0.0348	0.0348	derived from oral	Health Canada (2010b)
Chromium (Cr)	0.000008	0.000008	nasal septum atrophy	US EPA IRIS (1998)
Cobalt (Co)	0.0001	0.0001	respiratory effects	ATSDR (2004)
Copper (Cu)	0.001	0.001	lung and immune system effects	RIVM (2001)
Lead (Pb)	0.00368	0.00368	provisional – derived from oral	OMOE (1994)
Manganese (Mn)	0.00005	0.00005	impairment of neuro-behavioral function	US EPA IRIS (1993)
Mercury (Hg) - total	0.0003	0.0003	hand tremors and increases in memory disturbance	US EPA IRIS (1995)
Molybdenum (Mo)	0.012	0.012	no observed adverse effect concentration	RIVM (2001)
Nickel (Ni)	0.022	0.022	provisional – derived from oral	Health Canada (2010b)
Thallium (Tl)	0.000028	0.000028	provisional – derived from oral	Cal EPA (1999)
Tungsten (W)	0.0033	0.0033	not specified	NIOSH (1994)
Uranium (U)	0.0012	0.0012	provisional – derived from oral	Health Canada (2010b)
Vanadium (V)	0.0001	0.0001	respiratory effects	ATSDR (2009)
Zinc (Zn)	0.95	0.95	provisional – derived from oral	Health Canada (2010b)
Oral (mg/kg-day)				
Aluminum (Al)	1	1	neurotoxic	ATSDR (2008)
Arsenic (As)	Not applicable	Not applicable	assessed as a carcinogen	Health Canada (2010b)
Boron (B)	0.0175	0.0175	testicular atrophy	Health Canada (2010b)
Chromium (Cr)	0.001	0.001	hepatotoxicity (liver effects)	Health Canada (2010b)
Cobalt (Co)	0.01	0.01	polycythemia (blood disease)	ATSDR (2004)
Copper (Cu)	0.091	0.141	hepatotoxicity (liver effects)	Health Canada (2010b)
Lead (Pb)	0.0019	0.0019	behavioral effects and learning disabilities in children	OMOE (1994)
Manganese (Mn)	0.136	0.156	Parkinsonian-like neurotoxicity	Health Canada (2010b)
Mercury (Hg) - inorganic	0.0003	0.0003	nephrotoxicity (kidney effects)	Health Canada (2010b)
Methyl mercury (MeHg)	0.0002	0.0002 (women of childbearing years)	neurotoxicity	Health Canada (2010b)
Molybdenum (Mo)	0.023	0.028	reproductive effects	Health Canada (2010b)
Nickel (Ni)	0.011	0.011	perinatal lethality	Health Canada (2010b)

Table 7.7.20 Chronic Inhalation Toxicological Reference Values (Non-Carcinogens)

COPC	Toddler Toxicological Reference Value (TRV) (mg/m^3)	Adult Toxicological Reference Value (TRV) (mg/m^3)	Health Endpoint	Source
Thallium (Tl)	0.000014	0.000014	alopecia (hair loss)	Cal EPA (1999)
Tungsten (W)	0.0075	0.0075	body weight	Schroeder and Mitchener (1975)
Uranium (U)	0.0006	0.0006	nephrotoxicity (kidney effect) and hepatotoxicity (liver effects)	Health Canada (2010b)
Vanadium (V)	0.009	0.009	decreased hair cystine	US EPA IRIS (1988)
Zinc (Zn)	0.48	0.57	decreased growth of infants	Health Canada (2010b)

Table 7.7.21 Chronic Inhalation Toxicological Reference Values (Carcinogens)

COPC	Lifetime Toxicological Reference Value (TRV) (mg/m^3)	Health Endpoint	Source
Inhalation [1/(mg/m^3)]			
Arsenic (As)	6.4	bladder, lung, and liver cancer	Health Canada (2010b)
Chromium (Cr)	11	lung cancer	Health Canada (2010b)
Nickel (Ni)	1.3	lung and nasal cancer	Health Canada (2010b)
Oral [1/(mg/kg-day)]			
Arsenic (As)	1.8	lung cancer	Health Canada (2010b)

7.7.3.3 Exposure Assessment

The main objective of the exposure assessment is to develop a quantitative estimate of exposure for the human receptors to each COPC, based on the media concentrations and the receptor characteristics.

7.7.3.3.1 Exposure Point Concentrations (EPCs)

Section 7.7.2.2 presented the EPCs used in the risk assessment for the air, soil, water, vegetation, fish tissue, and game for the Baseline Case, the Project Alone Case, and the Project + Baseline Case. The HHRA used these EPCs in the assessment of human health risk at each of the HHERA receptor locations. For fish and moose, the concentrations used in the HHERA were calculated as an average for the HHERA Study Area, since no one location could support the consumption rates.

For the purposes of this assessment, receptors were conservatively assumed to harvest their country foods (*i.e.*, vegetation, game, and fish) from the HHERA Study Area over the exposure time (2 days/week), and consume the food collected throughout the year.

Although speciation of metals was not completed, existing guidance for the assessment of mercury and arsenic in fish tissues have been applied. For the purposes of the HHRA, it has been assumed that all mercury in fish occurs as the more toxic methyl mercury, consistent with US EPA (2005) guidance. The Canadian Ministry of the Environment performed studies analyzing concentrations of organic and inorganic arsenic in freshwater fish, determining that 10% of total arsenic is inorganic (Weiler 1987), while the other 90% appears to occur as organic arsenic, which is considered non-toxic. Therefore, it has been assumed that 10% of the total arsenic in fish from the HHERA Study Area occurs as inorganic arsenic.

7.7.3.3.2 Calculation of Average Daily Dose

Daily intakes from each type of food are determined for each individual COPC. In the absence of community specific consumption and use details for traditional foods in the HHERA Study Area, the Health Canada (2010) recommended consumption quantities were used in the assessment, with assumptions regarding what portion of the total consumption would originate from the HHERA Study Area. The consumption quantities are included in Section 7.7.3.1.1.

Daily intakes are calculated in the form of chronic daily intakes (CDIs) (to assess non-carcinogenic endpoints) and lifetime average daily doses (LADDs) (to assess carcinogenic endpoints), using the equations presented below.

$$CDI_i = Intake_{nc} \text{ x } EPC_i$$

$$LADD_i = Intake_c \text{ x } EPC_i$$

where:

CDI_i = chronic daily intake via pathway *i*, mg/kg bw-day (Note: bw means body weight);

$LADD_i$ = lifetime average daily dose via pathway *i*, mg/kg bw-day;

$Intake_{nc}$ = intake rate for medium *i* (*e.g*., game) (non-carcinogenic), kg medium/kg bw-day;

$Intake_c$ = intake rate for medium *i* (*e.g*., game) (carcinogenic), kg medium/kg bw-day; and

EPC_i = Exposure concentration of contaminant in medium *i* (*e.g*., game), mg COPC/kg medium.

7.7.3.4 Risk Characterization

The final step in the HHERA is risk characterization. This involves the estimation, description, and evaluation of risk associated with exposure to COPC by comparing the estimated exposure to the appropriate TRV. For human receptors, the benchmark is different depending on whether or not the COPC are possibly cancer-causing.

7.7.3.4.1 Non-Cancer Causing Contaminants

The assessment of human health risks from non-cancer causing contaminants is conducted using Concentration Ratios (CR) for the inhalation pathway, and Hazard Quotients (HQ) for all other pathways.

Concentration Ratios (CR) were used to evaluate the health risks from short-term and long-term exposure of all life stages to contaminants in air. CRs were calculated by dividing the predicted ground-level air concentration (*i.e.,* 1-hour, 24-hour, or annual average) as predicted by air dispersion modelling by the appropriate TRV. Note that the TRVs for non-cancer causing contaminants are considered protective of the general population, including all life stages. For assessment of non-carcinogenic health risks due to short- and long-term direct inhalation of COPC by people, a benchmark of CR<1.0 was used for comparison of calculated CR, consistent with guidance from Alberta Health and Wellness (2011). In general, the risks associated with direct inhalation are distinct from those associated with oral and dermal exposures and are therefore assessed separately.

Hazard Quotients (HQ) were calculated by dividing the predicted exposure (or dose) by the TRV for a specific COPC. People are potentially exposed to contaminants through five main media (*i.e*., air, water, soil, food, and consumer products), and Health Canada and the Canadian Council of Ministers of the Environment (CCME) assume that no more than 20% of a person's daily intake comes from any one medium (*i.e*., 100% divided by 5 media is 20%). This translates into an HQ where the benchmark is HQ<0.2. For this HHRA, the potential health risks associated with water, soil, and country foods was undertaken, and the health risks associated with each source compared to the benchmark of HQ<0.2.

When predicted human health risks are less than the benchmark (*e.g.*, CR<1.0, HQ<0.2), adverse human health outcomes are not expected. If predicted human health risks are higher than the benchmark, it does not necessarily indicate a health problem, but rather triggers a more in-depth review. Review of such HQ and CR values is important since both the exposure estimates and the toxicological criteria are based on a series of conservative assumptions, including multiple predictive models and reasonable "worst case" exposure scenarios.

7.7.3.4.2 Cancer-Causing Contaminants

The assessment or comparison for potential health risks from cancer-causing COPC was expressed as Incremental Lifetime Cancer Risks (ILCRs), and represents the increased risk of a person within a given population developing cancer over his or her lifetime as a result of the Project. ILCR consider the increase in risk over and above background risk. ILCR estimates resulting from direct air inhalation were calculated by multiplying the concentration in air resulting from the Project by the TRV (for any cancer-causing contaminants in air, also known as a UR).

For those cancer-causing COPC evaluated as part of the soil, water, or food pathway assessment, ILCR estimates resulting from a lifetime of exposure through multiple pathways were calculated by estimating a lifetime average daily dose (LADD) (over an assumed lifetime for a person of 80 years), and multiplying that LADD by the TRV (for cancer-causing contaminants in media other than air, also known as a SF). Consistent with Health Canada (2010a) and Atlantic PIRI (2007) guidance, the ILCR was compared to a benchmark of 1 person in a population of 100,000 (*i.e.,* 0.00001, or 1E-05) predicted to develop cancer as a result of their contaminant exposure from Project-related releases. It is noted that a risk estimate that exceeds an ILCR of 1E-05 would not, in and of itself, necessarily indicate that the proposed action or activity is not safe or presents an unacceptable risk (USEPA 2005). Rather, a risk estimate that exceeds a regulatory objective triggers careful consideration of the underlying scientific basis (USEPA 2005) and further monitoring to confirm the prediction and plan for adaptive management, as applicable.

The Lifetime Cancer Risk (LCR) is a measure used to assess risks related to contaminants that are capable of producing cancer, similar to the ILCR. Unlike ILCR, LCR includes the consideration of cancer risks from background or existing sources. Since regulators have not recommended an acceptable benchmark LCR for exposure to carcinogens associated with background or baseline conditions, interpretation of the significance of the LCR values is difficult. As such, the LCRs for the Baseline Case and the Project + Baseline Case are provided for reference and context only.

7.7.3.4.3 Risk Characterization Results

7.7.3.4.3.1 Human Health Risks via Inhalation – Criteria Air Contaminants (CACs)

The short-term (1-hour and 24-hour) and long-term (annual average) assessment of inhalation health risks for criteria air contaminants (CACs) at the location of the maximum ground-level concentration (GLC) within the LAA as predicted by the air dispersion modelling (Section 7.1) for the Baseline Case and the Project + Baseline Case are provided in Table 7.7.22.

Table 7.7.22 Maximum Acute and Chronic Inhalation Human Health Risks – Criteria Air Contaminants (CACs)

COPC (CACs)	Inhalation Human Health Risk, as measured by Concentration Ratio (CR dimensionless)					
	All Life Stages					
	Baseline Case			Project + Baseline Case		
	1-hour (CR)	24-hour (CR)	Annual Average (CR)	1-hour (CR)	24-hour (CR)	Annual Average (CR)
SO_2	0.0061	0.0075	-	0.0062	0.0078	-
NO_2	0.034	0.028	-	0.25	0.13	-
CO	0.052	-	-	0.053	-	-
PM	-	0.19	-	-	**7.0**	-
$PM_{2.5}$	-	0.21	-	-	0.95	-
PM_{10}	-	N/A	-	-	0.78	-

Notes:
- Indicates that a regulatory TRV for the selected averaging period is not available.
N/A Indicates that a predicted ground-level concentration for the selected averaging period is not available.
Bold indicates that the value exceeds the applicable benchmark (CR<1.0).

Results of the acute inhalation analyses indicate that the predicted maximum future GLCs of CACs were less than the benchmarks for acute inhalation (CR<1.0), with the exception of the maximum 24-hour PM (or total suspended particulate, TSP) concentration. The maximum predicted GLC for PM (837 μg/m^3) is above the regulatory guideline of 120 μg/m^3, as was discussed in Section 7.1, and consequent CR values exceed the benchmark. It is important to note that the location of the maximum GLC for PM is not at any of the HHRA locations. The PM predicted maximum concentration is located at the edge of the quarry and TSF area, as indicated in Section 7.1.

Given the low likelihood of a person being exposed to PM at the location of the maximum GLC where and when it occurs, it is important to evaluate the potential short-term risks related to exposures to PM at the locations where people currently reside, to gain a true understanding of human health risks to which people may be exposed at places where they are currently likely to be exposed. The CR values associated with the maximum predicted PM concentrations at the previously identified recreational cabins and nearest residences (Section 7.1), as well as each of the HHERA receptor locations were reviewed and are provided in Table 7.7.23.

Table 7.7.23 Acute and Chronic Inhalation Health Risks at Selected Receptor Locations – Criteria Air Contaminants (CACs)

COPC (CACs) (Exposure Period)	Location	Inhalation Human Health Risks (CRs, dimensionless)	
		All Life Stages	
		Baseline Case	Project + Baseline Case
PM (24-hour)	Maximum GLC (near quarry and TSF)	0.19	**7.0**
	Maximum at nearest recreational cabin or nearest residence	0.19	0.24

Notes:
Bold indicates that the value exceeds the applicable benchmark (CR<1.0).

With the exception of PM concentrations located within the quarry and TSF area, none of the PM concentrations are predicted to result in a CR value that exceeds the applicable benchmark (CR<1.0) at these locations (Table 7.7.23).

7.7.3.4.3.2 Human Health Risks via Inhalation – Non-Criteria Air Contaminants (non-CACs)

The CR values for exposures to predicted non-CAC COPC concentrations as predicted by the air dispersion modelling (Section 7.1) are presented in Table 7.7.24. The CR values for the 1-hour, 24-hour and annual average exposure periods are based on the maximum overall GLC predicted by the model within the entire HHERA Study Area.

Table 7.7.24 Maximum Acute and Chronic Inhalation Human Health Risks – Non-Criteria Air Contaminants (non-CACs)

COPC (non-CACs)	Inhalation Human Health Risk, as measured by Concentration Ratio (CR) , dimensionless					
	All Life Stages					
	Baseline Case			Project + Baseline Case		
	1-hour (CR)	24-hour (CR)	Annual Average (CR)	1-hour (CR)	24-hour (CR)	Annual Average (CR)
Aluminum (Al)	0.014	-	8.3E-05	**2.3**	-	1.6E-04
Arsenic (As)	0.060	0.0082	-	**2.7**	0.038	-
Boron (B)	1.2E-04	2.1E-05	7.1E-05	1.3E-04	1.1E-05	7.6E-05
Cadmium (Cd)	0.020	0.033	0.072	**1.3**	0.21	0.074
Chromium (Cr)	0.0025	0.0021	0.10	0.44	0.037	0.17
Cobalt (Co)	0.010	0.0082	0.0072	0.41	0.034	0.0083
Copper (Cu)	0.0066	0.0054	0.19	0.012	0.0010	0.19
Lead (Pb)	0.0044	0.0054	4.7E-04	0.20	0.025	5.8E-04
Manganese (Mn)	0.013	0.053	0.13	**4.3**	**1.8**	0.27

Table 7.7.24 Maximum Acute and Chronic Inhalation Human Health Risks – Non-Criteria Air Contaminants (non-CACs)

COPC (non-CACs)	Inhalation Human Health Risk, as measured by Concentration Ratio (CR) , dimensionless					
	All Life Stages					
	Baseline Case			Project + Baseline Case		
	1-hour (CR)	24-hour (CR)	Annual Average (CR)	1-hour (CR)	24-hour (CR)	Annual Average (CR)
Mercury (Hg)	-	4.0E-06	2.3E-05	-	3.1E-05	4.3E-05
Molybdenum (Mo)	1.0E-04	1.0E-05	1.0E-04	0.0032	1.6E-04	3.0E-04
Thallium (Tl)	0.010	-	0.15	0.0061	-	0.15
Tungsten (W)	3.7E-04	-	4.4E-04	0.017	-	1.7E-03
Uranium (U)	0.13	0.18	0.019	0.035	0.0049	0.019
Vanadium (V)	-	4.1E-04	0.0076	-	0.011	0.014
Zinc (Zn)	-	2.0E-04	1.6E-05	-	3.5E-04	1.7E-05

Notes:
- Indicates that a regulatory criteria or TRV for the selected averaging period is not available.
Bold indicates that the value exceeds the applicable benchmark (CR<1.0).

Results of the acute and chronic inhalation analyses indicate the following.

- Predicted maximum Project + Baseline Case GLCs of non-CACs were less than the regulatory guidelines (CR<1.0) for acute inhalation, with the following exceptions: the maximum 1-hour aluminum, arsenic, cadmium, and manganese as well as the maximum 24-hour manganese; these are generally only marginally above their respective regulatory guidelines.

- Predicted maximum Project + Baseline Case GLCs of non-CACs were less than the TRV for chronic inhalation (CR<1.0).

It is important to note that the location of the maximum GLCs for aluminum, arsenic, cadmium and manganese are not at any of the HHRA locations. The aluminum, arsenic, cadmium and manganese predicted maximum concentrations are located at the edge of the quarry and TSF area, as indicated in Section 7.1.

Given the low likelihood of a person being exposed to aluminum, arsenic, cadmium and manganese at the location of the maximum GLC where and when it occurs, it is important to evaluate the potential short-term risks related to exposures to aluminum, arsenic, cadmium and manganese at the locations where people currently reside, to gain a true understanding of human health risks to which people may be exposed at places where they are currently likely to be exposed. The CR values associated with the maximum predicted aluminum, arsenic, cadmium and manganese concentrations at the previously identified recreational cabins and nearest residences, as well as each of the HHERA receptor locations shown on Figure 7.7.3, were reviewed and are presented in Table 7.7.25. Only those human health risks that were predicted to exceed an applicable benchmark in Table 7.7.24 are provided, as there is no need for further analysis of those parameters and averaging periods that met the benchmark.

Table 7.7.25 Acute and Chronic Inhalation Human Health Risks at Selected Receptor Locations – Non-Criteria Air Contaminants (non-CACs)

COPC (non-CACs) (Exposure Period)	Location	Inhalation Human Health Risk (CR, dimensionless)	
		All Life Stages	
		Baseline Case	Project + Baseline Case
Aluminum (Al) (1-hour)	At the location of the Maximum predicted GLC	0.014	**2.3**
	Maximum at the nearest recreational cabin or nearest residence	0.014	0.035
	Maximum of the 46 HHERA Receptor Locations	0.014	0.28
Arsenic (As) (1-hour)	At the location of the Maximum predicted GLC	0.060	**2.7**
	Maximum at the nearest recreational cabin or nearest residence	0.060	0.084
	Maximum of the 46 HHERA Receptor Locations	0.060	0.33
Cadmium (Cd) (1-hour)	At the location of the Maximum predicted GLC	0.020	**1.3**
	Maximum at the nearest recreational cabin or nearest residence	0.020	0.032
	Maximum of the 46 HHERA Receptor Locations	0.020	0.15
Manganese (Mn) (1-hour)	At the location of the Maximum predicted GLC	0.013	**4.3**
	Maximum at the nearest recreational cabin or nearest residence	0.013	0.066
	Maximum of the 46 HHERA Receptor Locations	0.013	0.49
Manganese (Mn) (24-hour)	At the location of the Maximum predicted GLC	0.053	**1.8**
	Maximum at the nearest recreational cabin or nearest residence	0.053	0.10
	Maximum of the 46 HHERA Receptor Locations	0.053	0.26

Notes:
Bold indicates that the value exceeds the applicable benchmark (CR<1.0).

With the exception of concentrations located within the quarry and TSF area, none of the aluminum, arsenic, cadmium and manganese concentrations are predicted to result in a CR value that exceeds the benchmark (CR<1.0) at the nearest recreational cabin or nearest residence locations (Table 7.7.25).

In addition, cancer risks associated with three non-CACs that are considered carcinogens through the inhalation pathway were also evaluated for the chronic exposure scenario. These three metals include arsenic, chromium, and nickel. The results are provided in Table 7.7.26.

Table 7.7.26 Maximum Carcinogenic Human Health Risks Associated with Inhalation

COPC	Maximum Air Lifetime Cancer Risk (LCR or ILCR, dimensionless)		
	Lifetime		
	Baseline (LCR)	Project Alone (ILCR)	Project + Baseline (LCR)
Arsenic (As) (inhalation only)	1.4E-05	2.3E-06	1.6E-05
Chromium (Cr) (inhalation only)	8.9E-06	6.2E-06	1.5E-05
Nickel (Ni) (inhalation only)	1.4E-06	2.2E-07	1.7E-06

Notes:
Bold indicates that value exceeds applicable ILCR benchmark (ILCR<1E-05).

The Project-related ILCRs for all three metals are less than the benchmark of 1 in 100,000 (*i.e.*, ILCR<1E-05), indicating negligible health risks. As noted previously, the LCRs associated with the Baseline Case and the Project + Baseline Case have been provided for reference only as there are no benchmarks for the LCR values.

7.7.3.4.3.3 Human Health Risks via Ingestion and Dermal Contact with Soil

Hazard quotients (HQs) were determined for each of the HHERA receptor locations (as shown on Figure 7.7.3) based on incidental ingestion, inhalation of dust from soil, and direct dermal contact with soil. As noted in Section 7.7.3.3, people were assumed to spend two days per week, each week, in the HHERA Study Area. A summary of the maximum HQs for the toddler (*i.e.*, the most sensitive life stage for non-carcinogens) is provided in Table 7.7.27.

