

Appendix C.4

Groundwater Assessment

**Crawford Nickel Project
Technical Data Report –
Groundwater Assessment**

September 30, 2024

Prepared for:

Canada Nickel Company



Prepared by:


Stantec Consulting Ltd.



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Executive Summary

The Canada Nickel Company Incorporated (Canada Nickel) proposes to develop, construct, operate, and progressively reclaim a new open pit nickel mine and processing facility, collectively known as the Crawford Nickel Project ('the Project'), approximately 42 km north of Timmins, Ontario. The Project includes the development of an Open Pit, Stockpiles, two ore Processing Plants, and other mine-related infrastructure, as well as a new rail spur line. Highway 655 and an existing 500 kilovolt (kV) transmission line will be relocated to facilitate the Project. The Project has an expected project life of 41 years.

The following Technical Data Report (TDR) consolidates the results of the assessment of the effects of each of the Project components and physical activities, in all phases of the Project, based upon a comparison of baseline environmental, health, social and economic conditions and the predicted future conditions with and without the Project for groundwater. The TDR will inform the completion of the associated Valued Component (VC) chapter and will be appended to the Impact Statement.

This TDR has been prepared pursuant to the *Impact Assessment Act*, 2019 and in consideration of the Tailored Impact Statement Guidelines (TIS Guidelines) for the Project.

This TDR provides a groundwater assessment of predicted change from baseline conditions based on the proposed Project design and corresponding activities proposed during construction, operation, and passive closure phases of the Project. The scope of the report includes:

- assessment of the Project activities on groundwater quantity
- assessment of the Project activities to groundwater quality

Groundwater models to assess potential Project effects on groundwater flow were developed in two-phases, as follows:

- The development of a hydrostratigraphic conceptual model was the first step in the preparation of a numerical groundwater flow model. The conceptual model reflects the fundamental hydrogeological concepts considering geological, hydrogeological, and hydrological data pertinent to the site that will be modelled.
- Next, a numerical, three-dimensional groundwater flow model was developed to represent baseline conditions and to assess the potential effects of the Project on groundwater resources and the consequent indirect effects on surface water resources. This three-dimensional numerical groundwater flow model was developed using the hydrostratigraphic units of the conceptual model. Modifications were completed to simulate operation and decommissioning/post closure phases of mine development. The construction phase of the Project was not simulated for groundwater since dewatering activities are anticipated to be short term (e.g. temporary dewatering for construction of foundations for site infrastructure) and within the first one to two metres below shallow groundwater table.

The calibrated groundwater flow model described above was used to predict the water table elevation and groundwater flow under baseline conditions. The primary effect of the Project on groundwater quantity and flow is a lowering of the water table as a result of dewatering the Open Pit during

construction and operations and, to a lesser extent, during closure when the Open Pit refills. The maximum rate of groundwater inflow to the Open Pit is predicted to be 10,500 cubic metres per day (m^3/day) and is predicted to occur at the end of Year 17 when the Main Zone is developed to full depth and development of the East Zone is ongoing. The associated 1 m drawdown cone is predicted to extend up to 3.2 kilometres (km) to the east, 3.9 km to the west, 2.5 km to the south, and 7.3 km to the north of the Open Pit.

The effect on groundwater quality is an increase in concentrations of parameters in groundwater from seepage to groundwater from the Impoundment Facility, East and West Stockpiles, Tailings Management Facility (TMF), and from tailings impounded within the Open Pit. The following trends were observed when comparing water quality in seepage from the TMF, Impoundment Facility, and East and West Stockpiles to relevant regulatory criteria:

- Seepage from the TMF is not predicted to exceed MDMER but is predicted to exceed the ODWQS and/or the GCDWQ aesthetic guidelines for chloride and manganese, and the Medical Officer of Health reporting limit for sodium. Concentrations of manganese above the ODWQS and/or GCDWQ are typical of baseline groundwater quality.
- Seepage from the Impoundment Facility is not predicted to exceed MDMER but is predicted to exceed the ODWQS and/or the GCDWQ for arsenic, manganese, uranium, and nitrate, and the Medical Officer of Health reporting limit for sodium. Seepage from the Impoundment Facility is also predicted to exceed the 10 x PWQO (interim) criteria for copper, but not the 10 x CWQG-FAL criteria. Concentrations of arsenic and manganese above the ODWQS and/or the GCDWQ are typical of baseline groundwater quality.
- Seepage from the East and West Stockpiles is not predicted to exceed MDMER, the ODWQS, or the GCDWQ for the parameters analyzed. Seepage from the East and West Stockpiles may exceed 10 x PWQO and 10 x CWQG-FAL for Hexavalent Chromium.

The fate of groundwater recharging beneath the mine infrastructure was predicted using the groundwater flow model. For groundwater recharge originating at the TMF during operation of the TMF is predicted to discharge predominantly to the Open Pit as well as Jocko Creek, West Buskegau River, an Unnamed Lake (South of Zed Lake), and Gerry Lake. Once the TMF is rehabilitated (after Year 17), recharge through the TMF is reduced and groundwater recharge originating at the TMF is predicted to discharge predominantly to an Unnamed Lake (south of Zed Lake) and Gerry Lake with a minor component of discharge to the Open Pit and other watercourses. Groundwater recharge originating at the Impoundment Facility is predicted to predominantly discharge to the Open Pit and an unnamed lake (West Stockpile), North Driftwood River, and/or West Buskegau River during operations with discharge to the North Driftwood River, West Buskegau River, and the Open Pit in closure. The majority of recharge originating beneath the stockpiles is predicted to be captured by the Open Pit with the majority of recharge through the impounded tailings in the Open Pit predicted to remain within the Open Pit (90%).