Table 7.7.27 Maximum Non-Carcinogenic Human Health Risks to Toddlers Associated with Soil Exposure

COPC[a]	Maximum Total Soil Hazard Quotient (HQ, dimensionless)		
	Toddler		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.064	8.5E-08	0.064
Boron (B)	3.2E-04	6.8E-10	3.2E-04
Chromium (Cr)	0.066	2.2E-07	0.066
Cobalt (Co)	3.2E-03	3.4E-09	3.2E-03
Copper (Cu)	1.0E-03	6.3E-09	1.0E-03
Lead (Pb)	0.022	4.4E-08	0.022
Manganese (Mn)	0.14	4.3E-08	0.14
Mercury (Hg)	1.9E-03	6.5E-10	1.9E-03
Molybdenum (Mo)	1.0E-03	7.8E-09	1.0E-03
Nickel (Ni)	4.3E-03	5.5E-09	4.3E-03
Thallium (Tl)	0.030	1.8E-07	0.030
Tungsten (W)	1.7E-03	4.5E-08	1.7E-03
Uranium (U)	8.0E-03	1.3E-08	8.0E-03
Vanadium (V)	0.020	2.5E-08	0.020
Zinc (Zn)	3.7E-04	1.0E-09	3.7E-04

Notes:
Bold indicates that value exceeds applicable HQ benchmark (HQ<0.2).
[a] Arsenic assessed as a carcinogen only (see Table 7.7.28), consistent with Health Canada (2010b).

As indicated in Table 7.7.27, maximum HQs for the soil pathway were below the relevant benchmark of HQ<0.2 for Baseline Case, Project Alone Case, and Project + Baseline Case.

Cancer risks associated with the COPCs that are considered carcinogens were also assessed at each of the HHERA receptor locations. The results are provided in Table 7.7.28. As noted previously, the LCRs associated with the Baseline Case and the Project + Baseline Case have been provided for reference only as there are no benchmarks for the LCR values. It is noted that carcinogenic health endpoints are assessed over the lifetime of an individual, and not for any particular life stage.

Table 7.7.28 Maximum Carcinogenic Human Health Risks Associated with Soil Exposure

COPC	Maximum Soil Lifetime Cancer Risk (LCR or ILCR, dimensionless)		
	Lifetime		
	Baseline Case (LCR)	Project Alone Case (ILCR)	Project + Baseline Case (LCR)
Arsenic (As)	3.4E-05	2.9E-11	3.4E-05
Chromium (Cr) [a]	1.3E-09	4.3E-15	1.3E-09
Nickel (Ni) *	1.2E-10	1.5E-16	1.2E-10

Notes:
Bold indicates that value exceeds applicable ILCR benchmark (ILCR<1E-05).
[a] Potential carcinogenic effects for chromium and nickel associated with inhalation of dust from soil. Health risks associated with chromium and nickel from incidental ingestion of soil and dermal with soil are provided in Table 7.7.27.

The ILCRs associated with each of these metals at the HHERA receptor locations were less than the benchmark of 1 in 100,000 (*i.e.*, ILCR<1E-05). Based on these results, the potential health risks associated with predicted increases in COPC concentrations in soil associated with deposition of ore dust are negligible.

7.7.3.4.3.4 Human Health Risks via Ingestion of Water

Although there are no groundwater users in the immediate vicinity of the Project, and although streams in the HHERA Study Area have not been identified as sources of potable water, the HHERA considered the possibility that people may drink water from the streams while in the HHERA Study Area (assumed to be two days per week, a highly conservative assumption). A summary of the maximum HQs for the toddler (*i.e.*, the most sensitive life stage for non-carcinogens) is provided in Table 7.7.29.

Table 7.7.29 Maximum Non-Carcinogenic Human Health Risks Associated with Ingestion of Water

COPC [a]	Maximum Surface Water Ingestion Hazard Quotient (HQ, dimensionless)		
	Toddler		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	1.5E-03	1.5E-03	2.8E-03
Boron (B)	1.2E-03	0.13	0.13
Chromium (Cr)	5.6E-03	5.8E-03	0.012
Cobalt (Co)	6.3E-05	1.3E-03	1.4E-03
Copper (Cu)	6.1E-05	2.0E-04	2.6E-04
Lead (Pb)	1.1E-03	1.6E-03	2.3E-03
Manganese (Mn)	9.8E-04	2.5E-03	3.1E-03
Mercury (Hg)	4.5E-04	1.4E-05	4.7E-04
Molybdenum (Mo)	1.7E-04	6.4E-03	6.4E-03
Nickel (Ni)	4.7E-04	1.9E-03	2.4E-03
Thallium (Tl)	0.037	0.12	0.16
Tungsten (W)	3.0E-03	0.025	0.028
Uranium (U)	3.4E-03	0.033	0.036
Vanadium (V)	7.4E-04	0.014	0.015
Zinc (An)	5.3E-05	2.4E-04	2.7E-04

Notes:
Bold indicates that value exceeds applicable HQ benchmark (HQ<0.2).
[a] Arsenic assessed as a carcinogen only (see Table 7.7.30), consistent with Health Canada (2010b)

As indicated in Table 7.7.29, maximum HQs for the ingestion of water pathway were below the benchmark of HQ<0.2.

The lifetime cancer risk associated with arsenic (the only COPC that is considered a potential carcinogen via oral exposure) was also assessed at each of the HHERA receptor locations. The resulting maximum health risks are provided in Table 7.7.30. As noted previously, the LCRs associated with the Baseline Case and the Project + Baseline Case have been provided for reference only as there are no benchmarks for the LCR values.

Table 7.7.30 Maximum Carcinogenic Human Health Risks Associated with Ingestion of Water

COPC	Maximum Surface Water Lifetime Cancer Risk (LCR or ILCR, dimensionless)		
	Lifetime		
	Baseline Case (LCR)	Project Alone Case (ILCR)	Project + Baseline Case (LCR)
Arsenic (As) (water ingestion)	7.8E-06	4.4E-05	5.1E-05

The maximum ILCRs associated with ingestion of arsenic in surface water at the HHERA receptor locations was greater than the benchmark of 1 in 100,000 (*i.e.*, ILCR<1E-05) for the Project Alone Case and the Project + Baseline Case. Based on these results, the predicted increases in COPC concentrations in surface water represent a non-negligible health risk to those who may occasionally drink from the streams while in the HHERA Study Area. Further information is as follows.

Health Risks Associated with Arsenic in Water

As per Alberta Health and Wellness (2011), exceedances of the threshold do not necessarily indicate that adverse health effects are expected to occur, or that the health risks are considered unacceptable. However, an exceedance is normally a trigger for further evaluation of the significance of the estimated risks, which usually incorporates locally validated data as opposed to reliance on default assumptions and models to better reflect local conditions, or it may indicate the need for risk management of the project.

The calculated ILCR is based on model predictions that annual average arsenic concentrations in surface water will increase from 0.00069 mg/L to 0.00455 mg/L. These annual average arsenic concentrations for the Project + Baseline case meet the Canadian Drinking Water Quality Guideline of 0.010 mg/L (Health Canada 2012); however, the estimated lifetime cancer risk associated with the ingestion of drinking water containing arsenic at 0.010 mg/L is greater than the risk level that is considered by Health Canada to be “essentially negligible”.

The oral slope factor of 1.8 $(mg/kg\text{-}day)^{-1}$ used in this assessment was derived by Health Canada based in the incidence of internal (lung, bladder, and liver) cancers in a population in southwestern Taiwan exposed to arsenic levels ranging from 0.35 to 1.14 mg/L of arsenic in their drinking water (Health Canada 2006). Health Canada (2006) acknowledged that the extrapolation method used to estimate the risks of internal organ cancers from exposure to low levels of arsenic, as well as confounding factors (*e.g.*, genetic differences, differences in health status, arsenic metabolism, and nutritional status of the southwestern Taiwanese study population), may lead to an overestimate of the risks of internal organ cancers.

Epidemiological studies conducted in the United States (Steinmaus *et al.* 2003, Lamm *et al.* 2004 and U.S. EPA and AWWA Research Foundation 2004) have not found a clear association between cancer risks and arsenic in drinking water at levels below 0.05 mg/L. More recently, a study of a prospective Danish cohort of 57,053 people that was followed from 1970 to 2003 found no association with lung, bladder, liver, kidney, prostate, colorectal, or skin melanoma cancers from exposure to arsenic drinking water concentrations up to 0.0253 mg/L (Baastrap *et al* 2008), .

Although water from small spring-fed tributaries to Napadogan Brook was observed to be used at recreational campsites, the Napadogan Brook is not a known to be a regular source of drinking water. Therefore, potential exposures to the water are expected to be intermittent, and the assumption that water from the brook would be the sole source of water to a person for two days a week for 80 years overstates the risk.

The maximum predicted annual average concentration of arsenic in Napadogan Brook of 0.00455 mg/L is very unlikely to result in health effects since:

- Napadogan Brook is not used as a regular supply of potable water;
- the predicted concentration meets the Canadian Drinking Water Quality Guideline for arsenic of 0.010 mg/L; and
- recent epidemiological studies have not found an association between cancer risks and arsenic in drinking water at concentrations less than 0.010 mg/L.

7.7.3.4.3.5 Human Health Risks via Ingestion of Food

For the diet exposure pathway, Hazard Quotients were determined for each of the HHERA receptor locations based on ingestion of game, fish and vegetation. A summary of the maximum total HQs for the toddler is provided in Table 7.7.31.

Table 7.7.31 Maximum Non-Carcinogenic Human Health Risks Associated with Ingestion of Food

COPC [a]	Maximum Total Diet Hazard Quotient (HQ, dimensionless)		
	Toddler		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.069	0.0038	0.073
Boron (B)	0.13	**0.21**	**0.34**
Chromium (Cr)	**0.43**	0.042	**0.47**
Cobalt (Co)	**0.37**	0.097	**0.47**
Copper (Cu)	0.076	0.0045	0.081
Lead (Pb)	0.20	0.0045	0.20
Manganese (Mn)	**4.6**	0.089	**4.6**
Mercury (Hg)	0.12	1.7E-05	0.12
Methyl Mercury (fish only)	**0.74**	0.022	**0.76**
Molybdenum (Mo)	0.026	0.022	0.048
Nickel (Ni)	0.16	0.0046	0.16
Thallium (Tl)	**3.8**	**3.8**	**7.6**
Tungsten (W)	0.053	0.0082	0.059

Table 7.7.31 Maximum Non-Carcinogenic Human Health Risks Associated with Ingestion of Food

COPC [a]	Maximum Total Diet Hazard Quotient (HQ, dimensionless)		
	Toddler		
	Baseline Case	Project Alone Case	Project + Baseline Case
Uranium (U)	0.012	0.055	0.067
Vanadium (V)	0.026	0.061	0.087
Zinc (Zn)	0.082	0.007	0.089

Notes:
Bold indicates that value exceeds the applicable benchmark (HQ<0.2).
[a] Arsenic assessed as a carcinogen only (see Table 7.7.33), consistent with Health Canada (2010b)

HQs for the diet pathway were below a HQ of 0.2, with the following exceptions: boron, chromium, cobalt, lead, manganese, methyl mercury (fish only), and thallium.

Further breakdown for these metals that exceed the applicable HQ benchmark in Table 7.7.31 is provided in Table 7.7.32 according to game, fish, and vegetation HQs for the most sensitive life stage (*i.e.,* toddler).

Table 7.7.32 Maximum Non-Carcinogenic Human Health Risks Associated with Ingestion of Game, Fish, and Vegetation

Parameters	Maximum Total Diet Hazard Quotient (HQ)							
Scenario	Baseline Case				Project + Baseline Case			
Pathway	Game	Fish	Vegetation	Total	Game	Fish	Vegetation	Total
Boron (B)	0.020	0.0017	0.11	0.11	0.022	**0.21**	0.11	**0.34**
Chromium (Cr)	0.16	0.040	**0.27**	**0.43**	0.12	0.082	**0.27**	**0.47**
Cobalt (Co)	**0.35**	0.0046	0.011	**0.37**	**0.36**	0.10	0.011	**0.47**
Lead (Pb)	0.0041	0.010	0.18	0.20	0.0043	0.014	0.18	0.20
Manganese (Mn)	**0.26**	0.034	**4.3**	**4.6**	**0.26**	0.11	**4.3**	**4.7**
Methyl Mercury (fish only)	---	**0.74**	---	**0.74**	---	**0.76**	---	**0.76**
Thallium (Tl)	**2.1**	**1.2**	**0.57**	**3.8**	**2.1**	**4.9**	**0.57**	**7.6**

Notes:
--- = in fish, mercury is evaluated as methyl mercury.
Veg = vegetation.
Bold indicates that the value exceeds the applicable benchmark (HQ<0.2).

Results of this analysis indicate the following.

- The predicted future HQs (*i.e.,* the health risks for Project + Baseline Case) associated with chromium, lead, manganese, and methyl mercury (fish only) in food did not increase substantially relative to the health risks associated with the existing conditions (*i.e.*, Baseline Case), as indicated by a change in health risk that is less than 10% relative to existing conditions.

- The predicted future HQs (*i.e.,* the health risks for Project + Baseline Case) associated with boron, cobalt, and thallium in food increased compared to the existing conditions (*i.e.,* baseline case). The change in health risks is associated with the consumption of fish.

Additional discussion of the potential health risks associated with boron, cobalt, and thallium in food is provided later in this section.

The lifetime cancer risk associated with arsenic (*i.e.,* the only COPC that is considered a potential carcinogen via oral exposure) was also assessed at each of the HHERA receptor locations. The maximum health risks are provided in Table 7.7.33. As noted previously, the LCRs associated with the Baseline Case and the Project + Baseline Case have been provided for reference only as there are no benchmarks for the LCR values.

Table 7.7.33 Maximum Carcinogenic Health Risks Associated with Ingestion of Food

COPC	Maximum Diet Lifetime Cancer Risk (LCR or ILCR, dimensionless)		
	Lifetime		
	Baseline Case (LCR)	Project Alone Case (ILCR)	Project + Baseline Case (LCR)
Arsenic (As)	1.9E-04	**6.2E-04**	8.1E-04
Notes: **Bold** indicates that the value exceeds the applicable ILCR benchmark (ILCR<1E-05).			

The ILCRs associated with ingestion of arsenic in food at the HHERA receptor locations were higher than the benchmark of 1 in 100,000 (*i.e.*, ILCR<1E-05).

Table 7.7.34 Maximum Carcinogenic Human Health Risks Associated with Ingestion of Game, Fish, and Vegetation

COPC	Maximum Diet Lifetime Cancer Risk (LCR or ILCR, dimensionless)											
	Lifetime											
	Baseline Case (LCR)				Project Alone Case (ILCR)				Project+ Baseline Case (LCR)			
	Game	Fish	Veg	Total	Game	Fish	Veg	Total	Game	Fish	Veg	Total
Arsenic (As)	3.1E-05	1.1E-04	4.1E-05	1.8E-04	1.8E-06	**7.7E-05**	4.5E-10	**7.9E-05**	3.3E-05	1.9E-04	4.1E-05	2.6E-04
Notes: **Bold** indicates that the value exceeds the applicable ILCR benchmark (ILCR<1E-05).												

Further breakdown for these metals according to game, fish and vegetation ingestion cancer risks are provided in Table 7.7.34. As indicated in Table 7.7.34, the ILCR associated with Project contributions to arsenic in food are related almost entirely to consumption of fish. Additional discussion of the potential health risks associated with arsenic is provided below.

Health Risks Associated with Boron

Boron is a widely occurring element in minerals, and is the 51st most common element found in the earth's crust (ATSDR 2010). Human exposure to boron is typically through consumption of food (boron is an essential element in plants), and to a lesser extent, ingestion of water (ATSDR 2010).

The health risk estimate for boron relied on toxicological data from Health Canada. Health Canada (2010b) provided a tolerable daily intake (TDI) of 0.0175 mg/kg-day for boron, based on information used by Health Canada (1991) to develop the Guidelines for Canadian Drinking Water Quality. The TDI was derived following several studies in mice, dogs, and rats that indicated exposure to boron caused testicular atrophy; however, USEPA IRIS (2004) has published a more recent oral reference dose of 0.2 mg/kg-day for boron, based on developmental effects (*i.e.*, decreased birth weight).

There is very limited information regarding typical boron concentrations in fish tissue samples. In a study completed by Allen *et al.* (2001) of elemental concentrations in fish tissue collected from four different river sites in southeastern Kansas, boron was not detected (*i.e.*, was less than the laboratory detection limit of 2 to 4 mg/kg) in any of the fish tissue samples analyzed. The findings of Allen *et al*.

(2001) are consistent with the baseline sampling in the HHERA Study Area, where boron was not detected in any of the fish carcass samples analyzed (*i.e*., the baseline fish tissue concentration for boron in fish carcass provided in Table 7.7.14 is simply ½ of the laboratory detection limit).

The predicted boron concentration increases in fish tissue relies on both the baseline fish tissue concentrations and on water quality modelling results. Predictive water modelling results indicate that boron concentrations in surface water may increase from less than 0.002 mg/L in the baseline condition to approximately 0.2 mg/L, which is similar to the reported average surface water concentration in the United States of about 0.1 mg/L (ATSDR 2010).

Since boron was not detected in the fish tissue carcass samples from the HHERA Study Area, the use of the ½ detection limit as a basis for predicting future fish tissue concentrations introduces uncertainty. As boron was not detected in fish tissue samples from other areas (Allen *et al.* 2001), and the predicted future surface water concentrations of boron are similar to average surface water concentrations of boron, the fish tissue concentrations used to assess the potential health risks for the Project + Baseline Case may be highly conservative.

Given the conservativeness in the toxicological data and the predicted fish tissue concentrations, it is unlikely that exposure to boron in food will result in adverse health problems.

Health Risks Associated with Cobalt

Cobalt is a naturally occurring element found in rocks, soil, water, plants, and animals, and has properties similar to iron and nickel (ATSDR 2004). At low levels, it is part of vitamin B12, which is essential for good health; however, at high levels, it may harm the lungs and heart (ATSDR 2004). Neither Health Canada nor US EPA IRIS have developed a TRV for oral exposures to cobalt. For the purposes of this assessment, the intermediate minimal risk level of 0.01 mg/kg-day developed by ATSDR (2004) was used to assess the potential health risks (*i.e*., with increases in red blood cell numbers) associated with cobalt as adequate chronic studies of the oral toxicity of cobalt or cobalt compounds in humans and animals are not presently available.

Baseline health risks associated with consumption of cobalt in food (HQ=0.37) is already higher than the benchmark of 0.2. For those instances where the existing conditions (*i.e*., Baseline Case) result in a calculated health risk above the benchmark, Health Canada (2010a) recommended that health risks posed by the Project alone should not exceed 0.2. As indicated in Table 7.7.31, the health risks associated with consumption of food for the Project Alone Case are 0.097. Even when combined with the health risks associated with ingestion of cobalt in water (HQ=0.0013), and exposures to soil (HQ=3.4E-09), the increased health risks associated with Project are less than 0.2, and therefore meet the Health Canada (2010a) recommendation.

Health Risks Associated with Thallium

The available toxicity database for thallium contains studies that are generally of poor quality (USEPA 2009). The TRV for thallium of 0.000014 mg/kg-day used in this assessment was obtained from the California Environmental Protection Agency (Cal EPA 1999), and is based on alopecia (hair loss) in rats. Alopecia is characteristic of thallium toxicity in both animals and humans, and it appears that alopecia is part of a continuum of dermal morphological changes and is therefore an early sign of an adverse health effect (Cal EPA 1999).

The existing concentration of thallium (*i.e.,* Baseline case) in brook trout was 0.017 mg/kg wet weight (whole fish) and 0.014 mg/kg wet weight (carcass). As indicated in Table 7.7.13, predicted future concentrations of thallium in brook trout were up to 0.072 mg/kg wet weight (whole fish) and 0.060 mg/kg wet weight (carcass). These concentrations of thallium in brook trout are less than the thallium concentration in whole fish samples of lake trout collected from Lake Michigan of 0.1408 mg/kg ± 0.1105 mg/kg (Lin *et. al* 2001), and thallium concentrations in whole fish collected from a pristine unaltered ecosystem in Peru by Gutleb *et. al* (2002), that were determined to be within the same range as those reported by Lin *et. al* (2001). Since the maximum predicted concentrations of thallium in fish tissue are less than concentrations of thallium in fish tissue samples from reference or pristine locations, the predicted fish tissue concentrations appear to be within the range of natural variability.

Health Risks Associated with Arsenic

Health Canada reviewed arsenic in food and found it is present at very low levels (low parts per billion [ppb]) in many foods, including meat and poultry, milk and dairy products, bakery goods and cereals, vegetables, and fruits and fruit juices (Health Canada 2008). These trace levels of arsenic generally reflect normal accumulation from the environment.

Carcinogenicity is considered the critical endpoint for arsenic exposures. The oral slope factor of 1.8 $(mg/kg\text{-}day)^{-1}$ used in this assessment was derived by Health Canada based in the incidence of internal (lung, bladder, and liver) cancers in individuals in southwestern Taiwan, and is similar to the oral scope factor of 1.5 $(mg/kg\text{-}day)^{-1}$ developed by the USEPA (2004).

Although arsenic exposures via game ingestion in the HHERA for the Baseline Case were based on a theoretical model (see Section 7.7.2.2.8), the moose tissue concentrations used in the HHERA are similar to published values. Concentrations of arsenic in moose (*i.e.*, game) were studied by the Maliseet Nation Conservation Council (2012), and included 44 moose carcass samples from 12 hunting zones in New Brunswick. The arsenic concentrations of the moose carcass in all samples analyzed were less than 0.05 mg/kg, while the moose tissue concentrations used in the HHERA were 0.0046 mg/kg (Baseline Case) and 0.0048 mg/kg (Project + Baseline Case).

Similarly, the arsenic concentrations in vegetation used in the HHERA were similar to reported concentrations of arsenic in fiddleheads in New Brunswick (Maliseet Nation Conservation Council n.d.). Concentrations of arsenic in 25 fiddlehead samples collected from Jemseg, Sugar Island, Mactaquac and Naskwaaksis had arsenic concentrations of less than 2 mg/kg. The concentrations of arsenic in vegetation used in this HHERA were 0.037 mg/kg for both the Baseline Case and the Project + Baseline Case.

Baseline concentrations of arsenic in brook trout from the HHERA Study Area of 0.89 mg/kg were compared to published fish tissue concentrations obtained from reference locations or natural areas. Baseline concentrations of arsenic in brook trout from the Study Area are higher than the mean total arsenic in rainbow trout (n=100) of 0.15 mg/kg in fish sampled from 54 lakes throughout British Columbia (BC Environment 1992), as well as observed mean concentrations elsewhere in North and South America (Gutleb *et al*. 2002; Hinck *et al*. 2009; Schmitt 2004), suggesting that existing concentrations of arsenic in fish from the HHERA Study Area may be naturally enriched with arsenic. However, the arsenic concentrations in fish tissue of 0.89 mg/kg (Baseline Case) and 1.5 mg/kg

(Project + Baseline Case) are below the Canadian Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products of 3.5 mg/kg for arsenic (CFIA 2007).

Given the similarity between the concentrations of arsenic in game and vegetation within the HHERA Study Area and concentrations found in moose and vegetation elsewhere in New Brunswick, and that the arsenic concentrations in fish tissues for both the Baseline Case and the Project + Baseline Case are below the Canadian guidelines for arsenic in fish tissues, the consumption of arsenic in food from the HHERA Study Area is considered very unlikely to result in adverse health problems.

7.7.3.5 Uncertainty Analysis

All HHRAs have inherent uncertainty, which are addressed by incorporating conservative assumptions into every aspect of the risk assessment. Although many factors contribute to a risk estimate, results are generally sensitive to only a few of these factors, which are described below.

7.7.3.5.1 Uncertainties in Toxicological Information

There is limited toxicological information on the effects associated with low-level chemical exposures to humans. Most information available is based on epidemiological studies of occupationally exposed workers. These are usually based on an 8 h/d or 40 h/week, higher level exposure regimes and do not apply well to low-level, chronic exposures. Additionally reference doses and cancer potency estimates for many contaminants are based on laboratory dose-response estimates in animals. The use of animals requires certain assumptions to be made, which introduces further uncertainty. Assumptions include:

- the toxicological effect in animals also occurs in humans;
- the short-term exposures used in animal studies can be extrapolated to chronic or long term human exposures;
- the toxicokinetic and toxicodynamic processes that occur in animals also occur in humans;
- the uptake of the contaminant from the test vehicle (the medium within which the test compound is delivered to the animals, *e.g.* water) will be representative of the uptake of the contaminant from real-world environmental media (*e.g.,* soil, biota); and
- the assumption that extrapolation from high-dose laboratory studies to low-dose environmental studies accurately reflects the shape of the dose response curve at the low dose-response range.

To account for these and other related uncertainties, regulatory agencies such as Health Canada and the USEPA adopt conservative assumptions to account for uncertainties. The use of Uncertainty Factors accounts for uncertainties by lowering the reference dose of the Hazard Quotient calculation well below the level where no effects were seen in animals. Uncertainty Factors are applied by factors of 10 to account for uncertainties such as, interspecies differences (*e.g.*, physiology), individual variation (*e.g.*, unusually sensitive individuals), limitations in toxicological information, and extrapolation from acute exposures to chronic exposures. Depending on the degree of uncertainty, typical factors will range from 100 to 10,000, with some being lower than 10 (in the case where solid human data is available). The incorporation of these factors results in risk estimates that are extremely conservative and ensure that limited exposures above reference doses or reference concentrations will not result in adverse human health outcomes.

7.7.3.5.2 Sensitive Populations

A susceptible population will exhibit a different or enhanced response to a COPC than will most persons exposed to the same level of the contaminant in the environment. Reasons may be genetic makeup, age (*e.g.*, children or seniors), health and nutritional status, behaviour and exposure to other toxic substances (*e.g.*, cigarette smoke) (ATSDR 2002). Human receptors are selected such that the most sensitive individuals and individuals having the greatest potential for exposure to COPCs and adverse responses from such exposures are represented. For these reasons, a First Nations receptor (toddler and lifetime) was selected. It is assumed that the First Nations receptor will rely exclusively on local wild game, and rely heavily on local fish and vegetation to supplement their diets and therefore represent a high level exposure scenario. The First Nations toddler will represent the most sensitive individual for non-carcinogens for reasons just mentioned plus the physiological (nutritional needs) and behavioural (frequent hand to mouth transfer) considerations associated with children of that age. The non-cancer TRVs used in this risk assessment are estimates of a continuous exposure to the human population, including sensitive subgroups, that are to be without appreciable risk of adverse non-cancer effects during a lifetime. Toxicity doses used in the assessment have accounted for sensitive populations by applying uncertainty factors (see Toxicity Assessment above).

7.7.3.5.3 Uncertainties in Exposure Assessment

As noted in Section 7.7.2.2, the air concentrations and deposition rates are obtained directly from the air dispersion and deposition modelling results while future surface water concentrations were obtained directly from water quality modelling results. Conservative assumptions were used in the development of the air dispersion and deposition model (Section 7.1) and the predictive water quality model (Section 7.6).

Maximum predicted 1-hour, 24-hour, and annual average concentrations in air at each HHERA receptor location were used to evaluate all acute and chronic inhalation risk estimates. In reality, the frequency with which the maximum concentration would occur at any one receptor location is relatively low for most COPC. Therefore, the risk estimates tend to overestimate, rather than underestimate, health risks.

Estimation of COPC uptake through the food chain involves the use of assumptions regarding many factors, including the various uptake factors. Typically, these uptake factors are conservative and tend to overestimate, rather than underestimate, concentrations in biota. In addition, these uptake factors were applied to the reasonable maximum concentrations (*e.g.*, soil concentrations at the end of Operation, maximum annual average surface water concentrations), and are assumed to remain constant throughout the lifetime of the receptor (*e.g.*, 80 years for lifetime exposure); thus, the resulting exposure predictions are conservative.

7.7.3.5.4 Receptor Characteristics

For each receptor scenario, published characteristics and professional judgment were used in determining exposure durations, consumption patterns and ingestion rates (*e.g.,* Health Canada 2009, 2010a). For this assessment, the fraction of the total diet that a First Nations receptor would obtain from the HHERA Study Area (*i.e*., 100% of game, 20% of fish, and 10% of vegetation) represents a reasonable maximum exposure, which likely overstates the potential risk.

7.7.3.5.5 Uncertainties in Risk Characterization

The risk assessment of contaminants is complicated by the reality that most toxicological studies are on single contaminants but exposures are rarely to single contaminants. Exposures generally involve more than one contaminant. Although contaminants in the environment are most often present in some sort of mixture, guidelines for the protection of human health are almost exclusively based on exposure to single contaminants. The lack of approaches to evaluate biological effects of chemical mixtures and the use of single-compound toxicity data makes their use highly speculative.

Chemicals in a mixture may interact in four general ways to elicit a response:

- **Non-interacting –** contaminants have no effect in combination with each other; the toxicity of the mixture is the same as the toxicity of the most toxic component of the mixture;

- **Additive –** contaminants have similar targets and modes of action but do not interact, the hazard for exposure to the mixture is simply the sum of hazards for the individual contaminants;

- **Synergistic –** there is a positive interaction among the contaminants such that the response is greater than would be expected if the contaminants acted independently; or

- **Antagonistic –** there is a negative interaction among contaminants such that the response is less than would be expected if the contaminants acted independently.

For human health exposures, quantitative information on interactions among chemicals in mixtures is rarely available. In the absence of information on the mixture, risk is sometimes based on the addition of the risks of the individual mixture components, unless there is information indicating that the interaction is other than additive in nature. However, this practice is only appropriate if the COPC in question have similar modes of action and similar toxic endpoints in the human body. There is uncertainty associated with any of the above approaches in that risk may be overestimated or underestimated.

In this risk assessment, the COPC-specific HQs, ILCRs and LCRs for a receptor have been characterized for single COPCs only. This approach has been accepted in past risk assessments by various provincial jurisdictions and Health Canada.

7.7.4 Ecological Health Assessment (ERA)

Risk Quotient (RQ) values are used to evaluate health risks to ecological receptors, similar to HQs for human health. However, for the assessment of potential risk to community-based receptors (*e.g.,* soil invertebrates, terrestrial plants), the RQ was calculated by dividing the contaminant concentration in the environmental medium by an appropriate toxicological benchmark concentration, rather than by a daily dose. Ecological health risks have been assessed using RQ in previous assessments accepted by various provincial jurisdictions and Environment Canada. The framework used for this Ecological Risk Assessment (ERA) considered environmental effects at the population level for common mammals and birds, and at the individual level for species identified as “Endangered”, “Threatened”, or “Extirpated” under the *Species at Risk Act* (*SARA*) or under the New Brunswick *Species at Rick Act* (NB *SARA*).

7.7.4.1 Ecological Receptor Identification and Characterization

Key indicators were chosen for the ERA by focusing on wildlife species that are:

- Indigenous to the general area within which the Project is located;
- Likely to be highly exposed to affected environmental media due to their habitat, behavioural traits, and/or home range; or
- Representative of various levels in the trophic web (*e.g.,* herbivore, omnivore, carnivore).

Key indicators are considered to be representative of other wildlife receptors that would have generally similar lifestyle or foraging habits, but may be less likely to be adversely affected. For example, due to their small home range, small herbivorous mammals such as voles or rabbits are expected to be more affected by changes in the local environment than larger herbivores such as moose or deer, which would have a larger home range, and which would average their exposure over a larger area. Likewise, a nesting bird such as the American robin, which must obtain all of the food required to raise a brood of young from within a small radius of the nest site is expected to be more exposed than migratory birds that are simply passing through the area. Therefore, if there is no significant risk to key indicators with smaller home ranges and/or high residency factors when exposed to COPCs in an area of high concern, then by extension there will be no risk to key indicators with larger home ranges, or migratory behaviour, as these organisms are much less exposed than species with a limited home range.

Air dispersion and deposition modelling shows that metal deposition from dust associated with mining activities will be concentrated in areas of high disturbance, near the Project site. Therefore, it is reasonable and conservative to focus the ERA on small mammals and birds that have a small home range or foraging radius. If there are no significant environmental effects on small mammals inhabiting areas of maximum metal deposition closest to the Project site, then there will be no significant environmental effects on larger mammals that forage over much larger areas (where metal deposition decreases with increasing distance from the Project site and at some extent is considered negligible) and/or that are likely to avoid areas of high metal deposition due to the high level of physical disturbance, noise, and/or presence of humans. The species selected as key indicators, and their foraging habits, are listed in Table 7.7.35.

Table 7.7.35 Ecological Receptors Identified as Key Indicators of Risk

Common Name of Species	Scientific Name (Genus and Species)	Foraging Type
Masked shrew	*Sorex cinereus*	Insectivorous mammal
Meadow vole	*Microtus pennsyvanicus*	Herbivorous mammal
Snowshoe hare	*Lepus americanus*	Herbivorous mammal
Red fox	*Vulpes vulpes*	Omnivorous mammal
American mink	*Mustela vison*	Piscivorous mammal
Moose	*Alces alces*	Herbivorous mammal
Black bear	*Ursus americanus*	Herbivorous mammal
American robin	*Turdus migratorius*	Omnivorous bird
Red-tailed hawk	*Buteo jamaicensis*	Carnivorous bird
American black duck	*Anas rubripes*	Insectivorous bird
Belted kingfisher	*Megaceryle alcyon*	Piscivorous bird
Ruffed grouse	*Bonasa umbellus*	Herbivorous bird
Bald eagle	*Haliaeetus leucocephalus*	Piscivorous bird

Several amphibian and reptile species have been identified as being potentially present within the PDA (Section 8.6.2). In order to perform a quantitative ERA, appropriate toxicological data must be available. However, there is a general lack of appropriate toxicological data for amphibians and reptiles. As per ERA guidance (Environment Canada 2010; USEPA 2011), amphibians and reptiles were assessed using a surrogate receptor approach (*i.e.,* if no unacceptable risk is present for fish and other aquatic life, or for mammals and birds, then it is assumed that there is also no unacceptable risk present for amphibian or reptilian receptors).

7.7.4.2 Ecological Receptor Profiles

7.7.4.2.1 Masked Shrew

The masked shrew (*Sorex cinereus*) is the most widely distributed shrew in North America, and is found throughout most of Canada (Lee 2001). It is common in moist environments and is found in open and closed forests, meadows, riverbanks, lakeshores, and willow thickets (Lee 2001). Home range sizes are 0.2 to 0.6 ha (Saunders 1988). Masked shrews, which weigh approximately 5 g (U.S. EPA 1993), are prey to many small predators such as weasels, hawks, falcons, owls, domestic cats, foxes, snakes, and short-tailed shrews (Lee 2001). The masked shrew does not hibernate (NWF 2007), but feeds year-round on invertebrates (Lee 2001; NWF 2007), including insect larvae, ants, beetles, crickets, grasshoppers, spiders, harvestmen, centipedes, slugs, and snails. It will also consume seeds and fungi (Lee 2001). It consumes approximately 3 g (wet weight) of food per day, and 1 mL of water (or its equivalent) per day. The masked shrew's diet is modelled as including 2.5% terrestrial plant material and 97.5% invertebrates. Based on its consumption of these foods, the masked shrew is estimated to incidentally ingest about 0.044 g/day of dry soil.

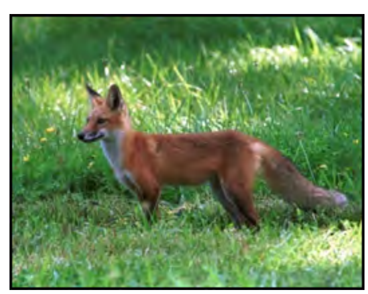
7.7.4.2.2 Meadow Vole

The meadow vole (*Microtus pennsylvanicus*) is a small rodent (approximately 42 g) which makes its burrows along surface runways in grasses or other herbaceous vegetation (USEPA 1993). It is active year-round and is the most widely distributed small grazing herbivore in North America, inhabiting moist to wet habitats including grassy fields, marshes, and bogs (USEPA 1993). Meadow voles are found throughout Canada, roughly to the limit of the tree line in the north. Home ranges vary considerably, from less than 0.0002 ha to greater than 0.083 ha (USEPA 1993). Meadow voles are a major prey item for predators such as hawks and foxes, and they feed primarily on vegetation such as grasses, leaves, sedges, seeds, roots, bark, fruits, and fungi, but will occasionally feed on insects and animal matter (USEPA 1993; Neuburger 1999). It consumes approximately 11 g (wet weight) of food per day and 6 mL of water (or its equivalent) per day. The meadow vole's diet is modelled as including 98% terrestrial plant material and 2% invertebrates. Based on its consumption of these foods, the meadow vole is estimated to incidentally ingest approximately 0.32 g/day of dry soil.

7.7.4.2.3 Snowshoe Hare

The snowshoe hare (*Lepus americanus*) is an herbivore weighing approximately 1.35 kg (USEPA 1993), which is found throughout Canada in every province and territory (CWS & CWF 2005a). The snowshoe hare tends to inhabit forests, swamps, and riverside thickets (USEPA 1993). Home ranges vary from 3 ha to 7 ha (Shefferly 1999). A frequent prey item, the snowshoe hare may be a keystone species in boreal forests, maintaining food webs (CWS & CWF 2005a). Active year-round, it feeds on herbaceous plants and leaves from shrubs in summer, and small twigs, buds, and bark in winter; it will eat meat occasionally, if available (CWS & CWF 2005a). The snowshoe hare consumes approximately 0.26 kg of wet weight food per day and 0.13 L of water (or its equivalent) per day. The snowshoe hare's diet is modelled as including 95% terrestrial plant material and 5% small mammal or bird carrion. Based on its consumption of these foods, the snowshoe hare is estimated to incidentally ingest 3.58 g/day of dry soil.

7.7.4.2.4 Red Fox



The red fox (*Vulpes vulpes*), which weighs approximately 4.5 kg, is found throughout continental Canada and is the most widely distributed carnivore in the world (USEPA 1993). It is found in habitats as diverse as the Arctic and the temperate desert, and prefers areas with broken and diverse upland habitats (USEPA 1993). Family territories, which consist of home ranges of individuals from the same family, vary from approximately 57 ha to more than 3,000 ha (USEPA 1993). Foxes are active year-round and prey heavily on small mammals such as voles, mice and rabbits, and will also consume birds, insects, fruits, berries, and nuts; they are also noted scavengers (USEPA 1993). Red foxes consume approximately 0.76 kg (wet weight) of food per day and 0.38 L of water (or its equivalent) per day. The red fox's diet is modelled as including 10%

terrestrial plant material, 5% invertebrates, and 85% small mammal and bird prey. Based on its consumption of these foods, the red fox is estimated to incidentally ingest approximately 3 g/day of dry soil.

7.7.4.2.5 American Mink

The mink (*Mustela vison*), which weighs approximately 0.85 kg, is a small member of the weasel family and is the most abundant and widely distributed carnivorous mammal in North America (USEPA 1993). Mink are found throughout the continental portion of Canada, including Newfoundland, except in the most barren portions of northwestern Quebec, and eastern Nunavut. Minks are active year round and are associated with aquatic habitats such as rivers, streams, lakes, ditches, swamps, marshes, and backwater areas (USEPA 1993). Home ranges vary considerably but are in the range of 7.8 to 380 ha (USEPA 1993). Feeding extensively on small mammals, fish, amphibians, and crustaceans, as well as birds, reptiles, and insects depending on the season (USEPA 1993), mink consume approximately 0.22 kg of wet weight food per day and 0.09 L of water (or its equivalent) per day. The mink's diet comprises mainly small mammals or birds, as well as freshwater fish and benthic invertebrates. For this ERA, the mink's diet is assumed to comprise solely freshwater fish.

7.7.4.2.6 Moose

In Canada, moose (*Alces alces*) can be found inhabiting forests from the Alaskan boundary to the eastern tip of Newfoundland and Labrador (CWS & CWF 1997). Their geographic distribution follows, but is not confined to, the boundaries of the boreal forest. Moose are highly dimorphic between sexes, with cows weighing much less than bulls. The average body weight (for both sexes) is 435 kg, although bulls of the northern sub-species, *A. A. gigans*, can weigh as much as 800 kg (Dewey *et al.* 2000; NWF 2007; CWS & CWF 1997). Although seasonal home ranges are surprisingly small for a large herbivorous animal (500 to 1,000 ha), annual home ranges can be up to 4,000 ha or more depending on habitat and food availability (BC MOE 2000; Lawson & Rodgers 1997 in NaturServe 2006). Seasonal migration usually follows an elevational gradient, as moose seek higher grounds in summer and lower elevations in winter. Moose are entirely herbivorous, consuming an estimated 18.6 kg/day (wet weight) of food, comprised of a mixture of terrestrial and aquatic vegetation. The name “Moose” is derived from an Algonkian term meaning “eater of twigs”, and this appropriately reflected in their diet (Yukon DOE 2006). In winter, the diet consists primarily of confer and hardwood twigs and shrubs (CWS & CWF 1997; NatureServe 2006; Dewey *et al.* 2000). The summer diet is more variable, consisting of leaves, twigs, bark, roots, and shoots of woody plants, as well as some grasses. Additionally, a considerable portion of the summer diet is aquatic vegetation (*e.g.,* lilies, pondweed, *etc.*), which moose will occasionally dive underwater to retrieve (CWS & CWF 1997; NatureServe 2006; Dewey *et al.* 2000). Based on its consumption of these foods, the moose is estimated to incidentally ingest 0.14 kg/day of dry soil and 0.11 kg/day dry sediment. Water Intake is estimated to be approximately 23.5 L/day.

7.7.4.2.7 Black Bear

The American black bear (*Ursus americanus*) is smaller than the grizzly bear (*Ursus arctos*) or the polar bear (*Ursus maritimus*), weighing approximately 68 kg (Eder and Pattie 2001). Found throughout most of Canada (with the exception of the Arctic and southern portions of the prairies and Ontario), black bears prefer heavily wooded areas and dense bushland (CWS & CWF 2007). Not a true hibernator, the black bear enters its den in October to December and emerges in March to early May (Kronk 2007). Average home range sizes are approximately 1,000 to 4,000 ha for females and often more than 10,000 ha for males (CWS & CWF 2007). Although black bears will eat almost anything, their diets rely heavily on vegetation, consisting of berries and nuts, as well as insects such as ants which are also a favorite (CWS & CWF 2007). When available, they will supplement their diet with newborn ungulates, small mammals and birds, as well as fish (CWS & CWF 2007). Black bears consume approximately 14.0 kg of wet weight food per day and 4.1 L of water or its equivalent per day.

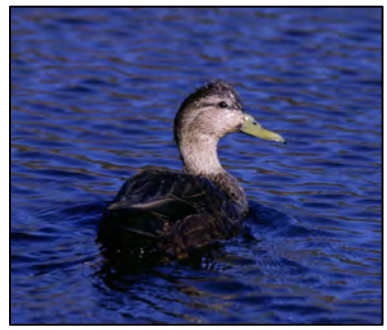
7.7.4.2.8 American Robin

The American robin (*Turdus migratorius*) is a medium-sized bird weighing approximately 80 g (USEPA 1993) that occurs throughout most of Canada during the breeding season and overwinters in mild areas of Canada (CWS & CWF 2005b). Access to fresh water, protected breeding habitat, and foraging areas are important to the American robin. Breeding habitat includes moist forest, swamps, open woodlands, orchards, parks, and lawns (USEPA 1993), and the American robin is well adapted to urban living, as well as having a summer range that extends up to the tundra. Foraging home range sizes (for fruit, earthworms, and insects) are approximately 0.15 to 0.81 ha (USEPA 1993). The American robin consumes approximately 65 g (wet weight) of food per day and 10 mL of water (or its equivalent) per day. The American robin diet is modelled as including 52.3% terrestrial plant material and 47.8% soil invertebrates. Based on its consumption of these foods, the American robin is estimated to incidentally ingest 0.49 g/day of dry soil.

7.7.4.2.9 Red-tailed Hawk

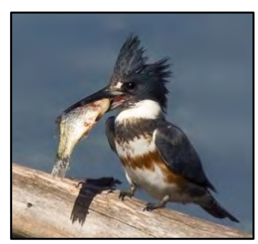
The red-tailed hawk (*Buteo jamaicensis*) is the most common and widespread hawk in North America (Cornell Lab of Ornithology 2003). The red-tailed hawk weighs approximately 1.1 kg (USEPA 1993). It breeds throughout southern Canada except in Newfoundland (Tufts 1986), where a similar niche is occupied by the short-eared owl. Northern populations of the red-tailed hawk are migratory, while populations from southern Canada may be year-round residents (USEPA 1993; Cornell Lab of Ornithology 2003). They are typically found in open areas with scattered, elevated perches in a wide range of habitats including scrub deserts, plains and montane grasslands, agricultural fields, pastures, urban parks, patchy coniferous and deciduous woodlands, and tropical rainforests (Arnold and Dewey 2002). Red-tailed hawks prefer a mixed landscape containing old fields, wetlands, and pastures for foraging, interspersed with groves of woodland, bluffs, or streamside trees for perching and breeding (USEPA 1993). Red-tailed hawk's home ranges vary in size from approximately 60 ha to greater than 2,400 ha, depending on the habitat (USEPA 1993, Arnold and Dewey 2002). They generally hunt from an elevated perch, foraging primarily (approximately 80 to 85% of diet) on small rodents such as mice, voles, shrews, rabbits, and squirrels, as well as birds and reptiles (Arnold and Dewey 2002). They consume approximately 190 g (wet weight) of food per day and 60 mL of water (or its equivalent) per day. The red-tailed hawk diet is modelled as including 100 percent terrestrial mammals. Based on its consumption of these foods, the red-tailed hawk is estimated to incidentally ingest approximately 0.66 g/day of dry soil.