Canada Nickel will develop a follow-up and monitoring program to monitor groundwater levels and groundwater quality at key Project locations. Monitoring data from these locations will be used to verify and confirm the predicted effects of the Project on groundwater and to meet regulatory requirements related to specific permits or conditions of approval.

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Acronyms and Abbreviations

amsl	Above mean sea level
APV	Aquatic Protection Values
bgs	below ground surface
CCME	Canadian Council of Ministers of the Environment
CWQG-FAL	Canadian Water Quality Guidelines for the Protection of Aquatic Health
DEM	Digital Elevation Model
ECA	Environmental Compliance Approval
EPA	Environmental Protection Act
EPM	Equivalent Porous Media
GCDWQ	Guidelines for Canadian Drinking Water Quality
GHB	General Head Boundary
HCT	Humidity Cell Test
HFB	Horizontal Flow Barrier
IPT	In-Process Tailings
LSA	Local Study Area
MDMER	Metal and Diamond Mining Effluent Regulations
MECP	Ministry of the Environment, Conservation and Parks
ODWQS	Ontario Drinking Water Quality Standards
OWRA	Ontario Water Resources Act
POPC	Parameter of Potential Concern
PA	Project Area

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PDEM	Provincial Digital Elevation Model
PTTW	Permit to Take Water
PWQO	Provincial Water Quality Objectives
RIV	River Boundary
RMS	Root Mean Square
RQD	rock quality designation
RSA	Regional Study Area
TDR	Technical Data Report
TIS	Tailored Impact Statement
TMF	Tailings Management Facility
VC	Valued Component

1 Introduction

Canada Nickel Company (Canada Nickel) proposes to develop, operate, and progressively reclaim the Crawford Nickel Project ('the Project'), a new open pit nickel mine and processing facility approximately 42 kilometres (km) north of Timmins, Ontario along Highway 655. The Project is being assessed in accordance with the *Impact Assessment Act, 2019*.

Stantec Consulting Ltd. (Stantec) has been retained by Canada Nickel to conduct an assessment of the effects of the Project on groundwater. This report provides a groundwater assessment of predicted change from baseline conditions based on the proposed Project design and corresponding activities proposed during construction, operation, and decommissioning of the Project.

This Technical Data Report – Groundwater has been prepared pursuant to the *Impact Assessment Act, 2019* and in consideration of the Tailored Impact Statement Guidelines: Crawford Nickel Project (TIS Guidelines; Appendix A.1 of the Impact Statement). Figures referenced throughout this report are provided in Appendix A of this report.

1.1 Study Objectives

The Technical Data Report – Groundwater will inform the Impact Statement for the Project. The objectives of this study are to describe and present the assessment of predicted changes to groundwater quantity and quality as a result of the Project. This assessment is consistent with Health Canada's Guidance for Evaluating Human Health Effects in Impact Assessment (Health Canada 2023) as summarized in Appendix B of this report.

The scope of the Technical Data Report – Groundwater includes the following:

- Assessment of the Project activities on groundwater quantity as follows:
 - Construction and calibration of a three-dimensional numerical groundwater flow model of the baseline hydrogeological system so that the model can be used to complete prediction scenarios that incorporate the Open Pit, Impoundment Facility, East and West Stockpiles, and Tailings Management Facility (TMF).
 - Using the three-dimensional numerical groundwater flow model, predict:
 - Open Pit groundwater inflow rates.
 - Groundwater drawdown and/or mounding related to the Project activities.
 - Changes in groundwater discharge to surface water, or surface water recharge to groundwater, relative to the calibrated baseline conditions for the operation and passive closure phases of the Project.

- Assessment of the Project activities to groundwater quality as follows:
 - Predicting the fate of seepage from the Impoundment Facility, East and West Stockpiles, and TMF using the three-dimensional numerical groundwater flow model.
 - Predicting the fate of groundwater that has come into contact with the tailings stored below the water table in the East and Main Zones of the Open Pit.
 - Review of seepage quality and quantity from the Impoundment Facility, East and West Stockpiles, and TMF with respect to groundwater users.
- Provide a conceptual follow-up monitoring program to validate predictions of the groundwater quantity and quality effects assessment.

1.2 Project Overview

The Project includes the development of an Open Pit, Stockpiles, two ore Processing Plants, and other mine-related infrastructure, as well as a new rail spur line and the relocation of Highway 655 and an existing 500 kilovolt (kV) transmission line. Ore will be extracted from a single Open Pit that will be divided into an East Zone and Main Zone. The projected maximum depth of the Open Pit is 690 metres (m). The Project has a mineral reserve estimate of 1,715 million tonnes (Mt) and an expected project life of 41 years.

The Project is located approximately 42 km north of the City of Timmins, Ontario, in the geographic Townships of Crawford, Carnegie, Kidd, Lucas, Beck, Nesbitt, Wark and Prosser. A small portion of the Project extent within Kidd Township also lies within the municipal boundary of the City of Timmins.

Based on the current Project design, the maximum rate of ore extraction will be up to 240,000 tonnes per day (tpd) during Year 5 of operations and an average rate of 160,000 tpd over the life of mine. The two ore Processing Plants and associated service facilities will process run of mine ore delivered to primary crushers to produce nickel concentrate, iron concentrate, and tailings at a rate of approximately 60,000 tpd at the start of mine life, ramping up to a maximum of 120,000 tpd. In addition to nickel and iron, other metals such as cobalt, chromium, palladium and platinum are expected to be recovered from concentrate streams.

Based on the proposed processing rate and current information regarding the ore body, the current life of the proposed Project is expected to be approximately 41 years. Mining would be completed at a faster pace than milling, thus mining of ore would occur for about 30 years, then milling alone for the last 11 years.

Concentrate from the processing plants will be loaded onto rail cars and shipped via the rail spur line for refinement offsite.