7.7.4.2.10 American Black Duck



The American black duck (*Anas rubripes*) is found in wooded parts of northeastern and north central North America (*i.e.,* from Manitoba east in Canada), nesting near woodland lakes and streams, or in freshwater and tidal marshes (USEPA 1993). Although all ducks tend to return to the same feeding grounds every year, this tendency is most pronounced in the American black duck (CWS & CWF 1980). The American black duck weighs approximately 1.16 kg. Home range sizes for the American black duck are similar in size to the mallard duck using the same habitat varying in size from approximately 40 ha to 1,400 ha (USEPA 1993). The American black duck feeds primarily on aquatic invertebrates as ducklings and adults during the breeding season and on aquatic and terrestrial plants during the nonbreeding season (CWS & CWF 1980). Breeding females consume approximately 0.61 kg of wet weight food per day and 0.07 L of water (or its equivalent) per day. The duck's diet is modelled as including 12.5% terrestrial plant material, 12.5% aquatic plant material, and 75% benthic invertebrates. Based on its consumption of these foods, the duck is estimated to incidentally ingest 0.438 g/day of dry soil, and 12.4 g/day of dry sediment.

7.7.4.2.11 Belted Kingfisher



The belted kingfisher (*Ceryle alcyon*) occurs throughout southern Canada (as far north as James Bay, across the northern portions of the Prairie Provinces, into the Yukon in the west, and into northern Quebec and southern Labrador in the east). Belted kingfishers are typically found along rivers and streams, lake and pond edges, or on seacoasts and estuaries (USEPA 1993). They usually nest in burrows in a steep bank, preferably near water, and the tunnels may extend as far as 5 m before ending in a nest chamber. The belted kingfisher weighs approximately 0.15 kg. Foraging territory sizes range from approximately 2 ha to greater than 10 ha (assuming a watercourse width of 50 m), depending on the season (USEPA 1993). Feeding primarily on fish, they prefer stream riffles and waters that are free from thick vegetation in order to see their prey (USEPA 1993). Belted kingfisher will also consume aquatic invertebrates, insects, mammals, birds, reptiles and amphibians (USEPA 1993). They consume approximately 0.06 kg of wet weight food per day and 0.02 L of water (or its equivalent) per day. For this ERA, the belted kingfisher's diet is assumed to comprise solely freshwater fish.

7.7.4.2.12 Ruffed Grouse

The Ruffed Grouse (*Bonasa umbellus*) is frequently called the "partridge." The Ruffed grouse lives in treed areas, usually where birch and poplar are present (Centre d'Expertise en Analyse Environnementale du Quebec 2005). The approximate weight of a ruffed grouse is 500 g (Centre d'Expertise en Analyse Environnementale du Québec 2005; CWS & CWF 1986). Male ruffed grouse are larger than the females (males 500 to 750 g; females 450 to 600 g) (CWS & CWF 1986). It is difficult to determine if a grouse is male or female at a distance, but males are larger with larger ruffs and a longer tail. Ruffed grouse do not migrate and once established in an area, live all their life within a few hectares. During winter months, ruffed grouse burrow into the snow to protect themselves from the cold and predators. If the snow is deep and soft, the ruffed grouse can walk across the snow with the help of their "snowshoes", which are lateral extensions of the scales of the toes (CWS & CWF 1986). The home range of a ruffed grouse is approximately 2.1 ha. The ruffed grouse spend most of their lives on the ground and are mainly herbivorous, foraging on buds, leaves, twigs. In the winter, catkins and the buds of broad-leaved trees such as poplars, birch, and alders are the preferred food source. Ruffed grouse chicks will also feed on insects when they are available (CWS & CWF 1986). Ruffed grouse are estimated to consume approximately 65 g (wet weight) of food per day (Nagy 1987) and 37 mL of water (Calder and Braun 1983) (or its equivalent) per day. The grouse's diet is modelled as including 99.6% terrestrial plant material and 0.4% soil invertebrates. Based on its consumption of these foods, the ruffed grouse is estimated to incidentally ingest approximately 0.11 g/day of dry soil.

7.7.4.2.13 Bald Eagle

The bald eagle is the second largest bird of prey found in North America, and the largest found in Canada (CWS & CWF 1992). Adult birds are readily identified by their striking appearance, characterized by dark brown body plumage contrasting sharply with white head and tail plumage (Buehler 2000). The bald eagle is restricted in range entirely to North America, where it prefers sea coasts, lake shores, or riverine habitat possessing suitable nesting trees in which to breed. Female bald eagles are larger than males by up to 25%, and birds from northern latitudes (Canada and Alaska) are larger than their counterparts in the southeastern and southwestern United States (Buehler 2000). The typical body mass of the bald eagle ranges from 3,000 to 6,300 g (Palmer *et al.* 1988 in Buehler 2000), although masses of 7,000 g have been recorded (CWS & CWF 1992). Immature eagles grow rapidly owing to a voracious appetite. Bald eagles are opportunistic feeders, taking live prey when available but preferring to scavenge carrion or pirate freshly killed prey from other predators (CWS & CWF 1992; USEPA 1993). Their preferred food items include fish, aquatic birds, and mammals; however choice of prey is site-specific and may vary widely across their range (Buehler 2000). Adult birds are more likely to hunt and kill food items whereas immature birds are more prone to obtaining food through scavenging and piracy (CWS & CWF 1992). Bald eagles are modelled as consuming 45% terrestrial vertebrates (mammals and birds) and 55% freshwater fish. The bald eagle consumes 0.649 kg of wet weight food per day and 0.162 L of fresh water per day, and ingests 0.0879 g of soil and 1.02 g of sediment per day.

7.7.4.2.14 Soil Invertebrates and Terrestrial Plants

For soil invertebrates and terrestrial plants, it is more appropriate to assess potential risk at the community level (*i.e.*, all terrestrial plants living in a contaminated area), than to consider individual species. As shown in the conceptual site model (Figure 7.7.5), the primary exposure pathway to COPCs for these key indicators is from direct contact with soil. The toxicity of COPCs in this medium is of principal importance when assessing the potential risks to these key indicators. Therefore, toxicity benchmarks are commonly derived which relate COPC concentrations in various media to adverse effects thresholds for organisms that reside or rely on that medium. Additionally, these benchmarks are typically generated using toxicity data for not one, but several species that rely on that medium. They are intended to represent a COPC concentration that will be protective of species associated with that medium (*i.e.*, the soil invertebrate community).

7.7.4.2.15 Benthic Invertebrates

Similarly as for the terrestrial community, it is more appropriate to assess potential risk to benthic invertebrates at the community level (*i.e.*, all terrestrial plants living in a contaminated area), than to consider individual species. As shown in the conceptual site model (Figure 7.7.5), the primary exposure pathway to COPCs for these key indicators is from direct contact with sediment. Sediment concentrations were compared to the available Canadian Sediment Quality Guidelines for the Protection of Aquatic Life probable effect levels which are generated using toxicity data for a range of benthic invertebrates.

7.7.4.3 Ecological Receptor Locations

Forty-six terrestrial receptor locations were selected to be assessed in the ERA, based on a 2 km x 2 km grid distributed across the Project site. The receptor locations were selected to include areas of anticipated high dust deposition, as well as providing a gradient to background conditions. Of the forty-six receptor locations, twenty-seven were considered to contain only terrestrial habitat, whereas nineteen were traversed by watercourses, of which some portions will be exposed to mine effluent or to seepage from the tailings storage facility. Therefore, those nineteen receptor locations were modelled as including aquatic receptor locations, in addition to terrestrial receptor locations. The aquatic receptor locations include fifteen sites on West Branch Napadogan Brook or its tributaries upstream and downstream of the PDA, and four locations on McBean Brook downstream of the PDA.

7.7.4.3.1 Exposure Pathway Screening

Contaminant transport and exposure pathways are used to describe the movement of COPCs from a release point or source (*e.g.,* ore dust released by mining activity, and mine effluent or other releases to watercourses) to the eventual point of contact with key indicators (*e.g.,* direct exposure or ingestion). The exposure pathway screening incorporates information about Project-related COPC releases, activities in the area, receptor characteristics, and the exposure pathways. For this ERA, it is assumed that ecological receptors can be exposed to contaminants in the environment by:

- direct contact with contaminated soil or water;

- ingestion of soil and water (*e.g.,* as a result of foraging, drinking, or grooming); and/or
- ingestion of foods that have accumulated COPCs from soil or other media.

Identifying the potential exposure pathways involves consideration of several factors including the life history traits of each key indicator (*e.g.*, habitat, diet), features of the mine site (*e.g.*, biota, habitat suitability), and environmental fate and transport properties of each COPC. A summary of potential exposure pathways for ecological receptors and the rationale for inclusion or exclusion from this ERA is shown in Table 7.7.36.

Table 7.7.36 Rationale for Exposure Pathway Inclusion in the ERA

Exposure Pathway	Included in the ERA?	Rationale
Soil Ingestion	Yes	Ecological receptors may ingest soil containing COPCs directly or indirectly as a result of consuming food items. Soil or dust may also be ingested as a result of grooming activity, nest or den construction and maintenance, or as a consequence of inhalation, if dust particles inhaled into the lung are coughed up and swallowed. Ingestion of soil, therefore, constitutes a potential source of exposure to mammalian and avian receptors.
Direct Contact with Soil	Yes	Direct contact with soil is the primary exposure pathway for soil invertebrates and plants. Direct (dermal) contact with soil could be a potential pathway for absorption of COPC by mammals and birds. It is not, however, expected to represent a major source of exposure for most mammalian and avian receptors due to the protection afforded by fur or feathers, which will significantly reduce soil contact with skin (Sample and Suter 1994). Soil adhering to fur and feathers may be ingested during grooming activity; however, this is captured as a component of incidental soil ingestion estimates.
Inhalation	No	Ecological receptors may be exposed to COPCs via inhalation of dust. However, this exposure pathway is believed to represent a relatively minor component of overall exposure. Toxicological dose/response models for inhaled COPCs are not necessarily the same as for ingested COPCs, and toxicological data to support the evaluation of inhalation as an exposure mechanism are generally lacking. Therefore, inhalation is not considered further in this ERA.
Ingestion of Foods from the Terrestrial Environment	Yes	The consumption of contaminated foods such as terrestrial plants, soil invertebrates, small mammals, birds or fish can be a source of exposure for mammalian and avian receptors.
Surface Water Ingestion	Yes	Ecological receptors may be exposed to COPCs present in surface water if they drink from these sources.
Ingestion of Foods from the Aquatic Environment	Yes	Some mammalian and avian receptors may consume foods (*e.g.*, fish) derived from the aquatic environment. Since the aquatic systems within and adjacent to the PDA are predominantly high- to medium-gradient streams, emphasis is placed on fish, rather than aquatic plants.
Direct Contact with Surface Water	No	Aquatic receptors (*e.g.*, fish, aquatic plants, and aquatic invertebrates) are addressed through the environmental effects assessment of the Aquatic Environment (Section 8.5), and are therefore not included in this ERA. This consideration is also assumed to extend to amphibians, which have an aquatic larval stage. For mammalian and avian receptors, direct contact with surface water is assumed to be a minor exposure pathway in comparison with direct ingestion of water, and ingestion of foods (*e.g.*, fish) from the aquatic environment.

Table 7.7.36 Rationale for Exposure Pathway Inclusion in the ERA

Exposure Pathway	Included in the ERA?	Rationale
Ingestion of Sediment	Yes	Ecological receptors may ingest sediment containing COPCs directly or indirectly as a result of consuming food items. Sediment may also be ingested as a result of grooming activity, nest or den construction and maintenance. Ingestion of sediment, therefore, constitutes a potential source of exposure to mammalian and avian receptors.
Ingestion of Foods from the Benthic Environment	Yes	Some mammalian and avian receptors may consume foods (*e.g.*, benthic invertebrates) derived from the benthic environment, therefore, this pathway was considered in the ERA.
Direct Contact with Sediment	Yes	Direct contact with sediment is the primary exposure pathway for benthic invertebrates. For mammalian and avian receptors, direct contact with sediment is assumed to be a minor exposure pathway in comparison with direct ingestion of sediment, and ingestion of foods (*e.g.*, fish) from the benthic environment.

The conceptual site model developed for this site, presented schematically in Figure 7.7.5, represents the interactions between the receptors and the COPCs, via the identified exposure pathways. In Figure 7.7.5, the relevant exposure pathways are designated by arrows leading from the contaminant source media to each receptor. The pathway is considered to be complete (*i.e.,* functioning) for a receptor when the exposure pathway box is marked with an "X".

Source Media	Exposure Media	Potential Exposure Pathways	Terrestrial Plant Community	Soil Invertebrate Community	Benthic Invertebrate Community	Masked Shrew (insectivore)	Meadow Vole (herbivore)	Snowshoe Hare (herbivore)	Red Fox (carnivore)	American Mink (carnivore/piscivore)	Moose (herbivore)	Black Bear (omnivore)	American Robin (omnivore)	Red-tailed Hawk (carnivore)	American Black Duck (insectivore)	Belted Kingfisher (piscivore)	Ruffed Grouse (herbivore)	Inland Bald Eagle (piscivore/carnivore)
Surface Soil	Surface Soil	Direct Exposure	X	X														
		Ingestion				X	X	X	X	X	X	X	X	X	X	X	X	X
	[Uptake] Plants	Ingestion				X	X	X	X		X	X	X		X		X	
	[Uptake] Soil Invertebrates	Ingestion				X	X		X			X	X			X	X	
	[Uptake] Small Mammals/Birds	Ingestion						X	X	X		X		X		X		X
Surface Water	Surface Water	Ingestion				X	X	X	X	X	X	X	X	X	X	X	X	X
[Uptake]	[Uptake] Fish	Ingestion								X		X				X		X
Sediment	Sediment	Direct Exposure			X													
		Ingestion								X	X				X	X		X
	[Uptake] Benthic Invertebrates	Ingestion								X					X	X		

SOURCE → RECEPTOR

Note:
1) **X** - Indicates a potentially complete exposure pathway.
2) Aquatic Plants are not considered since these are of limited quantity in the study area. Birds and mammals are assumed to replace this portion of their diet with terrestrial plants.

Figure 7.7.5 Conceptual Site Model for Ecological Receptors

7.7.4.4 Exposure Assessment

The objective of the exposure assessment is to develop a quantitative estimate of the exposure of each key indicator to each COPC, based on empirical or modelled data.

7.7.4.4.1 Calculation of Average Daily Dose

In order to conduct a risk assessment, it is necessary to estimate the amount of a COPC a receptor organism might be exposed to on a mg/kg body weight/day basis (referred to as the average daily dose, or ADD). For each receptor, the ADD was calculated for each COPC by considering the intake from all applicable exposure pathways (*e.g.,* ingestion of water, soil, vegetation, soil invertebrates, small mammals, fish, sediment, and/or benthic invertebrates, as appropriate). For this ERA, it is conservatively assumed that all of an ingested quantity of COPC will be absorbed across the gut and enter the bloodstream of the receptor organism, and therefore the absorption factor (AF, unitless) has a default value of 1.0. The generalized form for ADD is as follows:

$$ADD_i = IF \text{ X } AF_i \text{ X } EPC_i$$

where:

ADD_i = Average daily dose for COPC *i* (mg COPC/kg body weight/day);

IF = Intake factor (kg medium/kg body weight/day);

AF_i = Absorption factor for COPC *i* (conservatively set at 1.0 which assumes that 100% of the COPC is absorbed; unitless); and

EPC_i = Exposure point concentration for COPC *i* (mg COPC/kg medium).

The IF is calculated for each exposure pathway using the media-specific ingestion rate (IR) appropriate to each receptor. The IF is also a function of the fraction of time each receptor spends at the site (f_{Site}), which was conservatively set at 1.0 for this ERA which assumes that receptor spends 100% of their time within the PDA, and a function of the receptor's body weight (BW), as follows:

$$IF = (IR \times f_{Site})/BW$$

The total ADD value for each receptor organism is then the sum of the individual ADD_i values representing its various exposure pathways.

7.7.4.5 Hazard Assessment

The hazard assessment (also known as a toxicity assessment) is the process by which the potential toxicity of each COPC is determined. The toxicity of a contaminant (*i.e.,* its ability to harm or cause damage to the functioning of the receptor) is an inherent property of the contaminant itself, although subject to potential modifying factors. Toxicity is usually evaluated by administering measured doses of a contaminant to a test organism. One modifying factor is the fraction of the dose that is absorbed, and toxicity studies usually address this by administering doses in a way, or using a particular contaminant form, that results in maximum absorption.

Chemical interactions can also modify toxicity, and contaminant mixtures may interact in four general ways to elicit a response:

- **Non-interacting –** contaminants do not produce a response in combination with each other; the toxicity of the mixture is the same as the toxicity of the most toxic component of the mixture;
- **Additive –** contaminants have similar targets and modes of action but do not interact, the hazard for exposure to the mixture is simply the sum of hazards for the individual contaminants;
- **Synergistic –** there is a positive interaction among the contaminants such that the response is greater than would be expected if the contaminants acted independently or in an additive manner; or
- **Antagonistic –** there is a negative interaction among the contaminants such that the response is less than would be expected if the contaminants acted independently or in an additive manner.

There are contaminant classes that have similar modes of action and target organs, and in these cases, a more appropriate characterization of risk is achieved by summing the RQ for each compound. The COPCs evaluated in this ERA are mainly trace metals. Few data are available to describe the toxicity of metal mixtures. Therefore, contaminant mixtures were not considered in this ERA, and the potential toxicity of each COPC is evaluated in isolation. This approach has been accepted in previous assessments by various provincial jurisdictions and Environment Canada.

7.7.4.6 Toxicological Reference Values

The amount of a substance that can be tolerated, below which adverse effects are not expected to be observed, is referred to as the toxicological reference value (TRV). The toxicological database in support of a TRV ideally includes a number of chronic or multi-generational exposure studies involving exposure of relevant test species (*i.e.,* the ecological receptor of interest or a phylogenetically similar species (*i.e.,* species of similar evolutionary relationships)) to appropriate contaminant forms of the substance of interest. Ideally, one or more relevant biological endpoints such as growth, reproductive effects, or survival would be measured in the study. Databases that meet this requirement are available for some contaminants, but in most cases, available toxicity data are limited to studies conducted with laboratory or domesticated animals (*e.g.,* mammals: mice, rats, rabbits; birds: quail, chicken, and ducks).

Toxicity reference values for this ERA are based on dose response studies, typically conducted with laboratory animals where the lowest observed adverse effects level (LOAEL) or no observed adverse effects level (NOAEL) has been quantified. The continued use of the LOAEL and NOAEL in toxicology has recently been criticized, and it is true that these measures can be influenced by methodological decisions (*e.g.,* the selection of specific concentrations and exposure sequences during study design). However, it remains that most available toxicity studies were conducted in an era when these were preferred endpoints, and such studies dominate the available literature. In addition, TRVs used in this ERA were determined from studies in which endpoints were derived from the administered doses, rather than the absorbed doses. This is a conservative approach because compounds are often administered in a more available form than would be found in the environment.

The preferred toxicity measure used for derivation of TRVs in this ERA is the LOAEL; however, in the absence of a suitable LOAEL, NOAEL-based TRVs were used. The LOAEL identifies the lowest exposure concentration or dose level at which some adverse effect was observed, and can therefore be considered a threshold for the onset of effects that could affect individual organisms (but not necessarily populations). Generally, LOAELs used towards TRV derivation are based on long-term growth or survival, or sub-lethal reproductive effects determined from chronic exposure studies. As such, these endpoints are relevant to the maintenance of wildlife populations. The LOAEL represents a threshold dose at which adverse outcomes are likely to become evident (Sample *et al.* 1996). This threshold is considered an appropriate endpoint for ERA since TRVs are used as the denominator in the risk quotient (RQ) calculation, and RQ values equal to or greater than 1.0 may be considered indicative of potential adverse environmental effects on ecological receptors.

Risk quotients calculated with NOAEL-based TRVs are more conservative since NOAELs relate to the threshold at which no individual effects from COPC exposure are observed. NOAEL-based TRVs can be used to provide a higher level of protection, as in the case where an endangered species is under evaluation, and affects at an individual level would be unacceptable.

Numerous sources were reviewed to obtain the most relevant TRVs for ecological receptors. Information sources included, but were not limited to:

- CCME Environmental Quality Guidelines; (CCME 1999 and updates);
- USEPA Ecological Soil Screening Level (Eco-SSL) documents;
- Oak Ridge National Laboratory Toxicity Benchmarks for Wildlife (Sample *et al.* 1996);
- Agency for Toxic Substances and Disease Registry (ATSDR) toxicity profiles;
- *Canadian Environmental Protection Act* (CEPA), Priority Substance List Assessment Reports; and
- Primary scientific literature.

7.7.4.7 Ecological Risk Characterization

The potential for adverse environmental effects on mammalian and avian receptors is quantified by comparing the amount of a substance that can be tolerated, below which adverse environmental effects are not expected (*i.e.*, the TRV) with the amount of a COPC an organism is expected to be exposed to on a daily basis (*i.e.,* the ADD). The quotient of the two (the risk quotient, or RQ) is used to make inferences about the possibility of ecological risks. The RQ is calculated as follows:

$$RQ = ADD/TRV.$$

When the ADD is less than the TRV associated with a potential for adverse environmental effects, the RQ value is less than 1.0. As such, RQ values less than 1.0 are taken to indicate that there is a negligible probability of adverse environmental effects occurring to ecological receptors. Where RQ values are greater than 1.0, there is a possibility (but not a certainty) of adverse environmental effects to ecological receptors. Such cases require a careful review of both predicted exposure levels and

TRV derivations, and more focused investigations may be required to reduce conservatism in the assessment to provide a more accurate assessment of the actual level of risk. If it is ultimately determined that the RQ is indicating unacceptable risk, then mitigation or remediation activities may be appropriate in order to reduce risks to ecological receptors.

The maximum risk quotients for mammalian and avian receptors are summarized in Tables 7.7.37 through 7.7.49. Maximum risk quotients presented in these tables correspond to the maximum values encountered and may not represent co-occurring values at the same location. COPCs demonstrating risk quotients higher than 1.0 are also presented spatially in Figures to 7.7.6 to 7.7.12.