1.3 Key Project Activities

The timing of activities and installation of Project components will occur in sequence to allow for the efficient extraction of materials. Various construction, operations, and decommissioning activities are proposed throughout the life of the mine. For the purposes of the assessment, these Project activities are anticipated to be advanced in three phases:

- Construction (Year -3 to Year -1)
- Operations
 - Operations phase 1 (Year 1 to Year 5): 60 kilotons per day (kt/d) milling capacity with ore extraction
 - Operations phase 2 (Year 5 to Year 30): 120 kt/d milling capacity with ore extraction
 - Operations phase 3 (Year 30 to Year 41): 120 kt/d milling capacity with no ore extraction
- Decommissioning and closure
 - Active closure (Year 41 to Year 46)
 - Passive closure (Year 46+)

1.3.1 Construction Phase

The Construction Phase will include the preparation of the site up to the point at which the first Process Plant has been commissioned and is ready to commence operations. This phase will include site preparation, physical construction, pre-production, and commissioning activities. Construction is anticipated to begin in the Main Zone and East Zone, with some pit dewatering required to accommodate rock extraction. Rock extracted from the Open Pits at this time may be crushed into aggregate using a mobile aggregate crusher for use during the construction of roads and other infrastructure, as necessary.

It is noted that additional construction will occur through the operations phases of the Project, and that the operations phase is defined by the start of ore processing.

1.3.2 Operations Phase

The operations phase is focused on the active processing of ore and generation of concentrate for delivery to market, specifically operation of the Process Plant(s). Due to the sequential nature of the mine operations, the operations phase of the Project has been divided into three sub-phases based on the Open Pit extraction schedule and sequential operation of the two Process Plants.

The three sub-phases of the operations phase include:

- Operations Phase 1 – This phase includes the operation of the first of two Process Plants that will be operating at an ore processing capacity of approximately 60 kt/day (or 21.9 Mt/a). In-Process Tailings (IPT) carbonation within the Process Plant may also commence if a carbon dioxide source is available. Mining operations during this phase will produce more ore than the

Process Plant can process, with surplus material to be stockpiled in the East Stockpile location for future processing. Construction will continue during the phase to expand and construct the second Process Plant and other supporting mine infrastructure, including the Highway 655 realignment. Material will begin to be stored within the West Stockpile at the end of this phase.

- Operations Phase 2 – This phase includes the operation of both Process Plants that will be operating at an ore processing capacity of approximately 120 kt/d (or 43.8 Mt/a), including IPT carbonation. Mining operations during this phase will produce up to 240 kt/day, which is more ore than the Process Plants can process. Ore will continue to be stockpiled in the East and/or the West Stockpiles.
- Operations Phase 3 – This phase includes continuation of the operation of both Process Plants at an ore processing capacity of approximately 120 kt/d (or 43.8 Mt/a) following completion of mining operations (e.g., no further extraction of ore from the pit). The Process Plants, including IPT carbonation, will continue to operate by processing the ore stockpiled during operations phases 1 and 2. As mine operations cease, there will be an opportunity for progressive reclamation of the pit, haul routes, and other, no longer used, areas of the Project site.

1.3.3 Decommissioning and Closure Phase

Following the completion of ore processing, all Project operations will cease, and active closure will commence. Active closure includes the removal of buildings, structures, and other infrastructure, as well as reclamation and site stabilization activities. Once complete, the Project will then enter a passive closure phase as the pit lakes fill. During this time, closure monitoring and adaptive mitigation will occur. Following pit lake filling, the Project site will be permanently closed.

Activities completed during the decommissioning and closure phase of the Project are focused on reclaiming the environment, establishing physical, chemical, and biological stability at the site, and meeting desired end land functions and uses. The Closure Plan will be updated throughout the life of the Project as necessary to reflect the environmental requirements in place at the time of closure. The Closure Plan will be prepared, refined, and implemented in accordance with the Ontario *Mining Act* and Ontario Regulation 35/24.

Progressive reclamation will occur throughout the course of the mine life; however the majority of reclamation activities will occur during the five year period after ore processing ceases. Ongoing closure monitoring and maintenance activities will be carried out throughout active and passive closure phases until the closure objectives have been satisfied and the Project has been moved to a closed out and abandoned status.

2 Study Area

The Project comprises approximately 11,785 hectares (ha) along Highway 655, approximately 42 km north of the City of Timmins, Ontario. The Project is located mostly within the Geographic Townships of Crawford and Lucas, with elements also in the Townships of Nesbitt, Beck, Carnegie, and Prosser. The proposed Highway 655 realignment and rail spur line extend into the geographic Townships of Kidd and Wark (which are considered to be part of the City of Timmins).

2.1 Project Area

The Project Area (PA) encompasses the Project footprint and is the anticipated area of physical disturbance associated with the construction, operation, and decommissioning/closure of the Project. The PA is shown on Figure A.1.

2.2 Local Study Area

The Local Study Area (LSA) for groundwater encompasses the area in which Project-related effects (direct or indirect) were predicted or measured with a level of confidence appropriate for the assessment and in which there is a reasonable expectation that the potential effects in the LSA are of public interest. The LSA for groundwater was selected to extend beyond the likely extent of drawdown from dewatering the Open Pit and changes to flow or groundwater quality due to recharge from the Project components.

The LSA, as shown on Figure A.2, is defined by major river watershed boundaries with the Central Mattagami River watershed boundary to the west, northwest, and southwest; and the Abitibi River watershed boundary to the east, northeast, and southeast.

2.3 Regional Study Area

The Regional Study Area (RSA) for groundwater includes the area within which cumulative effects on groundwater are likely to occur, depending on the location of other past, present, or reasonably foreseeable future projects or activities.

Given the localized nature of potential Project-related effects to groundwater, the RSA for the groundwater assessment is equal to the LSA. The RSA is shown on Figure A.2.

3 Regulatory Setting

Federal and provincial water quality guidelines are used to protect drinking water and freshwater aquatic biota. This technical data report uses these guidelines to assess the effects of the Project on groundwater as part of the Impact Statement. These guidelines are described below, along with other laws, policies, and guidelines that govern the management and protection of groundwater in Canada and Ontario.

3.1 Impact Statement Guidelines

This technical data report (TDR) for groundwater has been prepared in accordance with the requirements of the TIS Guidelines (Appendix A.1 of the Impact Statement), specifically Section 8.6 that describe the requirements for the characterization of effects to groundwater for the Project.

3.2 Federal

The following provides a summary of federal regulations, policies, and/or guidelines that directly or indirectly apply to groundwater.

3.2.1 Fisheries Act

The *Fisheries Act*, administered primarily by Fisheries and Oceans Canada with some provisions administered by Environment and Climate Change Canada, restricts or controls the deposit of deleterious substances into waters or locations frequented by fish unless authorized by regulation. A number of regulations have been made to carry out the purposes and provisions of the *Fisheries Act*. The MDMER define un-ionized ammonia, arsenic, copper, cyanide, lead, nickel, zinc, total suspended solids and radium 226 as deleterious substances and Schedule 4 of the MDMER imposes limits on their concentrations in effluent at the final discharge point to the receiving body of water. With respect to groundwater, the MDMER defines effluent as seepage containing any deleterious substance that flows over, through, or out of the site of a mine. The MDMER Schedule 4 criteria are used to screen the quality of seepage from mine rock and tailings associated with the Project.

3.2.2 Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life

The *Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life* (CWQG-FAL) are established by the Canadian Council of Ministers of the Environment (CCME 2017) and are intended to protect all forms of aquatic life, as well as all aspects of aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term from anthropogenic stressors such as chemical inputs or changes to physical components. These guidelines are developed collaboratively among provincial, territorial and federal jurisdictions, and are regularly updated to reflect current toxicology information and guideline derivation approaches. They provide the science-based benchmark for a nationally consistent level of protection for aquatic life in Canada. The CWQG-FAL are used to characterize groundwater quality where groundwater is anticipated to discharge to surface water. For the

parameters analyzed as part of the Project, the CWQG-FAL generally have the same values as the Ontario Provincial Water Quality Objectives (PWQO). Where the criteria for the CWQG-FAL and PWQO differed, the criteria based on the most recent update was considered applicable. For this Project, the CWQG-FALs are used with a ten times dilution factor, in a manner consistent with the development of GW-3 values under Ontario Regulation 153/04, as a comparison where groundwater is anticipated to discharge to surface water features (refer to Section 3.3.2).

3.2.3 Guidelines for Canadian Drinking Water Quality

The *Guidelines for Canadian Drinking Water Quality* (GCDWQ) are established by Health Canada in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water and other federal government departments and are published by Health Canada (2022). These guidelines are based on current published scientific research related to health effects, aesthetic effects, and operational conditions of various parameters in drinking water.

The GCDWQ are used to characterize groundwater quality where groundwater is anticipated to be used as a source of drinking water and/or where groundwater is anticipated to flow beyond the Project Area prior to discharging to a surface water feature. The GCDWQ generally have the same values as the Ontario Drinking Water Quality Standards (ODWQS). Where the criteria for the GCDWQ and ODWQS differed, the criteria based on the most recent update was considered applicable.

3.3 Provincial

The following provides a summary of provincial regulations, policies, and/or guidelines that directly or indirectly apply to groundwater.

3.3.1 Mining Act and Building More Mines Act

The *Building More Mines Act* amends the *Mining Act* and sets out standards and criteria for mine closure through Ontario Regulation 35/24 (O. Reg. 35/24), Rehabilitation of Lands and the Mine Rehabilitation Code of Ontario. Specifically, with respect to groundwater, these statutes and regulations identify groundwater quality parameters to be monitored from mines, as well as monitoring and certification requirements for assessing the success of closure activities in protecting groundwater from potential mining effects. Additionally, these statutes and regulations provide guidance and direction regarding progressive rehabilitation to accelerate mine site rehabilitation in advance of close out activities. The monitoring requirements for the Project related to groundwater will be developed to meet the requirements under O. Reg. 35/24 and the Mine Rehabilitation Code of Ontario.

3.3.2 Environmental Protection Act

The *Environmental Protection Act* (EPA) is the principal pollution control statute in Ontario and is used in conjunction with the *Ontario Water Resources Act* (OWRA) to address sources of water pollution. The EPA contains general provisions that can be used to protect surface water and groundwater quality.

The EPA sets out requirements regarding discharges to the environment and environmental remediation. Part XV.1 of the EPA and O. Reg. 153/04 pertain to the remediation of contaminated properties.

O. Reg. 153/04 applies to properties that are being redeveloped from a less sensitive property use (e.g., industrial) to a more sensitive property use (e.g., residential), and where a Record of Site Condition (RSC) is required. In practice, the regulation is applied to the assessment and management of soil, groundwater, and sediment contamination regardless of whether or not an RSC is required.

Surface water resources may be affected by brownfield properties as a result of the discharge of impacted groundwater to surface water receivers. Under O. Reg. 153/04, the MECP has developed Aquatic Protection Values (APVs) to protect aquatic biota from migration of impacted groundwater to surface water (MOE 2011). The APVs are designed to provide a scientifically defensible and reasonably conservative level of protection for aquatic organisms from the migration of contaminated groundwater to surface water resources. The APVs are the established water quality criteria in surface water and are used to determine the acceptable concentrations in groundwater (GW-3 values) by back-calculating through a defined modelling process that considers a ten times dilution in the receiving environment. For this Project, the defined modelling process that considers a ten times dilution in the receiving environment compared to groundwater is used when comparing the groundwater quality data to surface water criteria.