For ease in interpreting Figures 7.7.6 to 7.7.12, grid squares in each figure correspond to grid squares as established in Figure 7.7.3. A particular grid square is identified by a letter and a number, corresponding to the letter on the x-axis of Figure 7.7.3 and the number on the y-axis of Figure 7.7.3 (*e.g.,* "Grid G8"). The grid squares are colour coded for quick identification of the resulting Risk Quotient (RQ) for that particular species in the grid square, with a green square corresponding to an RQ<1.0 and a red square corresponding to an RQ>1.0. Grey and white grid squares indicate that risk was not calculated for those particular grid squares either because there were no soil samples (grey squares) or, for the case of a semi-aquatic receptor, there is no watercourse at that location (white squares).

7.7.4.7.1 Risk Characterization for Terrestrial Ecological Receptors

Maximum risk quotients for terrestrial mammals (*i.e.,* masked shrew, meadow vole, snowshoe hare, red fox, moose and bear, Tables 7.7.37 to 7.7.42) were generally less than 1.0, with the exception of the masked shrew exposed to arsenic, copper, manganese and zinc for both the Baseline Case and Project + Baseline Case and the meadow vole exposed to arsenic for both the Baseline Case and Project + Baseline Case.

Table 7.7.37 Maximum Overall Risk Quotients for the Masked Shrew

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Masked Shrew		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.15	6.7E-04	0.15
Arsenic (As)	**2.9**	0.020	**2.9**
Boron (B)	0.012	1.6E-03	0.013
Chromium (total) (Cr)	0.26	7.0E-04	0.26
Cobalt (Co)	0.091	8.1E-05	0.091
Copper (Cu)	**1.63**	1.4E-03	**1.63**
Lead (Pb)	0.099	7.6E-06	0.099
Manganese (Mn)	**1.0**	1.4E-03	**1.0**
Mercury (Hg)	0.047	2.7E-06	0.047
Molybdenum (Mo)	0.099	4.3E-03	0.099
Nickel (Ni)	0.66	1.3E-03	0.66
Thallium (Tl)	0.088	4.5E-04	0.088
Tungsten (W)	0.047	7.2E-03	0.048

Table 7.7.37 Maximum Overall Risk Quotients for the Masked Shrew

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Masked Shrew		
	Baseline Case	Project Alone Case	Project + Baseline Case
Uranium (U)	7.4E-03	1.5E-04	7.4E-03
Vanadium (V)	0.79	4.2E-03	0.79
Zinc (Zn)	**1.1**	8.9E-05	**1.1**

Notes:
Bold indicates that value exceeds the RQ target (1.0).

Table 7.7.38 Maximum Overall Risk Quotients for the Meadow Vole

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Meadow Vole		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.033	5.2E-04	0.033
Arsenic (As)	**1.4**	0.014	**1.4**
Boron (B)	5.3E-03	1.2E-03	6.2E-03
Chromium (total) (Cr)	0.15	5.0E-04	0.15
Cobalt (Co)	0.026	5.8E-05	0.026
Copper (Cu)	0.31	9.9E-04	0.31
Lead (Pb)	0.012	5.4E-06	0.012
Manganese (Mn)	0.24	1.0E-03	0.24
Mercury (Hg)	6.9E-03	1.9E-06	6.9E-03
Molybdenum (Mo)	0.080	3.4E-03	0.080
Nickel (Ni)	0.44	9.4E-04	0.44
Thallium (Tl)	0.016	3.2E-04	0.016
Tungsten (W)	0.037	5.2E-03	0.037
Uranium (U)	4.4E-03	1.2E-04	4.4E-03
Vanadium (V)	0.53	3.0E-03	0.53
Zinc (Zn)	0.063	6.3E-05	0.063

Notes:
Bold indicates that value exceeds the RQ target (1.0).

Table 7.7.39 Maximum Overall Risk Quotients for the Snowshoe Hare

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Snowshoe Hare		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.033	8.3E-04	0.033
Arsenic (As)	0.51	9.4E-03	0.51
Boron (B)	0.021	1.1E-03	0.022
Chromium (total) (Cr)	0.060	3.4E-04	0.060
Cobalt (Co)	0.043	3.9E-05	0.043
Copper (Cu)	0.26	6.7E-04	0.26
Lead (Pb)	4.7E-03	3.7E-06	4.7E-03
Manganese (Mn)	0.30	6.9E-04	0.30
Mercury (Hg)	5.8E-03	1.4E-06	5.8E-03
Molybdenum (Mo)	0.083	5.4E-03	0.083
Nickel (Ni)	0.46	6.3E-04	0.46

Table 7.7.39 Maximum Overall Risk Quotients for the Snowshoe Hare

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Snowshoe Hare		
	Baseline Case	Project Alone Case	Project + Baseline Case
Thallium (Tl)	0.013	3.0E-04	0.013
Tungsten (W)	0.022	3.5E-03	0.023
Uranium (U)	3.8E-03	1.9E-04	3.8E-03
Vanadium (V)	0.27	2.8E-03	0.27
Zinc (Zn)	0.28	4.3E-05	0.28

Table 7.7.40 Maximum Overall Risk Quotients for the Red Fox

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Red Fox		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.019	9.9E-04	0.019
Arsenic (As)	0.16	8.3E-03	0.16
Boron (B)	3.1E-03	1.3E-03	4.3E-03
Chromium (total) (Cr)	0.033	3.0E-04	0.033
Cobalt (Co)	3.8E-03	3.4E-05	3.8E-03
Copper (Cu)	0.22	5.9E-04	0.22
Lead (Pb)	2.8E-03	3.2E-06	2.8E-03
Manganese (Mn)	0.039	6.1E-04	0.039
Mercury (Hg)	5.5E-03	1.6E-06	5.5E-03
Molybdenum (Mo)	0.051	6.5E-03	0.051
Nickel (Ni)	0.077	5.6E-04	0.077
Thallium (Tl)	0.030	3.6E-04	0.030
Tungsten (W)	4.1E-03	3.1E-03	4.4E-03
Uranium (U)	1.47E-03	2.29E-04	1.49E-03
Vanadium (V)	0.096	3.38E-03	0.096
Zinc (Zn)	0.079	3.78E-05	0.079

Table 7.7.41 Maximum Overall Risk Quotients for the Moose

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Moose		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.019	7.5E-04	0.019
Arsenic (As)	0.022	1.1E-03	0.023
Boron (B)	0.026	1.9E-04	0.026
Chromium (total) (Cr)	3.9E-03	1.9E-05	4.0E-03
Cobalt (Co)	0.011	4.4E-05	0.011
Copper (Cu)	0.073	1.3E-04	0.073
Lead (Pb)	4.6E-04	5.6E-06	4.6E-04
Manganese (Mn)	0.075	2.6E-05	0.075
Mercury (Hg)	4.9E-03	8.4E-07	4.9E-03
Molybdenum (Mo)	0.030	1.4E-03	0.031
Nickel (Ni)	0.10	2.2E-04	0.10
Thallium (Tl)	8.4E-03	1.3E-03	9.7E-03

Table 7.7.41 Maximum Overall Risk Quotients for the Moose

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Moose		
	Baseline Case	Project Alone Case	Project + Baseline Case
Tungsten (W)	3.2E-03	3.6E-04	3.5E-03
Uranium (U)	8.5E-04	2.6E-04	1.1E-03
Vanadium (V)	0.047	2.2E-03	0.049
Zinc (Zn)	0.082	2.7E-06	0.082

Table 7.7.42 Maximum Overall Risk Quotients for the Black Bear

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Black Bear		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.076	5.1E-04	0.077
Arsenic (As)	0.11	5.2E-03	0.11
Boron (B)	0.013	4.0E-04	0.013
Chromium (total) (Cr)	0.025	3.3E-04	0.025
Cobalt (Co)	3.6E-03	3.1E-04	3.9E-03
Copper (Cu)	0.14	9.6E-04	0.15
Lead (Pb)	3.6E-03	2.3E-06	3.6E-03
Manganese (Mn)	0.13	3.0E-04	0.13
Mercury (Hg)	0.011	7.6E-05	0.011
Molybdenum (Mo)	0.13	6.3E-03	0.13
Nickel (Ni)	0.10	1.6E-04	0.10
Thallium (Tl)	0.030	1.7E-03	0.032
Tungsten (W)	2.8E-03	2.1E-04	3.0E-03
Uranium (U)	3.3E-03	1.7E-04	3.5E-03
Vanadium (V)	0.19	4.0E-03	0.19
Zinc (Zn)	0.054	1.4E-04	0.055

The spatial distributions of Risk Quotients (RQ) for the masked shrew and meadow vole are presented in Figures 7.7.6 and 7.7.7, respectively.

The primary pathway contributing to risk for the masked shrew was ingestion of terrestrial invertebrates, followed by ingestion of soil. For the meadow vole, the primary pathway contributing to risk was ingestion of soil, followed by ingestion of vegetation. The primary pathway contributing to risk for the American robin was ingestion of soil, followed by ingestion of terrestrial invertebrates. Due to the very small effect of ore dust deposition on the Project + Baseline Case concentrations arsenic, copper, manganese, vanadium and zinc in soil, there was no substantive difference between the risks of the Baseline Case and the Project + Baseline Case for terrestrial wildlife species exposed to these COPCs, as can be observed in Figures 7.7.6 to 7.7.8. In other words, the identified exceedances of the target RQ to the masked shrew, the meadow vole, and the American robin (which in some cases are localized) are related to pre-existing baseline metal concentrations in the environment, and the Project-related contribution to these environmental effects is negligible.

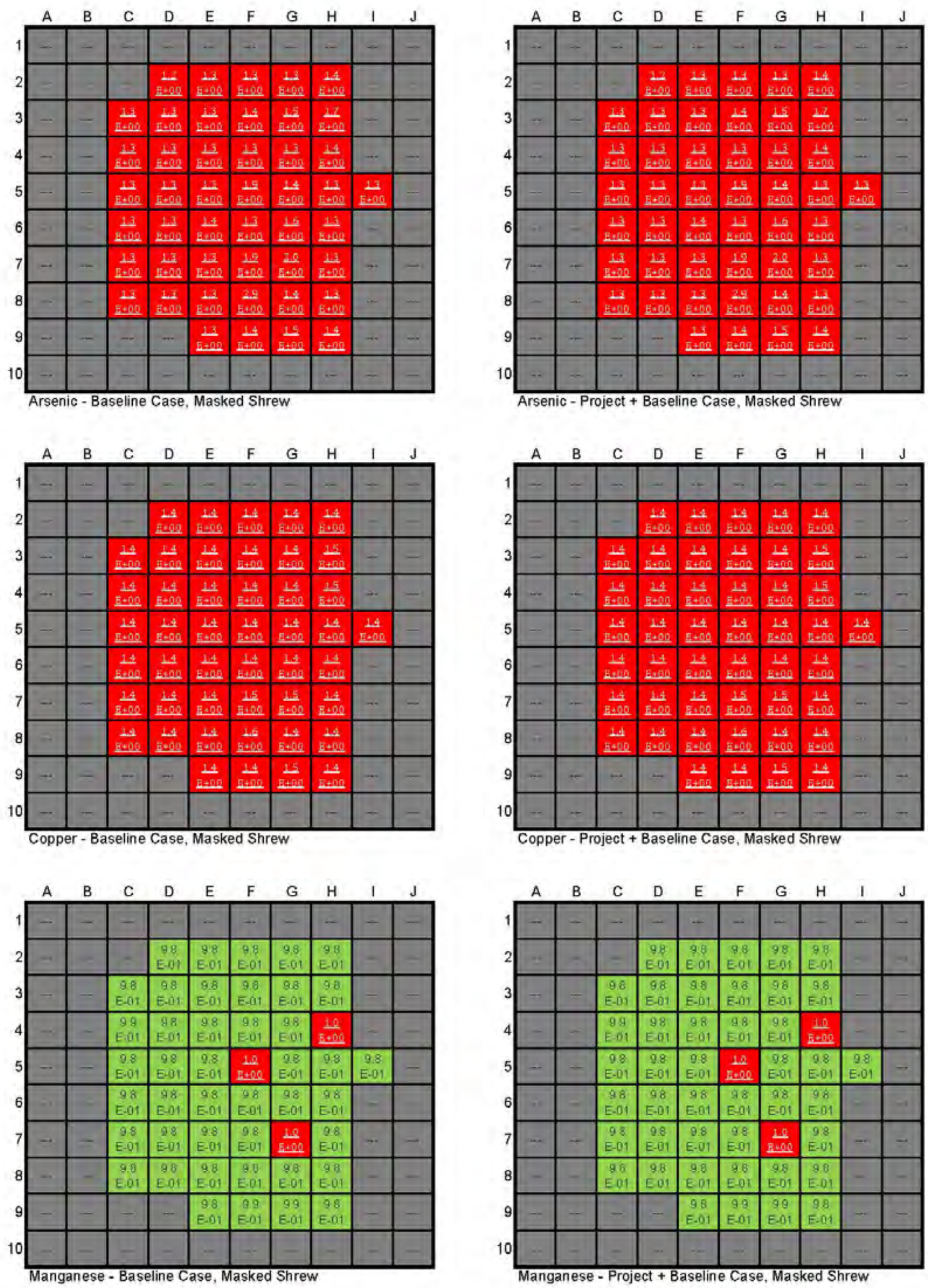


Figure 7.7.6 Distribution of Risk Quotients within the HHERA Study Area for the Masked Shrew

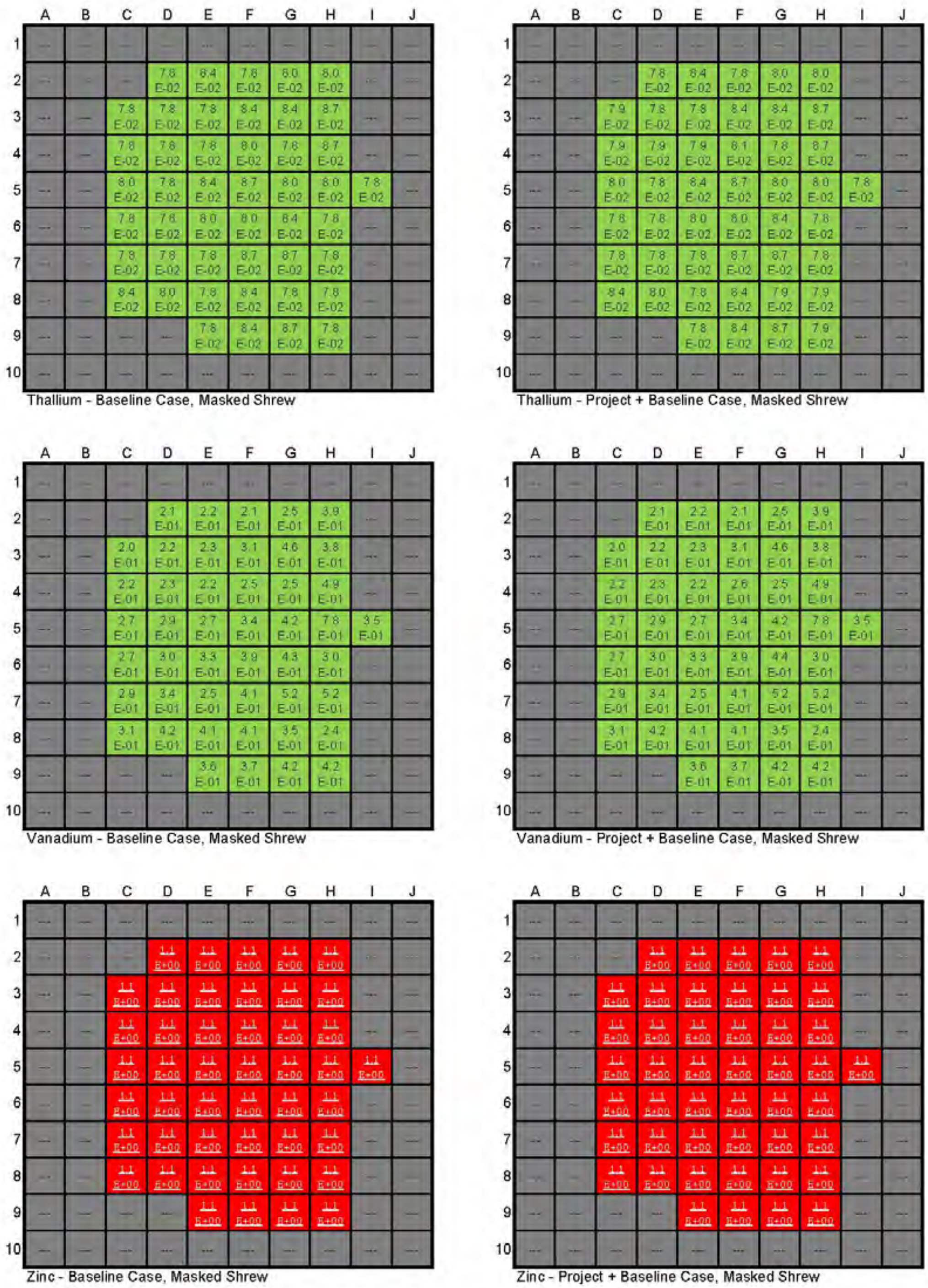


Figure 7.7.6 (continued) Distribution of Risk Quotients within the HHERA Study Area for the Masked Shrew

	A	B	C	D	E	F	G	H	I	J
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	2.9 E-02	7.6 E-02	3.6 E-02	9.0 E-02	1.3 E-01	—	—
3	—	—	3.6 E-02	4.9 E-02	4.9 E-02	1.1 E-01	2.2 E-01	3.7 E-01	—	—
4	—	—	5.0 E-02	5.0 E-02	5.0 E-02	3.6 E-02	1.0 E-01	1.8 E-01	—	—
5	—	—	6.3 E-02	7.6 E-02	1.0 E-01	5.3 E-01	1.4 E-01	1.0 E-01	1.0 E-01	—
6	—	—	4.9 E-02	6.3 E-02	1.5 E-01	6.3 E-02	3.6 E-01	7.6 E-02	—	—
7	—	—	4.9 E-02	6.3 E-02	4.9 E-02	5.3 E-01	7.0 E-01	9.0 E-02	—	—
8	—	—	7.6 E-02	1.0 E-01	6.3 E-02	1.4 E+00	1.5 E-01	5.0 E-02	—	—
9	—	—	—	—	6.3 E-02	1.5 E-01	2.8 E-01	1.4 E-01	—	—
10	—	—	—	—	—	—	—	—	—	—

Arsenic - Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	2.9 E-02	7.6 E-02	3.6 E-02	9.0 E-02	1.3 E-01	—	—
3	—	—	3.7 E-02	4.9 E-02	4.9 E-02	1.1 E-01	2.2 E-01	3.7 E-01	—	—
4	—	—	5.0 E-02	5.3 E-02	5.0 E-02	5.0 E-02	1.0 E-01	1.8 E-01	—	—
5	—	—	6.3 E-02	7.6 E-02	1.0 E-01	5.3 E-01	1.4 E-01	1.0 E-01	1.0 E-01	—
6	—	—	4.9 E-02	6.3 E-02	1.5 E-01	6.4 E-02	3.6 E-01	7.6 E-02	—	—
7	—	—	4.9 E-02	6.3 E-02	5.0 E-02	5.3 E-01	7.0 E-01	9.0 E-02	—	—
8	—	—	7.6 E-02	1.0 E-01	6.3 E-02	1.4 E+00	1.5 E-01	5.0 E-02	—	—
9	—	—	—	—	6.3 E-02	1.5 E-01	2.8 E-01	1.4 E-01	—	—
10	—	—	—	—	—	—	—	—	—	—

Arsenic - Project + Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	1.6 E-01	1.6 E-01	1.6 E-01	1.6 E-01	1.7 E-01	—	—
3	—	—	1.6 E-01	1.6 E-01	1.6 E-01	1.7 E-01	1.8 E-01	2.0 E-01	—	—
4	—	—	1.6 E-01	1.6 E-01	1.6 E-01	1.6 E-01	1.7 E-01	2.1 E-01	—	—
5	—	—	1.6 E-01	1.7 E-01	1.7 E-01	1.8 E-01	1.8 E-01	1.8 E-01	1.7 E-01	—
6	—	—	1.6 E-01	1.6 E-01	1.7 E-01	1.6 E-01	1.8 E-01	1.7 E-01	—	—
7	—	—	1.6 E-01	1.6 E-01	1.7 E-01	2.4 E-01	2.2 E-01	1.8 E-01	—	—
8	—	—	1.7 E-01	1.7 E-01	1.7 E-01	3.1 E-01	1.7 E-01	1.7 E-01	—	—
9	—	—	—	—	1.8 E-01	1.8 E-01	1.9 E-01	1.6 E-01	—	—
10	—	—	—	—	—	—	—	—	—	—

Copper - Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	1.6 E-01	1.6 E-01	1.6 E-01	1.6 E-01	1.7 E-01	—	—
3	—	—	1.6 E-01	1.6 E-01	1.6 E-01	1.7 E-01	1.8 E-01	2.0 E-01	—	—
4	—	—	1.6 E-01	1.6 E-01	1.6 E-01	1.6 E-01	1.7 E-01	2.1 E-01	—	—
5	—	—	1.6 E-01	1.7 E-01	1.7 E-01	1.8 E-01	1.8 E-01	1.8 E-01	1.7 E-01	—
6	—	—	1.6 E-01	1.6 E-01	1.7 E-01	1.6 E-01	1.8 E-01	1.7 E-01	—	—
7	—	—	1.6 E-01	1.6 E-01	1.7 E-01	2.4 E-01	2.2 E-01	1.8 E-01	—	—
8	—	—	1.7 E-01	1.7 E-01	1.7 E-01	3.1 E-01	1.7 E-01	1.7 E-01	—	—
9	—	—	—	—	1.8 E-01	1.8 E-01	1.9 E-01	1.6 E-01	—	—
10	—	—	—	—	—	—	—	—	—	—

Copper - Project + Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
3	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
4	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	2.3 E-01	—	—
5	—	—	1.9 E-01	1.9 E-01	1.9 E-01	2.1 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—
6	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
7	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	2.1 E-01	1.9 E-01	—	—
8	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
9	—	—	—	—	1.9 E-01	1.9 E-01	2.0 E-01	1.9 E-01	—	—
10	—	—	—	—	—	—	—	—	—	—

Manganese - Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
3	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
4	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	2.3 E-01	—	—
5	—	—	1.9 E-01	1.9 E-01	1.9 E-01	2.1 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—
6	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
7	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	2.1 E-01	1.9 E-01	—	—
8	—	—	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	1.9 E-01	—	—
9	—	—	—	—	1.9 E-01	1.9 E-01	2.0 E-01	1.9 E-01	—	—
10	—	—	—	—	—	—	—	—	—	—