3.3.3 Safe Drinking Water Act

The *Safe Drinking Water Act, 2002*, is an Act to prevent drinking water health hazards through the control and regulation of drinking water systems and drinking water testing in Ontario. A number of drinking water regulations have been made under the *Safe Drinking Water Act*, including O. Reg. 169/03 (ODWQS), which set out prescribed drinking water quality standards in Schedule 1 (microbiological), Schedule 2 (chemical), and Schedule 3 (radiological). The ODWQS are used to characterize groundwater quality in areas where the use of groundwater as a source of drinking water is anticipated or where groundwater is anticipated to flow beyond the Project Area. The ODWQS generally have the same values as the GCDWQ.

3.3.4 Ontario Water Resources Act

The OWRA is the principal statute governing water quality and quantity in Ontario. It is a general management statute that applies to groundwater and surface water. Administered by the MECP, the OWRA contains several important regulations that protect water resources, including:

- The Water Taking and Transfer Regulation (O. Reg. 387/04), which requires a permit for water takings of more than a total of 50 m³/d (with some exceptions). Section 34 of the OWRA requires the proponent to obtain a Permit to Take Water (PTTW) and Section 9 of O. Reg. 387/04 requires all permit holders to collect, record and report data on daily volumes of water withdrawals.
- Section 53 of the OWRA requires an Environmental Compliance Approval (ECA) which is a permission that allows a business to operate their facility or site with environmental controls that protect human health and the natural environment. The ECA prescribes site-specific criteria for the quality and quantity of effluent discharged from a facility or site.

3.3.5 Provincial Water Quality Objectives

The PWQOs were developed by MECP (MOE 1999) through its responsibilities under the OWRA and EPA, along with management policies and guidelines, for the protection of aquatic life and recreational uses; they are numerical and narrative ambient surface water quality criteria that represent a desirable level of surface water quality. PWQOs for the protection of aquatic life are conservative values that, when met, are intended to be protective of all forms of aquatic life and all aspects of the aquatic life cycle during an indefinite exposure to the water (MOE 1999).

For the Project, the PWQO (or interim PWQO if applicable) are used with a ten times dilution factor, in a manor consistent with the development of GW-3 values under O.Reg. 153/04, as a comparison where groundwater is anticipated to discharge to surface water features.

4 Background

The existing hydrogeological conditions within the RSA were summarized in the Groundwater Baseline Report (Appendix B.5 of the Impact Statement). The summary was based on a literature review and field surveys which included the installation of 31 monitoring wells and 7 drive-point piezometers; hydraulic response testing in 22 monitoring wells and 27 exploration boreholes; manual and automated water level monitoring at 31 locations; and, groundwater quality sampling in 33 overburden and bedrock monitoring wells. Key findings of the Groundwater Baseline Report (Appendix B.5 of the Impact Statement) were as follows:

- Topography across the LSA/RSA is generally flat, with local topographic lows typically associated with surface water features, and topographic highs associated with watershed boundaries and an esker. The PA is undeveloped and naturally forested with no known anthropogenic sources that may affect groundwater quantity or quality. Within the PA, local ground surface elevations typically range between a high of 286 m above mean sea level (amsl) to the south, with a low of 266 m amsl to the northwest.
- The PA is located primarily between the North Driftwood River and the West Buskegau River, both of which drain north into the Abitibi River. Jocko Creek crosses the southern portion of the PA and drains into Kidd Creek and subsequently the Mattagami River. Several lakes located adjacent to the PA drain into the North Driftwood River, including David Lake, Mel Lake, Sutherland Lake, Jack Lake, Gerry Lake and Martin Lake. Surface water flow is typically in a northerly direction, towards James Bay.
- Based on a review of the online MECP Water Well Record (WWR) database, there are three wells located within the PA, one of which is abandoned. The other two wells are registered as supply wells, one being a commercial water supply well screened within a sand and gravel overburden aquifer, and the second being a domestic supply well screened in bedrock. In addition, five private dwellings were identified near the PA, one of which was confirmed by Canada Nickel to have a drilled well. The other locations are assumed to use surface water intakes as a water source as they are seasonal camps or cottages.
- There are two active PTTWs within the LSA/RSA: one is for a water supply well and for dewatering from a mine sump that expires in 2024, (with a 10-year extension request currently under review with MECP), and the second is for dewatering of groundwater and surface water at the Carnegie Township Quarry that expires in 2027.
- The LSA/RSA is located in the Northern Clay Belt, which is characterized as low lying, undulating plain of glaciolacustrine clay. Underlying the clay is a discontinuous glaciofluvial sand deposit followed by glacial till (silt and/or clay) that overlies bedrock. A north-south trending esker composed of sand and gravel is located about 500 m west of the PA. There is only a small proportion of outcrop exposure, mostly confined to higher ground. Overburden thickness ranges from 10 m to 90 m, with an average thickness of about 40 m across the PA.