Manganese - Project + Baseline Case, Meadow Vole

Figure 7.7.7 Distribution of Risk Quotients within the HHERA Study Area for the Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	8.2 E-03	1.2 E-02	8.2 E-03	9.7 E-03	9.7 E-03	---	---
3	---	---	8.2 E-03	8.2 E-03	8.2 E-03	1.2 E-02	1.2 E-02	1.5 E-02	---	---
4	---	---	8.2 E-03	8.2 E-03	8.2 E-03	9.7 E-03	8.2 E-03	1.5 E-02	---	---
5	---	---	9.7 E-03	8.2 E-03	1.2 E-02	1.5 E-02	9.7 E-03	9.7 E-03	8.2 E-03	---
6	---	---	8.2 E-03	8.2 E-03	9.7 E-03	9.7 E-03	1.2 E-02	8.2 E-03	---	---
7	---	---	8.2 E-03	8.2 E-03	8.2 E-03	1.5 E-02	1.5 E-02	8.2 E-03	---	---
8	---	---	1.2 E-02	9.7 E-03	8.2 E-03	1.2 E-02	8.2 E-03	8.2 E-03	---	---
9	---	---	---	---	8.2 E-03	1.2 E-02	1.5 E-02	8.2 E-03	---	---
10	---	---	---	---	---	---	---	---	---	---

Thallium - Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	8.2 E-03	1.2 E-02	8.2 E-03	9.7 E-03	9.7 E-03	---	---
3	---	---	8.3 E-03	8.2 E-03	8.2 E-03	1.2 E-02	1.2 E-02	1.5 E-02	---	---
4	---	---	8.3 E-03	8.3 E-03	8.3 E-03	1.0 E-02	8.2 E-03	1.5 E-02	---	---
5	---	---	9.7 E-03	8.2 E-03	1.2 E-02	1.5 E-02	9.8 E-03	9.7 E-03	8.2 E-03	---
6	---	---	8.2 E-03	8.2 E-03	9.7 E-03	9.8 E-03	1.2 E-02	8.2 E-03	---	---
7	---	---	8.2 E-03	8.2 E-03	8.2 E-03	1.5 E-02	1.5 E-02	8.2 E-03	---	---
8	---	---	1.2 E-02	9.7 E-03	8.2 E-03	1.2 E-02	8.3 E-03	8.3 E-03	---	---
9	---	---	---	---	8.2 E-03	1.2 E-02	1.5 E-02	8.3 E-03	---	---
10	---	---	---	---	---	---	---	---	---	---

Thallium - Project + Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	4.1 E-02	5.0 E-02	4.1 E-02	7.2 E-02	1.9 E-01	---	---
3	---	---	2.8 E-02	4.6 E-02	5.4 E-02	1.2 E-01	2.4 E-01	1.8 E-01	---	---
4	---	---	4.6 E-02	5.9 E-02	5.0 E-02	7.7 E-02	7.6 E-02	2.7 E-01	---	---
5	---	---	9.4 E-02	1.1 E-01	9.0 E-02	1.4 E-01	2.2 E-01	5.2 E-01	1.5 E-01	---
6	---	---	9.4 E-02	1.2 E-01	1.3 E-01	1.9 E-01	2.3 E-01	1.2 E-01	---	---
7	---	---	1.0 E-01	1.5 E-01	7.2 E-02	2.1 E-01	3.0 E-01	3.0 E-01	---	---
8	---	---	1.3 E-01	2.2 E-01	2.1 E-01	2.1 E-01	1.6 E-01	6.3 E-02	---	---
9	---	---	---	---	1.6 E-01	1.7 E-01	2.2 E-01	2.1 E-01	---	---
10	---	---	---	---	---	---	---	---	---	---

Vanadium - Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	4.1 E-02	5.0 E-02	4.1 E-02	7.2 E-02	1.9 E-01	---	---
3	---	---	2.8 E-02	4.6 E-02	5.4 E-02	1.2 E-01	2.4 E-01	1.8 E-01	---	---
4	---	---	4.6 E-02	6.0 E-02	5.0 E-02	8.0 E-02	7.6 E-02	2.7 E-01	---	---
5	---	---	9.4 E-02	1.1 E-01	9.0 E-02	1.4 E-01	2.2 E-01	5.2 E-01	1.5 E-01	---
6	---	---	9.4 E-02	1.2 E-01	1.3 E-01	1.9 E-01	2.3 E-01	1.2 E-01	---	---
7	---	---	1.0 E-01	1.5 E-01	7.2 E-02	2.1 E-01	3.0 E-01	3.0 E-01	---	---
8	---	---	1.3 E-01	2.2 E-01	2.1 E-01	2.1 E-01	1.6 E-01	6.4 E-02	---	---
9	---	---	---	---	1.6 E-01	1.7 E-01	2.2 E-01	2.1 E-01	---	---
10	---	---	---	---	---	---	---	---	---	---

Vanadium - Project + Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	5.1 E-02	5.2 E-02	5.1 E-02	5.3 E-02	5.3 E-02	---	---
3	---	---	5.2 E-02	5.2 E-02	5.2 E-02	5.5 E-02	5.3 E-02	5.3 E-02	---	---
4	---	---	5.4 E-02	5.2 E-02	5.2 E-02	5.2 E-02	5.2 E-02	6.2 E-02	---	---
5	---	---	5.2 E-02	5.3 E-02	5.3 E-02	6.1 E-02	5.3 E-02	5.5 E-02	5.4 E-02	---
6	---	---	5.1 E-02	5.2 E-02	5.2 E-02	5.2 E-02	5.3 E-02	5.2 E-02	---	---
7	---	---	5.2 E-02	5.2 E-02	5.4 E-02	5.6 E-02	6.0 E-02	5.4 E-02	---	---
8	---	---	5.6 E-02	5.3 E-02	5.2 E-02	5.9 E-02	5.2 E-02	5.7 E-02	---	---
9	---	---	---	---	5.4 E-02	5.4 E-02	5.9 E-02	5.2 E-02	---	---
10	---	---	---	---	---	---	---	---	---	---

Zinc - Baseline Case, Meadow Vole

	A	B	C	D	E	F	G	H	I	J
1	---	---	---	---	---	---	---	---	---	---
2	---	---	---	5.1 E-02	5.2 E-02	5.1 E-02	5.3 E-02	5.3 E-02	---	---
3	---	---	5.2 E-02	5.2 E-02	5.2 E-02	5.5 E-02	5.3 E-02	5.3 E-02	---	---
4	---	---	5.4 E-02	5.2 E-02	5.2 E-02	5.2 E-02	5.2 E-02	6.2 E-02	---	---
5	---	---	5.2 E-02	5.3 E-02	5.3 E-02	6.1 E-02	5.3 E-02	5.5 E-02	5.4 E-02	---
6	---	---	5.1 E-02	5.2 E-02	5.2 E-02	5.2 E-02	5.3 E-02	5.2 E-02	---	---
7	---	---	5.2 E-02	5.2 E-02	5.4 E-02	5.6 E-02	6.0 E-02	5.4 E-02	---	---
8	---	---	5.6 E-02	5.3 E-02	5.2 E-02	5.9 E-02	5.2 E-02	5.7 E-02	---	---
9	---	---	---	---	5.4 E-02	5.4 E-02	5.9 E-02	5.2 E-02	---	---
10	---	---	---	---	---	---	---	---	---	---

Zinc - Project + Baseline Case, Meadow Vole

Figure 7.7.7 (continued) Distribution of Risk Quotients within the HHERA Study Area for the Meadow Vole

Maximum risk quotients for terrestrial birds (*i.e.,* American robin, red-tailed hawk, ruffed grouse and bald eagle, Tables 7.7.43 to 7.7.46) were less than 1.0, with the exception of the American robin exposed to vanadium for both the Baseline Case and the Project + Baseline Case. The spatial distribution of RQ for the American robin is presented in Figure 7.7.8.

No Baseline Case and Project + Baseline Case RQ values exceeded 1.0 for the snowshoe hare, red fox, moose, black bear, red-tailed hawk, ruffed grouse, or bald eagle. Differences in RQ values between the Baseline Case and the Project + Baseline Case scenarios were generally negligible for terrestrial mammalian and avian wildlife. Ore dust deposition is expected to negligibly affect soil quality, or COPC concentrations in terrestrial plants, soil invertebrates or small mammals, in areas that are not directly disturbed by mining activity.

Table 7.7.43 Maximum Overall Risk Quotients for the American Robin

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	American Robin		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	0.086	5.3E-04	0.086
Boron (B)	0.015	9.5E-04	0.015
Chromium (total) (Cr)	0.17	3.9E-04	0.17
Cobalt (Co)	0.18	1.5E-04	0.18
Copper (Cu)	0.20	1.5E-04	0.20
Lead (Pb)	0.25	1.8E-05	0.25
Manganese (Mn)	0.24	2.6E-04	0.24
Mercury (Hg)	0.037	1.9E-06	0.037
Molybdenum (Mo)	5.5E-03	2.0E-04	5.5E-03
Nickel (Ni)	0.068	9.9E-05	0.068
Thallium (Tl)	0.048	2.1E-04	0.048
Tungsten (W)	0.031	4.3E-03	0.031
Uranium (U)	5.9E-04	1.1E-05	5.9E-04
Vanadium (V)	**4.2**	0.019	**4.2**
Zinc (Zn)	0.66	4.7E-05	0.66

Notes:
"---" indicates not available or applicable.
There are insufficient data to define TRVs for avian receptors for aluminum; therefore, RQs are not calculated.
Bold indicates that value exceeds the RQ target (1.0).

Table 7.7.44 Maximum Overall Risk Quotients for the Red-tailed Hawk

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Red-tailed Hawk		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	5.6E-03	2.4E-04	5.6E-03
Boron (B)	1.3E-03	4.3E-04	1.7E-03
Chromium (total) (Cr)	0.030	1.7E-04	0.030
Cobalt (Co)	7.7E-03	6.4E-05	7.7E-03
Copper (Cu)	0.038	6.3E-05	0.038
Lead (Pb)	5.6E-03	7.8E-06	5.6E-03
Manganese (Mn)	4.2E-03	1.1E-04	4.2E-03
Mercury (Hg)	6.4E-03	1.3E-06	6.4E-03
Molybdenum (Mo)	1.0E-03	8.7E-05	1.0E-03
Nickel (Ni)	8.5E-03	4.3E-05	8.5E-03
Thallium (Tl)	0.024	1.7E-04	0.024
Tungsten (W)	3.4E-03	1.9E-03	3.6E-03
Uranium (U)	3.9E-05	4.8E-06	4.0E-05
Vanadium (V)	0.55	0.015	0.55
Zinc (Zn)	0.062	2.1E-05	0.062

Notes:
"---" indicates not available or applicable.
There are insufficient data to define TRVs for avian receptors for aluminum; therefore, RQs are not calculated.

Table 7.7.45 Maximum Overall Risk Quotients for the Ruffed Grouse

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Ruffed Grouse		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	4.0E-05	6.3E-06	4.0E-05
Boron (B)	2.1E-04	1.1E-05	2.2E-04
Chromium (total) (Cr)	1.5E-04	4.7E-06	1.5E-04
Cobalt (Co)	1.5E-03	1.7E-06	1.5E-03
Copper (Cu)	3.9E-04	1.7E-06	3.9E-04
Lead (Pb)	6.5E-05	2.1E-07	6.5E-05
Manganese (Mn)	1.0E-03	3.1E-06	1.0E-03
Mercury (Hg)	7.0E-05	2.9E-08	7.0E-05
Molybdenum (Mo)	5.7E-06	2.4E-06	6.1E-06
Nickel (Ni)	6.1E-04	1.2E-06	6.1E-04
Thallium (Tl)	7.5E-05	3.9E-06	7.5E-05
Tungsten (W)	1.5E-04	5.1E-05	1.8E-04
Uranium (U)	3.6E-07	1.3E-07	3.7E-07
Vanadium (V)	4.4E-03	3.3E-04	4.4E-03
Zinc (Zn)	3.4E-03	5.6E-07	3.4E-03

Notes:
"---" indicates not available or applicable.
There are insufficient data to define TRVs for avian receptors for aluminum; therefore, RQs are not calculated.

Table 7.7.46 Maximum Overall Risk Quotients for the Bald Eagle

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Bald Eagle		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	2.8E-03	1.7E-03	4.4E-03
Boron (B)	7.1E-04	8.6E-04	1.6E-03
Chromium (total) (Cr)	0.010	2.3E-03	0.012
Cobalt (Co)	2.2E-03	7.3E-03	9.4E-03
Copper (Cu)	0.015	1.3E-03	0.016
Lead (Pb)	1.5E-03	8.1E-05	1.6E-03
Manganese (Mn)	1.4E-03	6.4E-04	2.0E-03
Mercury (Hg)	0.013	5.5E-04	0.013
Molybdenum (Mo)	3.9E-04	6.6E-04	1.0E-03
Nickel (Ni)	2.5E-03	1.6E-04	2.7E-03
Thallium (Tl)	0.017	7.4E-03	0.024
Tungsten (W)	7.0E-04	8.6E-04	1.5E-03
Uranium (U)	1.5E-05	3.1E-05	4.5E-05
Vanadium (V)	0.097	0.15	0.24
Zinc (Zn)	0.040	1.1E-03	0.041

Notes:
"---" indicates not available or applicable.
There are insufficient data to define TRVs for avian receptors for aluminum; therefore, RQs are not calculated.

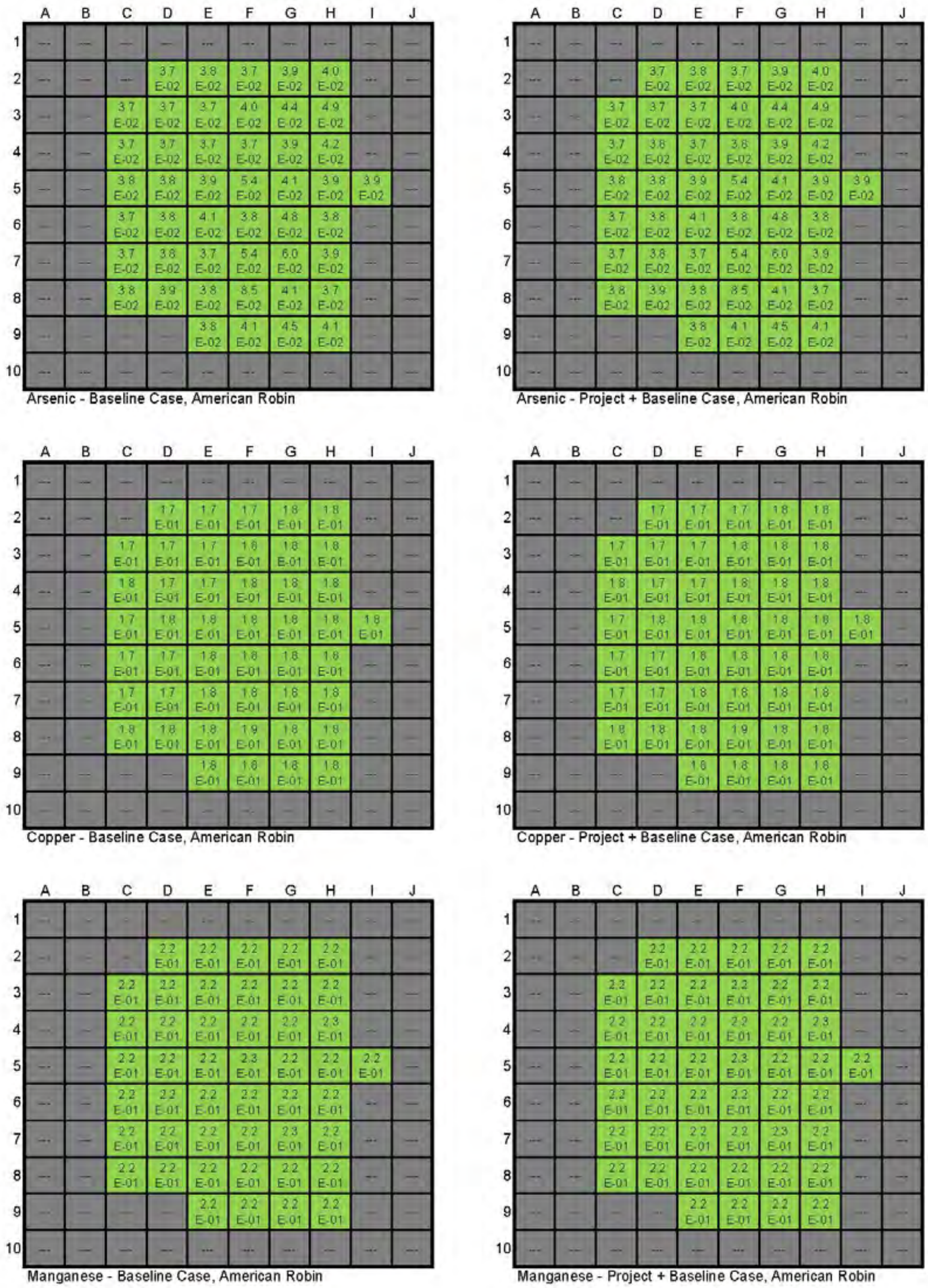


Figure 7.7.8 Distribution of Risk Quotients within the HHERA Study Area for the American Robin

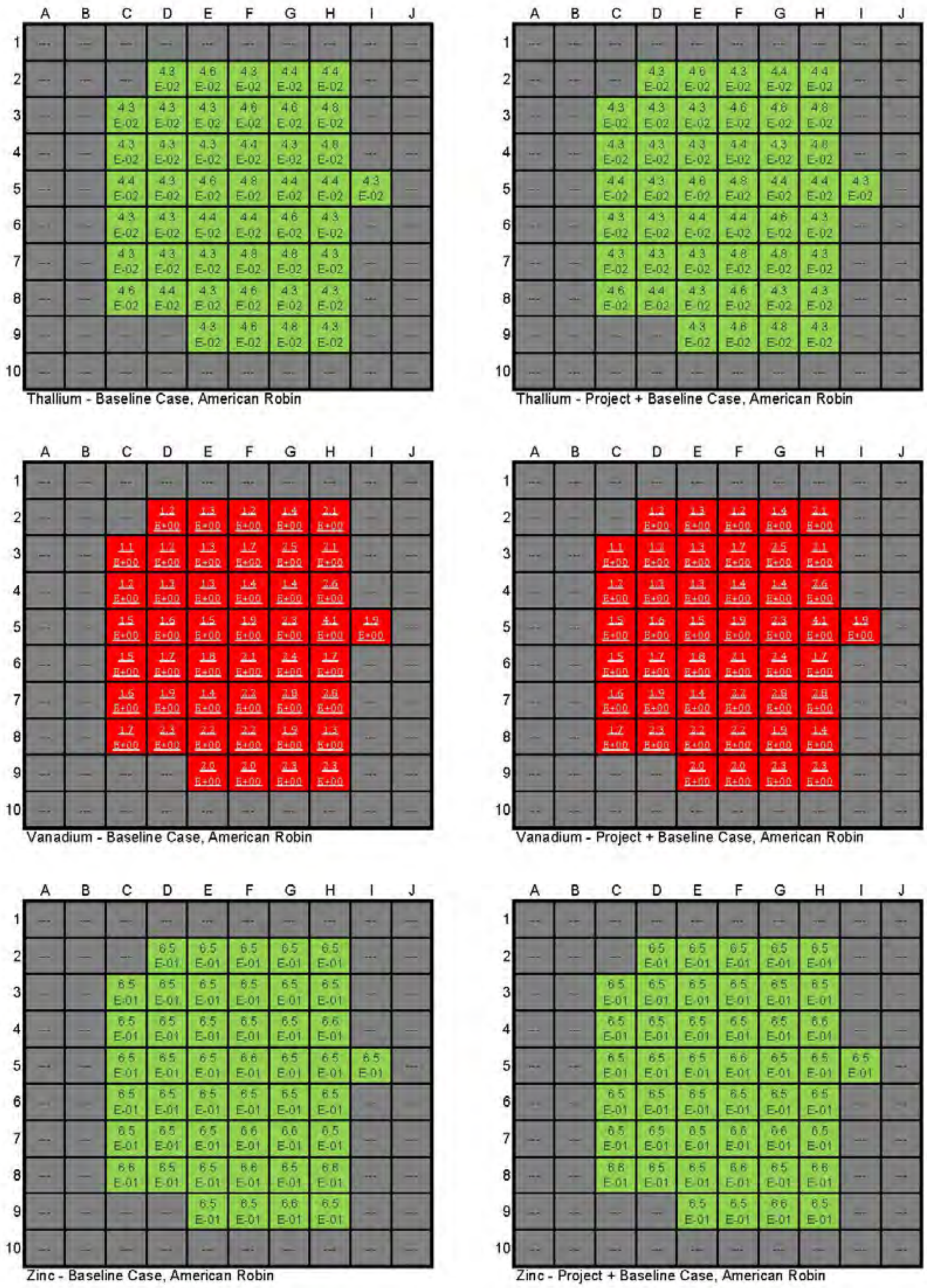


Figure 7.7.8 (continued) Distribution of Risk Quotients within the HHERA Study Area for the American Robin

7.7.4.7.2 Risk Characterization for Aquatic Ecological Receptors

Maximum risk quotients for aquatic mammals (*i.e.,* mink) and for aquatic birds (*i.e.,* American black duck and belted kingfisher) are presented in Tables 7.7.47 to 7.7.49.

Table 7.7.47 Maximum Overall Risk Quotients for the Mink

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Mink		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	0.049	0.085	0.12
Arsenic (As)	0.17	0.47	0.61
Boron (B)	1.6E-03	1.8E-02	2.0E-02
Chromium (total) (Cr)	0.032	0.074	0.098
Cobalt (Co)	3.0E-03	5.1E-02	5.3E-02
Copper (Cu)	0.22	0.35	0.55
Lead (Pb)	1.4E-03	1.2E-03	2.1E-03
Manganese (Mn)	0.012	0.057	0.068
Mercury (Hg)	0.013	8.5E-04	0.014
Molybdenum (Mo)	0.025	0.52	0.54
Nickel (Ni)	0.066	0.081	0.13
Thallium (Tl)	0.029	0.16	0.18
Tungsten (W)	5.5E-03	0.045	0.048
Uranium (U)	1.1E-03	0.012	0.012
Vanadium (V)	0.038	0.21	0.22
Zinc (Zn)	0.091	0.025	0.12

Table 7.7.48 Maximum Overall Risk Quotients for the American Black Duck

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	American Black Duck		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	4.7E-03	0.12	0.12
Boron (B)	4.6E-03	0.032	0.037
Chromium (total) (Cr)	0.030	0.14	0.16
Cobalt (Co)	0.012	0.098	0.11
Copper (Cu)	0.069	0.66	0.70
Lead (Pb)	0.016	0.056	0.069
Manganese (Mn)	0.049	0.013	0.061
Mercury (Hg)	0.026	6.9E-06	0.026
Molybdenum (Mo)	2.7E-03	0.085	0.087
Nickel (Ni)	0.024	0.11	0.14
Thallium (Tl)	0.11	**1.2**	**1.2**
Tungsten (W)	0.037	0.39	0.42
Uranium (U)	1.5E-04	2.8E-03	2.9E-03

Table 7.7.48 Maximum Overall Risk Quotients for the American Black Duck

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	American Black Duck		
	Baseline Case	Project Alone Case	Project + Baseline Case
Vanadium (V)	0.47	**4.4**	**4.6**
Zinc (Zn)	0.047	0.22	0.26

Notes:
"---" indicates not available or applicable.
There are insufficient data to define TRVs for avian receptors for aluminum; therefore, RQs are not calculated.
Bold indicates that value exceeds the RQ target (1.0).