- The LSA/RSA is situated in the Abitibi Greenstone belt within the Superior Province. The bedrock in the LSA/RSA is composed of a felsic to mafic volcanic assemblage hosting the Crawford Ultramafic Complex, local metasediments (i.e., iron formation, minor metavolcanic rocks), and other local ultramafic sills. There is only one area in the northwest portion of the LSA/RSA where bedrock is outcropping.
- Several regional faults are found in the LSA/RSA, generally showing a north-northwest to south-southeast strike. The major regional faults following this trend are the Mattagami River Fault, the Buskegau River Fault, and the Main Regional Fault. Multiple discontinuous, unnamed faults have a similar strike.
- Groundwater flow is generally in a south to north direction across the PA. Due to the surficial clay, artesian pressures are often observed at the monitoring wells. Given the confining nature of the surficial clay, direct water level responses to precipitation are not observed, and a muted seasonal water level response is noted (i.e., generally less than 1 m water level fluctuation throughout the year). Within the PA, the water table generally ranges from 267 to 281 m amsl.
- Where nested monitoring wells exist between the bedrock and overburden, a downward vertical hydraulic gradient was observed.
- A moderate baseflow index of 0.30 suggests that surface water features in the area may be groundwater discharge points and that upward vertical gradients are likely to be present in the shallow groundwater near surface water features.
- Mean concentrations of arsenic, cyanide (total and free), fluoride, iron, manganese, phosphorous, and hardness in overburden and/or bedrock wells in the PA exceeded at least one of the ODWQS, GCDWQ, PWQO, and/or CWQG-FAL. Concentrations of these parameters above these criteria are typical of groundwater in Ontario and are reflective of the natural mineralization and geochemical processes in the area.
- Within bedrock monitoring wells, the mean groundwater concentrations in collected samples exceeded at least one of the ODWQS, GCDWQ, PWQO, and/or CWQG-FAL for the following parameters considered atypical of groundwater in Ontario: pH, ammonia (un-ionized), boron and zinc.
- Within overburden monitoring wells, the mean groundwater concentrations in samples collected exceeded at least one of the ODWQS, GCDWQ, PWQO, and/or CWQG-FAL on a consistent basis for the following parameters considered atypical of groundwater in Ontario: pH, sodium and zinc.
- Within overburden monitoring wells, other parameters that were noted to be elevated above at least one of the ODWQS, GCDWQ, PWQO, and/or CWQG-FAL for mean concentrations in three or fewer wells included alkalinity, un-ionized ammonia, free cyanide, aluminum, cobalt, copper, silver, vanadium, and zirconium.
- Polycyclic aromatic hydrocarbons (PAHs) were generally non-detect in both overburden and bedrock wells. Select PAHs were detected in a single monitoring well screened within silty sand.

5 Methods

5.1 Hydrostratigraphic Conceptual Model

The development of a conceptual model is the fundamental first step in the preparation of a numerical groundwater flow model. The conceptual model reflects the fundamental hydrogeological concepts considering geological, hydrogeological, and hydrological data pertinent to the site that will be modelled.

The development of the conceptual model was facilitated using the geologic modelling software Leapfrog Works® Version 2023.1. The software was used to create three-dimensional volumes of the lithologies which make up each of the hydrostratigraphic units defined in the groundwater flow model. Inputs for volume generation included wireframes for the ground surface topography, structural features, as well as contact points for the various lithologies defined from borehole (74 geotechnical and 384 exploration boreholes) and outcrop data.

The following hydrostratigraphic units are interpreted across the LSA/RSA (Appendix B.5 of the Impact Statement). They are presented from most recent to most ancient. Since the deglaciation included a re-advance of the ice sheet, this sequence can repeat itself or be variable where stratigraphic sequences are incomplete.

5.1.1 Overburden

Organic deposits resulting from the accumulation of vegetative matter are a common surface material, found typically in poorly to very poorly drained areas and forming peatlands. This deposit occurs in isolated areas, is typically less than 1 m thick, and is not considered to be hydraulically significant as it relates to groundwater flow across the PA. Consequently, this unit was not included in the groundwater flow model.

Eskers – several eskers are located throughout the LSA/RSA, as shown on Figure A.3 (Unit 22), which are oriented north-northwest to south-southeast direction and are in direct contact with bedrock. One esker is located partially within the PA. Based on logs of two boreholes that were drilled into the esker within the PA, the lithology of the esker ranges from a poorly-graded to well-graded sand. The esker deposits extend from at or near ground surface to as deep as 42 m below ground surface (bgs) and are found to directly overly bedrock suggesting the meltwaters eroded away previously deposited materials prior to depositing the esker. Literature values for hydraulic conductivity of fine to medium-grained sand range from 1×10^{-5} m/s to 1×10^{-3} m/s, and from 1×10^{-7} m/s to 1×10^{-5} m/s for a silty sand to fine sand (Fetter 1994).

Glaciolacustrine Deposits – Clay deposits are fine-grained glaciolacustrine sediments settled in and along the margins of glacial lakes and can include materials released by the melting of floating ice. Within the LSA/RSA, clay occurs as thick, varved, at or near surface deposits that contain a varying amount of silt and are often 10 m to 20 m thick, but can reach thicknesses up to 40 m. They can be intersected with sand or till deposits. One hydraulic response test was completed for the surficial clay unit which was used

to estimate a hydraulic conductivity of 2×10^{-8} m/s. This is consistent with literatures values for clay, which range from 1×10^{-11} m/s to 1×10^{-8} m/s (Fetter 1994).

Glaciofluvial Deposits – Sand sediments are deposited by glacial meltwater streams often in close proximity to glacial ice, are typically well to moderately well drained, and rapidly permeable. These materials are composed of silty fine-grained sand to pebble gravel. They are discontinuous within the LSA/RSA and are mainly found as discontinuous or isolated deposits underlying the clay throughout the PA. These deposits can reach up to 40 m in thickness based on borehole data. There are 18 monitoring wells screened within buried sand or silty sand deposits for which *in situ* hydraulic conductivity testing was completed. The estimated hydraulic conductivity ranged from 5×10^{-7} m/s to 2×10^{-4} m/s, with a geomean of 1×10^{-5} m/s. The hydraulic conductivity estimates are consistent with literature values for a silty sand to fine sand, which range from 1×10^{-7} to 1×10^{-4} m/s (Fetter 1994).

Till - Silty sand/sandy till is a widespread deposit found predominantly underlying clay and overlying bedrock across the LSA/RSA. It is a sandy to silty sand till with 5 to 10% clasts of medium to high density. Borehole data suggests the formation to be interbedded with clayey till (see unit below) and commonly is between 5 to 10 m thick but can reach up to 64 m in the PA. Clayey till is found interbedded with the silty sand/sandy till and commonly is between 7 to 10 m thick but can reach up to 40 m in the LSA/RSA.

Hydraulic conductivity testing for the till was completed on five monitoring wells across the PA. The estimated hydraulic conductivity ranged from 1×10^{-8} m/s to 4×10^{-6} m/s, with a geomean of 2×10^{-7} m/s. The hydraulic conductivity estimates are consistent with literatures values for silt/sandy silt, clayey sand and tills, which range from 1×10^{-8} m/s to 1×10^{-6} m/s (Fetter 1994).

5.1.2 Bedrock

The LSA/RSA is situated in the Abitibi Greenstone belt within the Superior Province. The bedrock in the LSA/RSA is composed of a felsic to mafic volcanic assemblage hosting the Crawford Ultramafic Complex, local metasediments (i.e., iron formation, minor metavolcanic rocks), and other local ultramafic sills (OGS 2011). Literature suggests relatively steep dipping (near vertical) formations (Montison et al. 2021; Ayer 2019).

Metasedimentary rocks in the LSA/RSA such as wacke, siltstone, and argillite, among others, are located mainly in the south and north as well as local sills throughout (Unit 7 on Figure A.4. Mafic to intermediate volcanic rocks (Unit 5 on Figure A.4; basaltic and andesitic flows, tuff and breccias) and felsic to intermediate metavolcanic formations (Unit 6a on Figure A.4; dacitic and andesitic flows, tuffs and breccias) are widespread in the LSA/RSA. They are interrupted by intrusive granitoid rocks (Unit 15 on Figure A.4; massive to foliated granodiorite to granite and local diorite-monzodiorite-granodiorite suite) and mafic to ultramafic intrusions (Units 10 and 10c on Figure A.4). Thin, elongated Iron formations, as well as marble, chert and minor metavolcanic rocks, show a northwest-southeast trend, especially in the metavolcanic formations.

A total of 91 *in situ* hydraulic response tests were completed in 21 bedrock boreholes to a maximum depth of 465 m below the top of bedrock (WSP Golder 2022). The length of each testing interval ranged from 10 m to over 400 m. Figure A.5 presents the hydraulic conductivity and rock quality designation (RQD) with depth below top of bedrock.

Two hydraulic response tests completed in shallow weathered bedrock (0 to 10 m below top of rock) had a geometric mean hydraulic conductivity of 1×10^{-9} m/s, with a range of 2×10^{-10} m/s to 7×10^{-9} m/s. Fifty - six hydraulic response tests completed in weathered bedrock (10 to 200 m below the top of bedrock) had a geometric mean hydraulic conductivity of 2×10^{-8} m/s, with a range of 6×10^{-11} m/s to 7×10^{-6} m/s. Thirty-three hydraulic response tests completed in unweathered bedrock (200 m to 400 m below top of rock) had a geometric mean hydraulic conductivity of 2×10^{-9} m/s, with a range from 8×10^{-12} m/s to 8×10^{-7} m/s. While localized pockets of higher or lower than average hydraulic conductivity existed in some locations, there was no clear spatial, vertical, or lithological control on the hydraulic conductivity of the upper 400 m of bedrock.

Figure A.5 presents hydraulic conductivity and RQD with depth below top of bedrock. RQD and hydraulic conductivity are generally correlated because competent rock with few fractures (i.e., a high RQD) is commonly associated with a lower hydraulic conductivity. Figure A.5 shows that, for the upper 500 m of bedrock, there are no clear spatial, vertical, or lithological controls on RQD or hydraulic conductivity of bedrock. There is a trend of increasing RQD with depth for bedrock that is deeper than 500 m below the top of bedrock, which would suggest that hydraulic conductivity may be decreasing with depth below 500 m from the top of bedrock.

5.1.3 Structural Features

Several regional faults are found in the LSA/RSA, generally showing a north-northwest to south-southeast strike (Figure A.4). The major regional faults following this trend are the Mattagami River Fault, the Buskegau River Fault and the Main Regional Fault (also referred to as CUC Fault). Multiple discontinuous, unnamed faults are showing similar strike. Faults in the LSA/RSA are generally steeply dipping although literature is sparse on the dip of the faults. An 86-degree dip in varying east/west directions was interpreted in the Canada Nickel geological resource model for the Main Regional Fault based on observations from select exploratory boreholes that intersect the faults and was therefore carried through the hydrostratigraphic conceptual model for the site.

The locations of the main faults are shown on Figure A.4. The Main Regional Fault crosses the PA through the proposed Impoundment Facility, Open Pit, East Stockpile, and the TMF. Two sub-parallel faults cross the PA through the proposed TMF. Another set of discontinuous faults oriented perpendicularly to the first set described are found within the LSA/RSA (Figure A.4).

A hydraulic response test was completed across the Main Regional Fault in one borehole (WSP Golder 2022). The fault was logged between approximately 229 and 335 m depth along the hole while the hydraulic response test was completed from 293 to 351 m depth along the hole. The hydraulic conductivity for the testing interval which contains the fault was not significantly different than the average hydraulic conductivity estimated for the borehole suggesting that the fault is not a preferential pathway for

groundwater flow at this location. Descriptions of the fault in four exploration drillholes suggest that fault contains gouge and some chlorite mineralization. The description of one exploration borehole indicates that the shearing of the fault is mostly annealed.