Table 7.7.49 Maximum Overall Risk Quotients for the Belted Kingfisher

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Belted Kingfisher		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	0.047	0.057	0.075
Boron (B)	1.2E-03	0.040	0.041
Chromium (total) (Cr)	0.11	0.20	0.23
Cobalt (Co)	0.065	0.45	0.47
Copper (Cu)	0.045	0.15	0.18
Lead (Pb)	0.039	0.011	0.042
Manganese (Mn)	0.020	0.050	0.061
Mercury (Hg)	0.041	2.9E-03	0.043
Molybdenum (Mo)	2.9E-03	0.047	0.047
Nickel (Ni)	0.034	0.024	0.036
Thallium (Tl)	0.033	0.30	0.33
Tungsten (W)	0.031	0.11	0.11
Uranium (U)	4.2E-04	1.7E-03	1.8E-03
Vanadium (V)	**3.0**	**4.0**	**4.4**
Zinc (Zn)	0.14	0.056	0.19

Notes:
"---" indicates not available or applicable.
There are insufficient data to define TRVs for avian receptors for aluminum; therefore, RQs are not calculated.
Bold indicates that value exceeds the RQ target (1.0).

7.7.4.7.3 Risk Characterization for Semi-Aquatic Ecological Receptors

Maximum risk quotients for semi-aquatic mammals (*i.e.,* mink; Table 7.7.47) were less than 1.0. Maximum risk quotients for aquatic birds (*i.e.,* American black duck and belted kingfisher, Tables 7.7.48 and 7.7.49) were less than 1.0, with the exception of the American black duck exposed to thallium and vanadium for the Project + Baseline Case and the exception of the belted kingfisher exposed to vanadium for both the Baseline Case and the Project + Baseline Case. The spatial distributions of RQ for the American black duck and the belted kingfisher are presented in Figures 7.7.9 and 7.7.10, respectively.

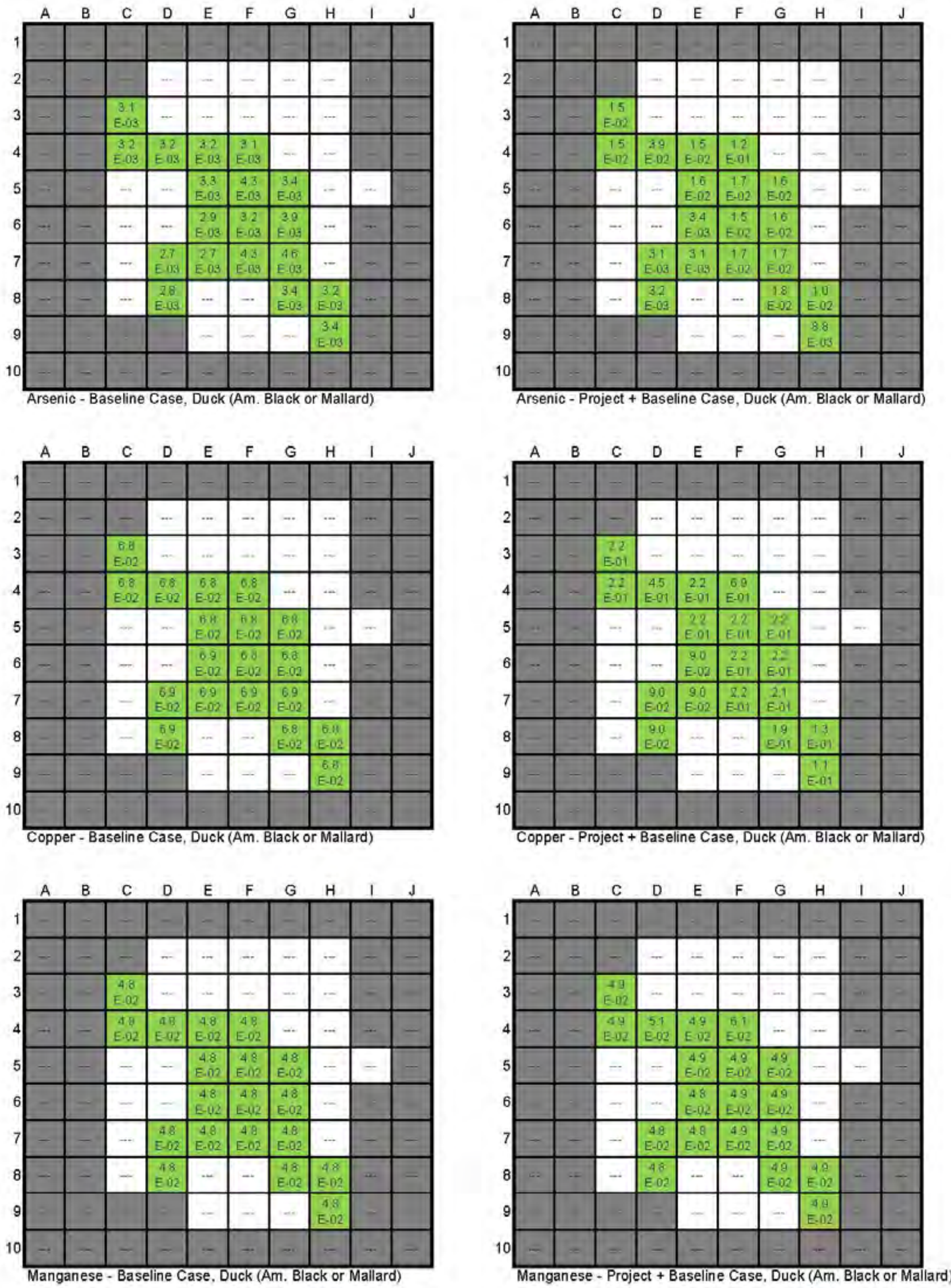


Figure 7.7.9 Distribution of Risk Quotients within the HHERA Study Area for the American Black Duck

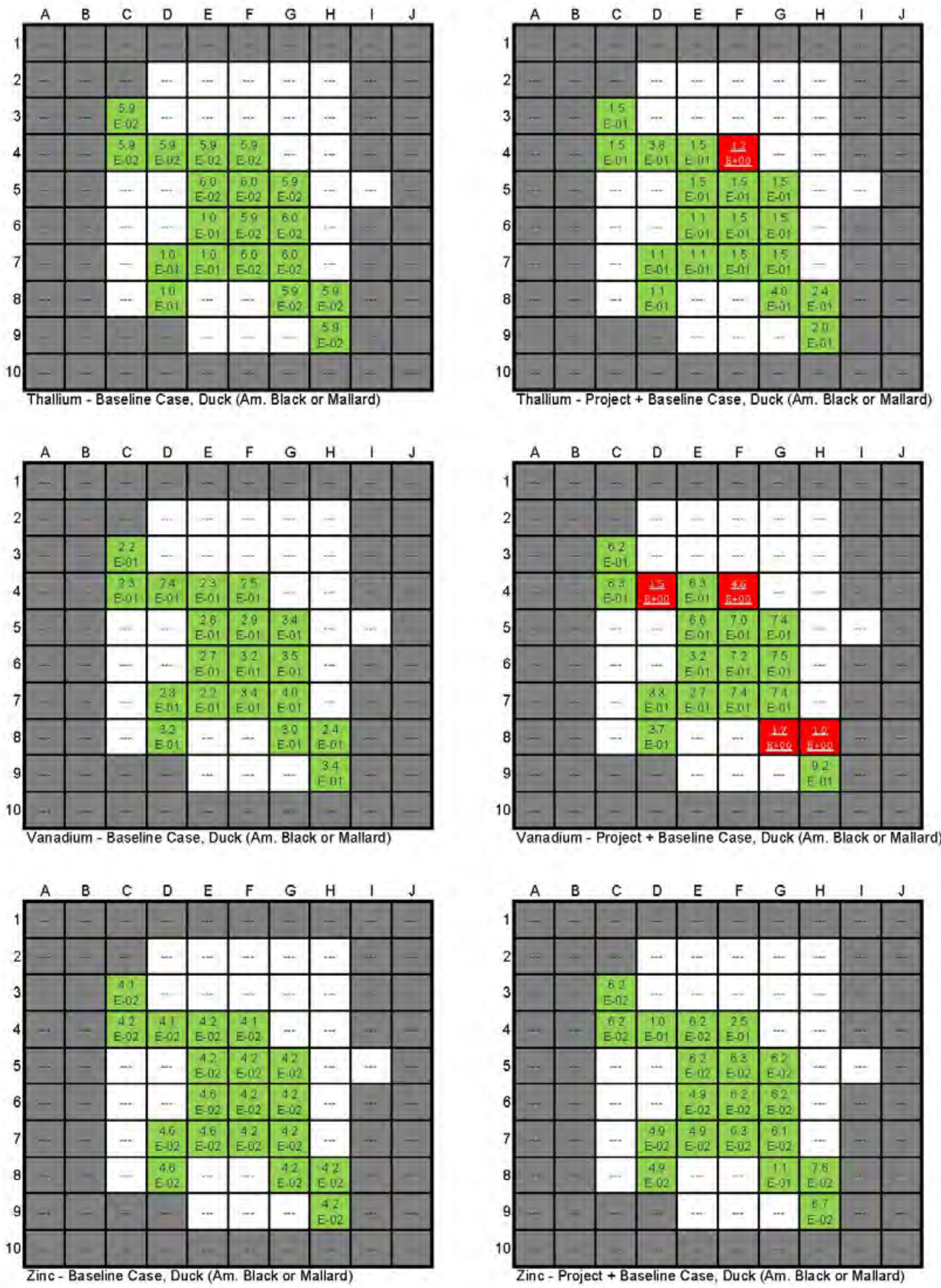


Figure 7.7.9 (continued) Distribution of Risk Quotients within the HHERA Study Area for the American Black Duck

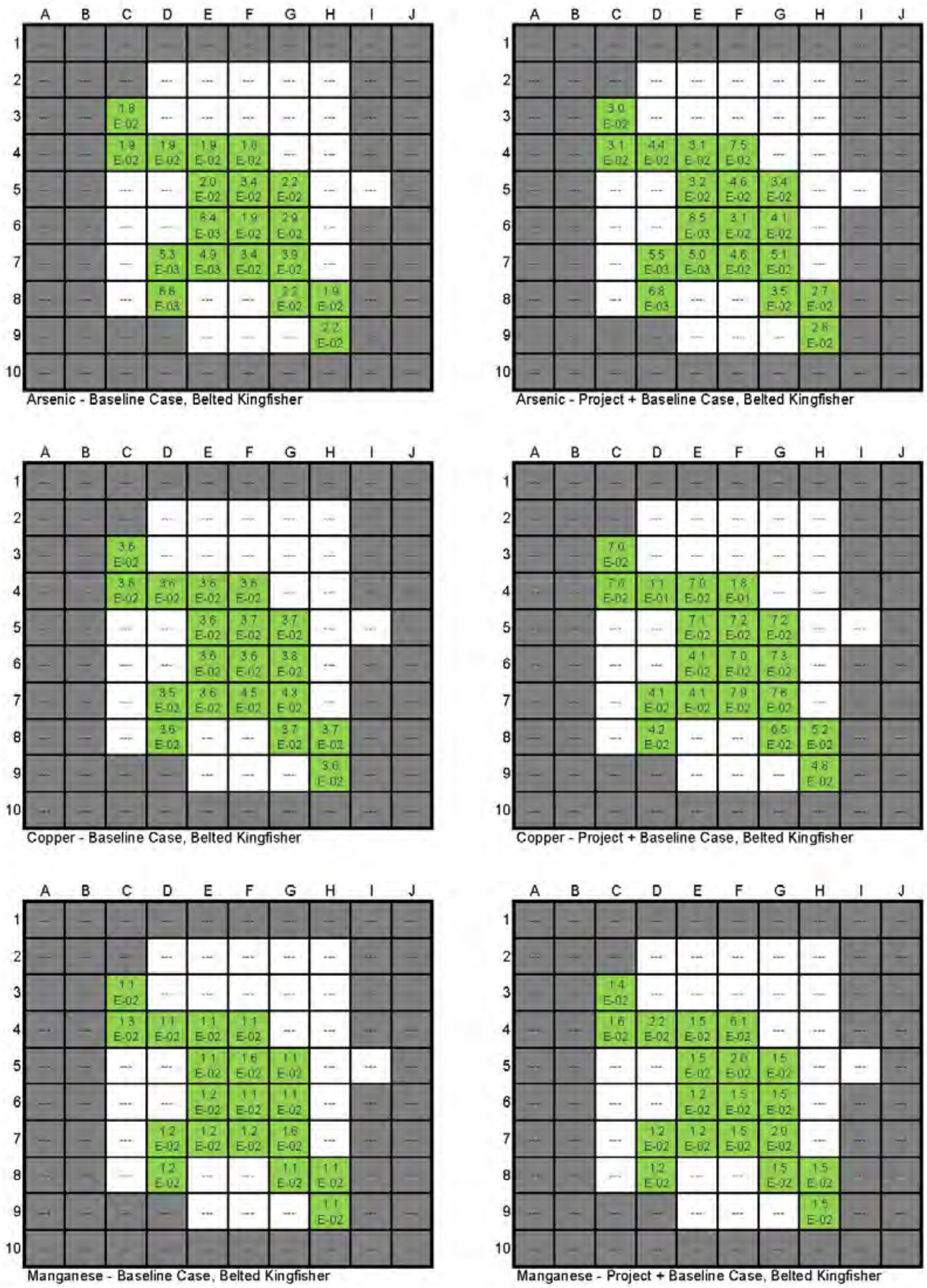


Figure 7.7.10 Distribution of Risk Quotients within the HHERA Study Area for the Belted Kingfisher

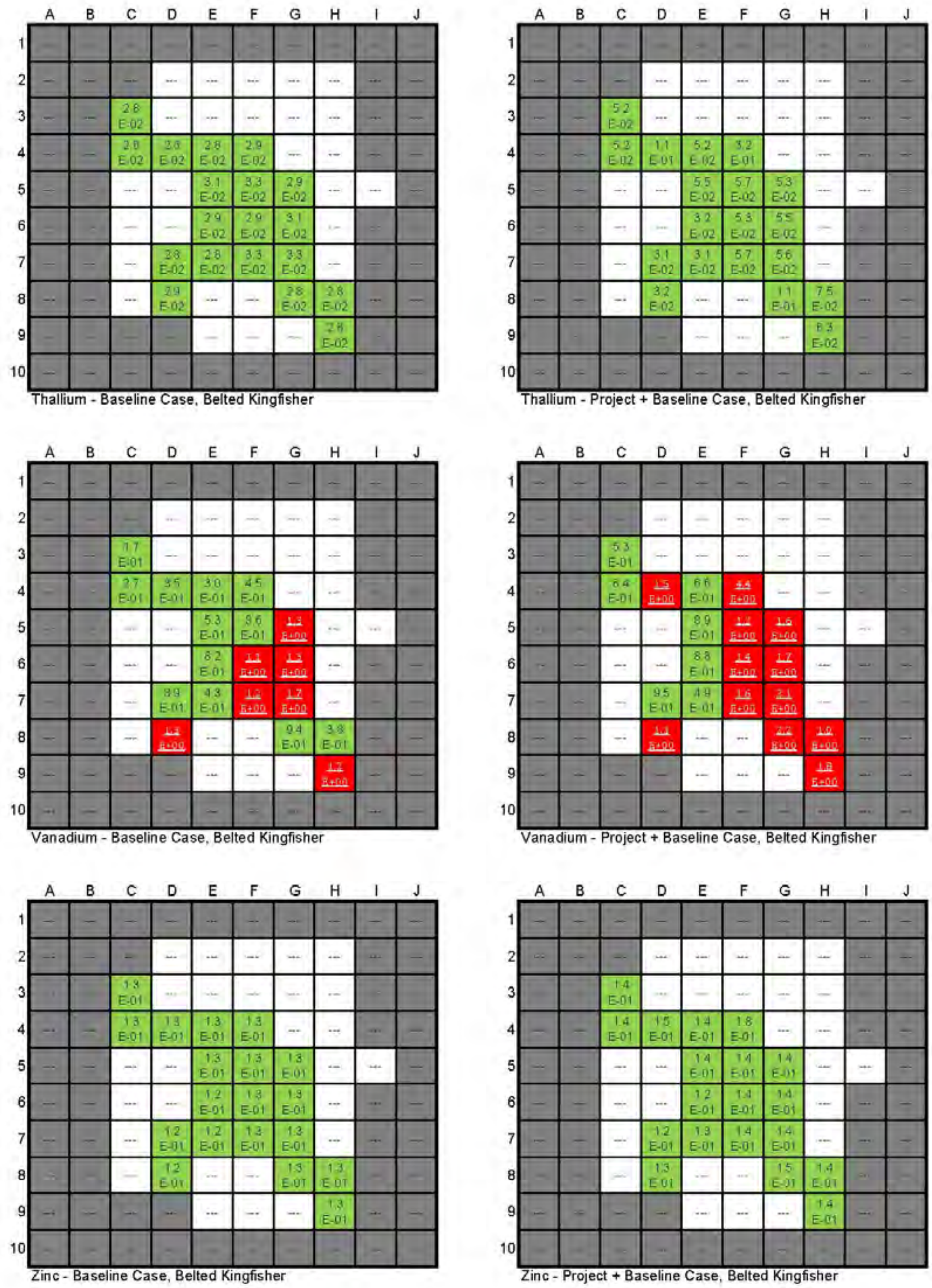


Figure 7.7.10 (continued) Distribution of Risk Quotients within the HHERA Study Area for the Belted Kingfisher

For the American black duck, risk quotients for thallium are generally less than 1.0, with one exception located in proximity of UT3&4 (corresponding to Grid F4 on Figure 7.7.3). The primary pathway contributing to thallium risk for the American black duck was ingestion of freshwater benthic invertebrates, followed by ingestion of freshwater sediments. Similarly, risk quotients for vanadium are generally less than 1.0, with four exceptions located in proximity of water prediction nodes UT3&4 (Grid F4), UT1 (Grid D4), NAP5 (Grid G8), and NAP7 (Grid H8) for vanadium. The primary pathway contributing to vanadium risk for the American black duck was ingestion of freshwater sediment followed by ingestion of freshwater benthic invertebrates. For both thallium and vanadium, the increase in RQ can be related to an increase in predicted surface water concentrations due primarily to modelled seepage from the TSF towards small tributaries of West Branch Napadogan Brook. These identified target RQ exceedances are generally only marginally higher than 1.0 and appear to be localized. As such, these are not expected to results in population-level effects for the American black duck.

For the belted kingfisher, risk quotients for vanadium exceeded the target RQ of 1.0 for both the Baseline Case and the Project + Baseline Case (Figure 7.7.10). The primary pathway contributing to risk for the belted kingfisher was ingestion of fish. Grids exhibiting exceedance of the target RQ with changes related to fish ingestion are localised in proximity of water prediction nodes UT3&UT4 (Grid F4) and UT1 (Grid D4), as well as within West Branch Napadogan Brook. As these are generally marginally higher than 1.0, these are not expected to result in population-level effects for the belted kingfisher.

7.7.4.7.4 Risk Characterization for Soil Invertebrates and Terrestrial Plants

Maximum risk quotients for soil invertebrates and terrestrial plants are provided in Tables 7.7.50 and 7.7.51, respectively. The tables provide Baseline Case, Project Alone Case and Project + Baseline Case RQ values using existing data for soils in the HHERA Study Area.

Maximum risk quotients for soil invertebrates were less than 1.0, with the exception of arsenic, boron and manganese for both the Baseline Case and the Project + Baseline Case. The spatial distribution of RQ for soil invertebrates is presented in Figure 7.7.11. Maximum risk quotients for terrestrial plants were less than 1.0, with the exception of arsenic, boron, manganese and vanadium for both the Baseline Case and the Project + Baseline Case. The spatial distribution of RQ for terrestrial plants is presented in Figure 7.7.12.

Due to the very small effect of ore dust deposition on the Project + Baseline Case concentrations of arsenic, boron, manganese and vanadium in soil, there was no substantive difference between the risks of the Baseline Case and the Project + Baseline Case for soil invertebrates and terrestrial plants exposed to these COPCs. The identified exceedances of the target RQ to (which in some cases are localized) are related to pre-existing baseline metal concentrations in the environment, and the Project-related contribution to these environmental effects is negligible.

Table 7.7.50 Maximum Overall Risk Quotients for Soil Invertebrates

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Soil Invertebrates		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	**1.7**	1.5E-06	**1.7**
Boron (B)	**2.7**	5.7E-06	**2.7**
Chromium (total) (Cr)	0.14	4.6E-07	0.14
Cobalt (Co)	0.56	6.0E-07	0.56
Copper (Cu)	0.44	2.8E-06	0.44
Lead (Pb)	0.029	5.7E-08	0.029
Manganese (Mn)	**14**	4.1E-06	**14**
Mercury (Hg)	0.040	1.4E-08	0.040
Molybdenum (Mo)	0.41	3.2E-06	0.41
Nickel (Ni)	0.12	1.5E-07	0.12
Thallium (Tl)	0.21	1.3E-06	0.21
Tungsten (W)	---	---	---
Uranium (U)	---	---	---
Vanadium (V)	0.58	7.3E-07	0.58
Zinc (Zn)	0.30	8.0E-07	0.30

Notes:
"---" indicates not available or applicable.
There are insufficient data to define a benchmark for aluminum, tungsten and uranium; therefore, RQs are not calculated.
Bold indicates that value exceeds the RQ target (1.0).

Table 7.7.51 Maximum Overall Risk Quotients for Terrestrial Plants

COPC	Maximum Overall Risk Quotient (RQ, dimensionless)		
	Terrestrial Plants		
	Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	---	---
Arsenic (As)	**5.2**	4.4E-06	**5.2**
Boron (B)	**2.7**	5.7E-06	**2.7**
Chromium (total) (Cr)	0.14	4.6E-07	0.14
Cobalt (Co)	0.56	6.0E-07	0.56
Copper (Cu)	0.44	2.8E-06	0.44
Lead (Pb)	0.20	3.9E-07	0.20
Manganese (Mn)	**28**	8.3E-06	**28**
Mercury (Hg)	0.040	1.4E-08	0.040
Molybdenum (Mo)	0.41	3.2E-06	0.41
Nickel (Ni)	0.34	4.3E-07	0.34
Thallium (Tl)	0.21	1.3E-06	0.21
Tungsten (W)	---	---	---
Uranium (U)	0.64	1.0E-06	0.64
Vanadium (V)	**1.2**	1.5E-06	**1.2**
Zinc (Zn)	0.30	8.0E-07	0.30

Notes:
"---" indicates not available or applicable.
There are insufficient data to define a benchmark for aluminum and tungsten; therefore, RQs are not calculated.
Bold indicates that value exceeds the RQ target (1.0).

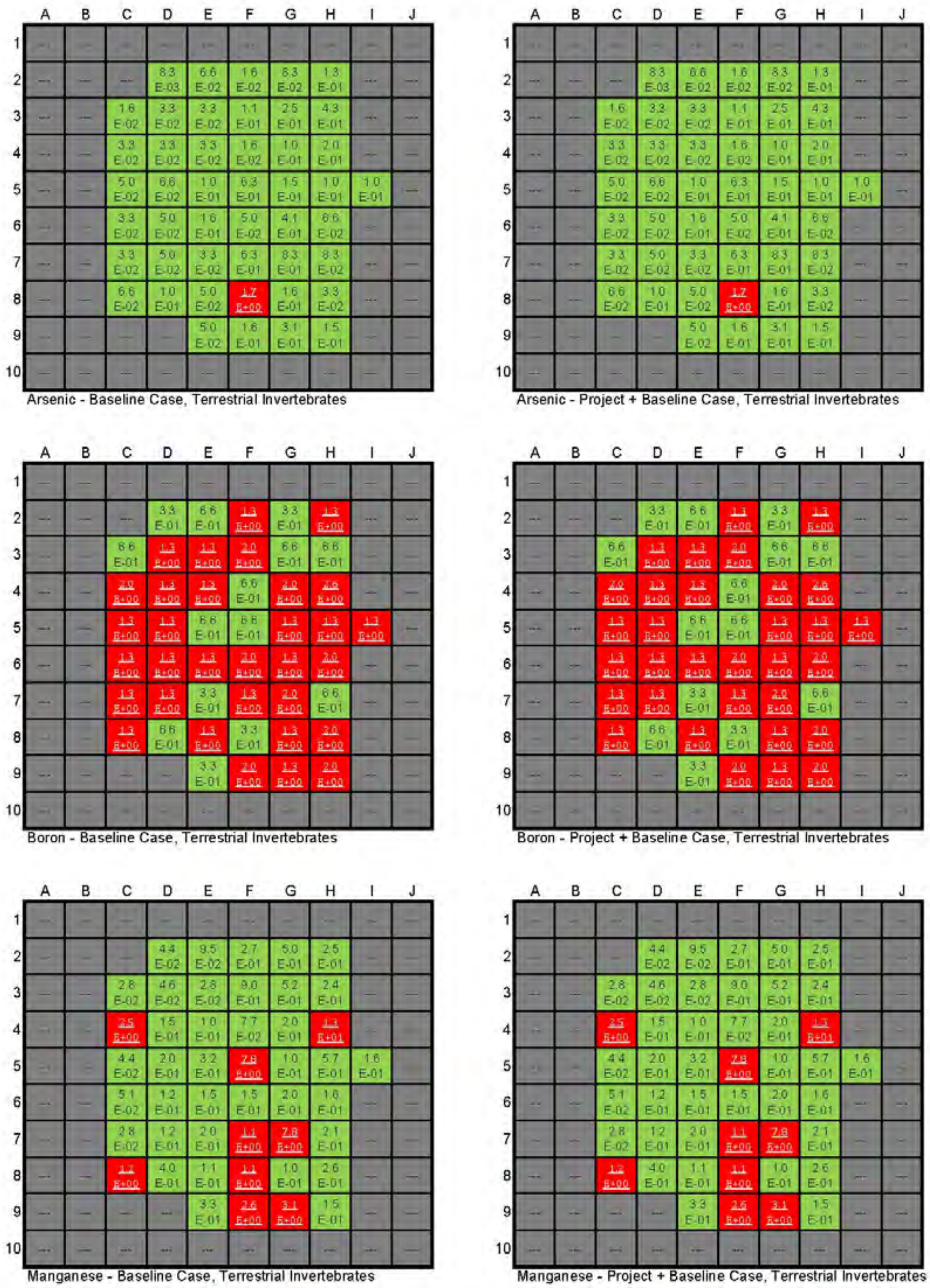


Figure 7.7.11 Distribution of Risk Quotients within the HHERA Study Area for Soil Invertebrates

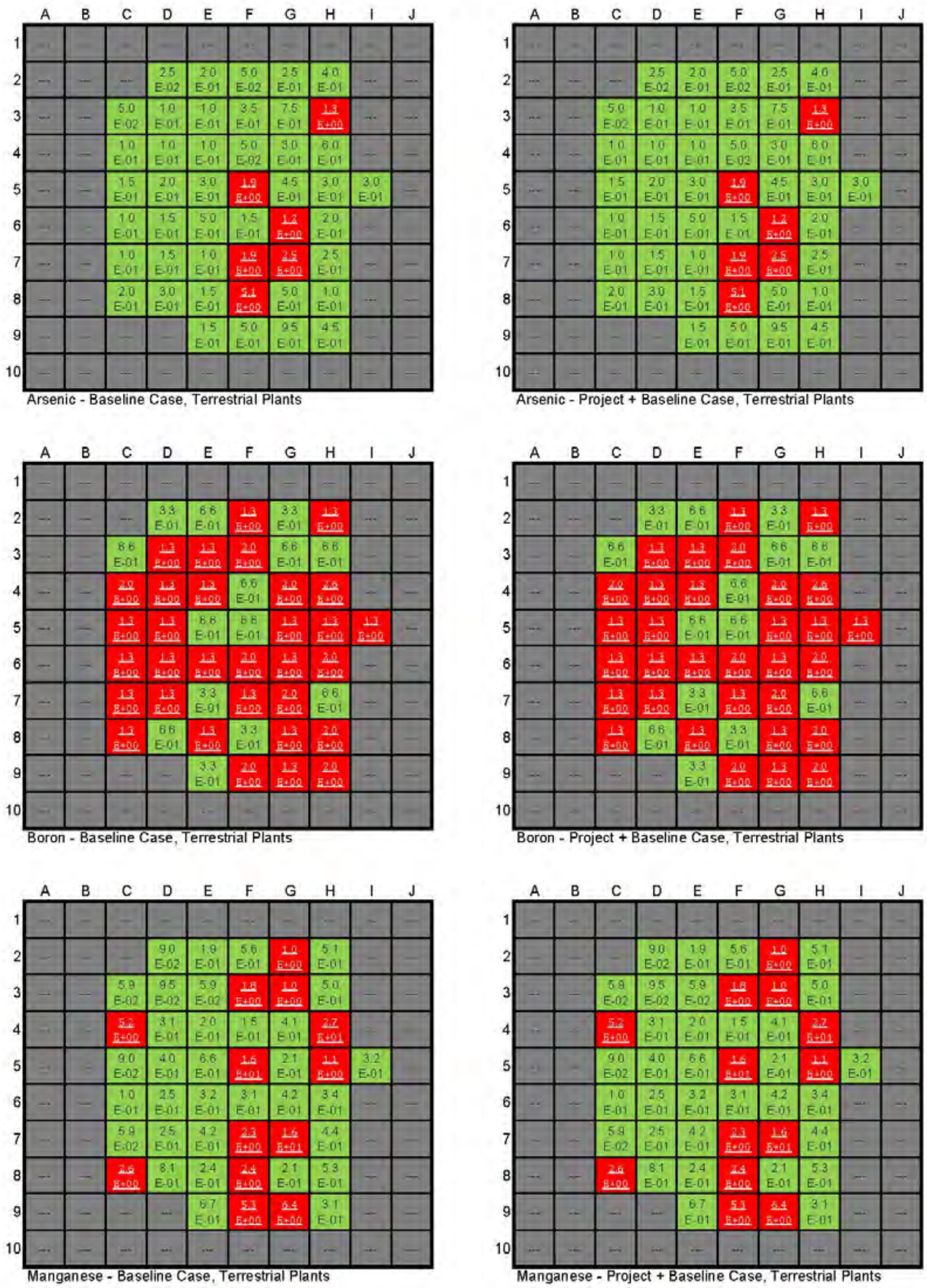


Figure 7.7.12 Distribution of Risk Quotients within the HHERA Study Area for Terrestrial Plants

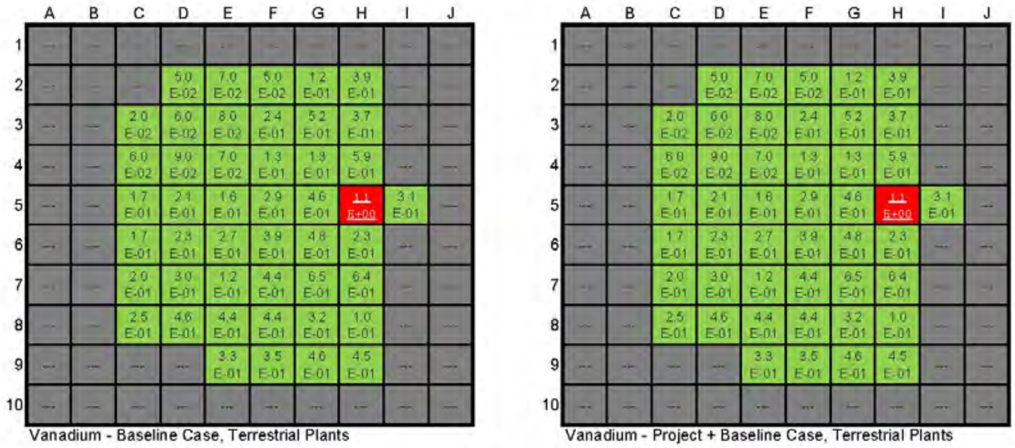


Figure 7.7.12 (continued) Distribution of Risk Quotients within the HHERA Study Area for Terrestrial Plants

7.7.4.7.5 Risk Characterization for the Sediment Community

Comparison of sediment concentrations for the Baseline Case, Project Alone Case and Project + Baseline Case to Canadian Sediment Quality Guidelines for the Protection of Aquatic Life probable effect levels are presented in Table 7.7.52. Maximum sediment concentrations were less than the available guidelines for the HHERA Study Area, with the exception of arsenic for Baseline Case, Project Alone Case and Project + Baseline Case. The Project + Baseline Case arsenic sediment concentrations are mainly related to pre-existing Baseline Case arsenic concentrations in the environment, and the Project-related contribution to these environmental effects is less than 33%. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life are meant to be protective for a range of species and as such, sediment concentrations less than these guidelines are indicative of a negligible probability of adverse environmental effects. Where concentrations are greater than these guidelines, there is a possibility (but not a certainty) of adverse environmental effects to ecological receptors. Such cases require a careful review of predicted exposure levels, and more focused investigations may be required to reduce conservatism in the assessment. Follow-up may be used to confirm the predicted changes in sediment arsenic concentrations in view of the modelling uncertainties and conservatism.

Table 7.7.52 Comparison Sediment Concentrations to Canadian Sediment Quality Guidelines

COPC	CCME SQG Guidelines [a] (mg/kg dry weight)	Maximum Sediment Concentration (mg/kg dry weight)		
		Baseline Case	Project Alone Case	Project + Baseline Case
Aluminum (Al)	---	1.29E+04	2.42E+04	3.21E+04
Arsenic (As)	17	**3.83E+01**	1.24E+01	**4.49E+01**
Boron (B)	---	2.00E+00	3.05E+01	3.25E+01
Chromium (total) (Cr)	90	1.36E+01	2.32E+00	1.36E+01
Cobalt (Co)	---	3.40E+01	2.13E+01	3.40E+01
Copper (Cu)	197	5.23E+01	1.83E+01	5.25E+01
Lead (Pb)	91.3	4.55E+01	1.21E+01	4.57E+01
Manganese (Mn)	---	1.82E+03	3.19E+02	2.14E+03

Table 7.7.52 Comparison Sediment Concentrations to Canadian Sediment Quality Guidelines

COPC	CCME SQG Guidelines [a] (mg/kg dry weight)	Maximum Sediment Concentration (mg/kg dry weight)		
		Baseline Case	Project Alone Case	Project + Baseline Case
Mercury (Hg)	0.486	1.71E-01	6.22E-05	1.71E-01
Molybdenum (Mo)	---	1.23E+01	1.38E+01	1.85E+01
Nickel (Ni)	---	1.64E+01	1.13E+01	2.77E+01
Thallium (Tl)	---	6.17E-01	3.58E+00	3.89E+00
Tungsten (W)	---	2.50E+00	3.07E+01	3.32E+01
Uranium (U)	---	5.11E+00	8.47E+00	1.36E+01
Vanadium (V)	---	2.17E+01	3.20E+01	5.24E+01
Zinc (Zn)	315	1.39E+02	5.50E+00	1.39E+02

Notes:
"---" indicates not available or applicable.
[a] Canadian Sediment Quality Guidelines (SQG) for the Protection of Aquatic Life probable effect levels.
Bold indicates that value exceeds the CCME guidelines.

7.7.4.8 Ecological Risk Uncertainty Assessment

As a result of the scientific investigations, literature reviews, and risk assessment guidance that has been undertaken or followed in the preparation of this ERA, it is believed that the risk assessment results present a reasonable yet conservative evaluation of the risk to ecological receptors present in the HHERA Study Area. Where uncertainty or lack of knowledge were encountered in the development of the risk estimates, reasonable yet conservative assumptions were made, or data were selected, in order to ensure that risks were not underestimated.

Some limitations and assumptions applied in this ERA were previously discussed as part of the HHRA (Section 7.7.3.5), including uncertainties related to exposure assessment and uncertainties related to risk characterization. Limitations and assumptions specific to the ERA are identified and described in the following subsections.

7.7.4.8.1 Habitat Survey and Receptor Selection

This risk assessment invested significant effort into an examination of existing habitats and the species that may exist within them through a site visit by an experienced biologist, review of previous investigations carried out at the site and through a review of available site information. Terrestrial habitats were examined in detail to identify relevant species, and to support the selection of appropriate receptors. Therefore, the receptors that were selected are known to be present, or can reasonably be expected to be present in or near the PDA. These receptors are also known to be reasonably or conservatively representative of other species that may be present in or near the PDA and exposed to COPCs. Use of site-specific receptors decreases the uncertainty, since local species are considered.

7.7.4.8.2 Utilization of Receptors as Sentinels to Represent Other Organisms

The use of receptors as sentinels is intended to limit the number of ecological receptors evaluated. The receptors selected are considered to be sensitive, and consistently present at or near the PDA, and to be highly exposed to the COPCs present at the site via relevant exposure pathways. Therefore, it is reasonable to assume that conclusions that are reached in respect of the modelled receptor organisms can be generalized to other biota that might use the Project site.

7.7.4.8.3 Receptor-Specific Toxicity Data

For most COPCs and receptors, toxicity data are available in some form. However, it is important to note that toxicity data are not necessarily available for the particular receptor species under consideration (*e.g*., black bears). Toxicity values are not necessarily specific to the receptor species, or to a reproductive or population-level endpoint. As a result, there is uncertainty associated with the extrapolations that may be used to translate toxicity data for one species into a TRV for a second species. The toxicity data represent an organism or organisms that are expected to be sensitive to the COPC. The conversion factors that are used are scientifically-based, and are applied in a manner that is believed to be reasonable. The use of the probable effects level (PEL) as a method to estimate the TRV is intended to provide an integration of multiple species toxicity data, as well as providing a weight-of-evidence evaluation of the toxicity data in support of the TRV.

7.7.4.8.4 Food Chain Interactions

Very limited "real world" data exist that allow quantification of the true relationship between a contaminant in an environmental medium and contaminant transfer through the food chain. Only a few classes of contaminants (excluding metals) appear to be magnified through the food chain. The extent of food chain magnification is another uncertainty that is generally treated in a conservative manner. Baseline (existing) concentrations of trace metals in a wide variety of environmental media and food items were measured, including surface water, sediment, soil, fish, forage, browse, berries, soil invertebrates, and small mammals. Future concentrations of trace metals in these environmental media and food items were predicted using methods and models that are considered to be realistic or conservative.

7.7.4.8.5 Wildlife Exposure Factors

Virtually every factor incorporated into dose calculations for wildlife species possesses a site-specific component. Validity of each exposure factor is dependent on consideration of the site-specific nature of these factors. In the absence of site-specific validation, exposure factors are incorporated based on validations performed elsewhere for other cases and sometimes for other species. Considerations such as food ingestion rates, water ingestion rates, incidental soil ingestion rates, dietary composition, home range, and time spent at the Project site were collected from the scientific literature based on other sites and locations.

7.7.4.8.6 Measurement Endpoints from the Toxicity Data

The paucity of toxicity data for many contaminants limited the measurement endpoints that were available. The risk of a toxic effect is evaluated using a lowest observed adverse effect level (LOAEL) based toxicity benchmark. Given the overall tendency to introduce conservatism (through the use of data or assumptions that are likely to overstate, rather than understate risk) into risk assessments, it is likely that no adverse environmental effect will exist below the RQ target value of less than 1.0. This approach is conservative, and if observed RQ values are lower than the target RQ values, it is assumed that there is little potential for observable environmental effects at the population or individual level, respectively. However, an RQ value greater than 1 is not by itself an indication that harm to receptor organisms is certain to occur. The conservatisms inherent in the model development mitigate this conclusion, and the movements of wildlife receptors and consequent risk-averaging tend to reduce their actual exposure level in comparison with the exposure level predicted at point locations.

7.7.4.8.7 Modelling Assumptions

Generally, uncertainties are addressed by incorporating conservative assumptions (*i.e.,* assumptions that are likely to overstate risk) in the analysis. Where several conservative assumptions are involved in the same calculation, a high level of conservatism can result from the combination of the assumptions. As a result, risk assessments tend to overstate the actual risk with the result that conclusions are very robust. Although many factors are considered in preparation of a risk assessment, the results are generally most sensitive to a few key assumptions. The uncertainty analysis is included to demonstrate that assumptions used are conservative, or that the result of the analysis is not sensitive to the key assumptions.

7.7.5 Summary

A Human Health and Ecological Risk Assessment (HHERA) was completed to quantify the potential risks to human and ecological health that could result from the Construction, Operation, and Decommissioning, Reclamation and Closure of the Project. The potential human and ecological health risks were assessed for both the existing (Baseline Case) and future (Project + Baseline Case) conditions, and followed published regulatory guidance for completion of HHERAs.

With respect to human health, as determined by the Human Health Risk Assessment (HHRA) the Project activities are not expected to result in short-term exposures above the health-based ambient air quality guidelines established by regulatory agencies at the recreational campsites, nearest residences in Napadogan, or the HHERA receptor locations. As well, the Project is not expected to affect the human health risks for long-term inhalation exposures, exposure to soil, or ingestion of water. Project-related activities have the potential to affect the human health risks for consumption of food.

The human health risks associated with consumption of food for the existing (Baseline Case) concentrations of a number of metals (*i.e.,* arsenic, chromium, cobalt, lead, manganese, methyl mercury (fish only), and thallium) found in the environment near the Project were determined through the HHRA to be high in relation to accepted benchmarks (even in the absence of the Project), thus potentially contributing to health risks to Aboriginal receptors that may currently be obtaining 100% of their game, 20% of their fish, and 10% of their total vegetation from the Study Area. Predicted human health risks associated with Project-related activities were generally similar to baseline human health risks, with the exception of predicted human health risks associated with predicted concentrations of arsenic, boron, cobalt and thallium in fish tissues. However, further examination of these data determined that concentrations of these metals in fish tissues or surface water are similar to published concentrations from other areas of Canada and North America obtained from reference locations or natural areas or meet fish tissue guidelines (where available).

With respect to ecological health, as determined by the Ecological Risk Assessment (ERA), predicted ecological health risks were identified for certain receptors in relation to arsenic, copper, manganese, thallium, vanadium and zinc exposure. However, differences in predicted ecological health risks between the Baseline Case and Project + Baseline Case scenarios were generally negligible for terrestrial mammalian and avian wildlife. Identified predicted ecological health risks to the terrestrial wildlife (which in some cases are localized) are generally related to pre-existing baseline metal concentrations in the environment, and the Project-related contribution to these environmental effects is negligible.

For semi-aquatic wildlife (*i.e.,* American mink, American black duck, and belted kingfisher), predicted ecological health risks were identified for certain receptors in relation to thallium and vanadium exposure. Ecological health risks in relation to thallium were identified for the Project + Baseline Case for the American black duck. Ecological health risks in relation to vanadium were identified for both the Baseline Case and the Project + Baseline Case for the American black duck and the belted kingfisher. Both can be related to an increase in predicted surface water concentrations due primarily to modelled seepage from the TSF toward small tributaries of West Branch Napadogan Brook. However, these ecological health risks are expected to be localized and as such are not expected to result in population-level environmental effects.

For the terrestrial community (*i.e.*, soil invertebrates and terrestrial plants), potential ecological health risks were identified for both soil invertebrates and terrestrial plants exposed to arsenic, boron, and manganese in soil for both the Baseline Case and the Project + Baseline Case; ecological health risks were also identified for terrestrial plants exposed to vanadium in soil for both the Baseline Case and Project + Baseline Case. Comparison of the Baseline Case soil concentrations to the predicted Project + Baseline Case soil concentrations revealed less than 0.001% increase arising from the Project. Therefore, ore dust deposition is expected to negligibly affect soil quality, or COPC concentrations, in terrestrial plants or soil invertebrates in areas that are not directly disturbed by mining activity.

For the sediment community (*i.e.*, benthic invertebrates), comparison of sediment concentrations to Canadian Sediment Quality Guidelines for the Protection of Aquatic Life probable effect levels revealed exceedances of the arsenic guideline. Predicted Project + Baseline Case sediment concentrations are mainly related to pre-existing Baseline Case metal concentrations. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life are meant to be protective for a range of species and, as such, sediment concentrations less than these guidelines are indicative of a negligible probability of adverse environmental effects. Where concentrations are greater than these guidelines, there is a possibility (but not a certainty) of adverse environmental effects to ecological receptors. Such cases require a careful review of predicted exposure levels, and more focused investigations may be required to reduce conservatism in the assessment. Follow-up may be used to confirm the predicted changes in sediment arsenic concentrations in view of the modelling uncertainties and conservatism.