5.2 Groundwater Flow Model Construction, Calibration, and Application

A numerical, three-dimensional groundwater flow model was developed to represent baseline conditions and to assess the potential effects of the Project on groundwater resources and the consequential indirect effects on surface water resources. This section describes the construction of the three-dimensional numerical groundwater flow model using the hydrostratigraphic units of the conceptual model described in Section 5.1. The calibration of the model using available information on water levels and baseflow collected as part of the baseline monitoring programs is also described. The simulations were completed as steady state.

MODFLOW 6 (Langevin et al. 2017) and the graphical user interface Groundwater Vistas (Version 8; Rumbaugh and Rumbaugh 2020) were selected for this evaluation. These are common platforms for simulating and predicting groundwater flow in mining environments. An equivalent porous media (EPM) approach was selected to simulate the flow within the overburden and underlying bedrock. The EPM approach assumes that groundwater flow through fractured bedrock can be approximated by a porous medium with equivalent hydrogeologic properties of the bulk of the rock.

At the regional scale, the EPM approach remains appropriate for predicting the effective groundwater discharge rates from the deeper bedrock into the underground workings but reduces the reliability of predicted travel times through discrete fractures (Wels et al. 2012). Travel times through the discrete fractures using the EPM approach could be under-predicted since the bulk porosity is likely lower than the effective fracture porosities in the bedrock; conversely, travel times could be over-predicted, if there is poor connectivity of fractures at depth.

5.2.1 Groundwater Flow Model Construction

5.2.2 Model Extent, Grid, and Layers

The extent of the groundwater flow model domain was chosen to correspond to the natural hydrogeologic boundaries and to extend beyond the area of potential effects from the Project such that model boundaries would not influence the model predictions. The model domain is defined by major river watershed boundaries with Central Mattagami River watershed boundary to the west, northwest, and southwest, and Abitibi River watershed boundary to the east, northeast, and southeast. The model domain is presented on Figure A.6 and has an active area of 5,432 km² across a total area of 8,818 km². The PA is located in the central portion of the model domain and is sufficiently distant (several km away) from each model boundary such that edge effects are expected to be negligible.

The model grid is unstructured and includes four levels of quadtree refinements in the grid from coarser grid cells around the limits of the domain (800 m x 800 m), to finer in the LSA, and finer still in the PA (100 m x 100 m). The grid is composed of 41,648 active cells in each model layer, with a total of 1,041,200 active cells distributed across 25 model layers.

The groundwater flow model extends from ground surface (average 275 m amsl in the groundwater flow model) to -600 m amsl (i.e., 600 m below mean sea level) to represent the projected depth of the bottom of the pit and sufficient bedrock beneath the pit to represent potential flow into the pit. Ground surface elevations for each model cell were defined based on the provincial digital elevation model (PDEM 2019). The hydrostratigraphic units described in Section 5.1 were transferred to the MODFLOW model via the groundwater flow model output utility in Leapfrog Works®. The overburden layers including the eskers, glaciolacustrine, glaciofluvial, and till units are included in layers 1 through 5 in the groundwater flow model. The thickness of layers 1 through 5 varies spatially based on the thickness of the overburden units. The thickness of layers 6 to 8 in the model transition from the thickness of the upper layers to the primary thickness of the bedrock, which was assigned as 30 m. This thickness was chosen based on the depth of the Open Pit and to maintain sufficient layers in the bedrock to simulate the Open Pit and vertical flow near the Open Pit, and also maintain a manageable number of cells in the model (approximately 1 million total active cells). The deeper layers in the model transition to thicker layers. The bottom of the Open Pit is within layer 23; consequently, the bottom two layers are below the pit.

5.2.3 Boundary Conditions

5.2.3.1.1 Recharge

The type of soil and vegetation present at surface is an important factor in determining whether precipitation will become runoff or groundwater recharge. Recharge rates were assigned based on the hydrostratigraphic units exposed at the top of the model domain in the hydrostratigraphic conceptual model as described in Section 5.1. Two recharge units were defined: one unit to represent the relatively low infiltration capacity of the surficial clay associated with the Northern Clay Belt and till, and one recharge unit to reflect the higher infiltration capacity of the coarser deposits associated with the mapped eskers. The groundwater recharge rate was adjusted during the model calibration process. The calibrated recharge rates are provided in Section 5.2.5.4.

5.2.3.1.2 Lakes

As shown on Figure A.6, several lakes within the model domain were simulated in the groundwater flow model using the MODFLOW General Head Boundary (GHB) package. The interaction between the surface water in the lakes and the groundwater in the underlying aquifers is defined in MODFLOW by the “conductance” term. This term represents the presence of a layer of sediment on the lakebed that can affect the rate of water transferred between the lake and the underlying model layer. A review of sediment analyses from sampling locations along the shores of Martin, Gerry, Jack, and Sutherland Lakes indicate the sediments are generally fine-grained, with an average of 72% silt and clay in the lakebed sediments (Appendix C of this report). These sediments are expected to have a hydraulic conductivity consistent with the till units present within the LSA/RSA (1×10^{-8} m/s to 4×10^{-6} m/s, with a geomean of 2×10^{-7} m/s).

The lakebed width and length were assigned based on the cell dimensions (100 m each), and the thickness of the lakebed material was assigned as 1 m. The lakebed hydraulic conductivity was adjusted during model calibration. The water level elevation of each lake (stage) was assigned based on the estimated shoreline elevations from LiDAR DEM (where available) or PDEM (2019). Bathymetric data were available for each lake included in the model: Martin Lake, Gerry Lake, Jack Lake, Sutherland Lake, Mel Lake, Zed Lake, and two unnamed lakes (West Stockpile and Zed Lake). The water surface elevation for each lake is summarized in Table 5.1. Within the lakes, the hydraulic conductivity was increased by a factor of 2 to 20 compared to the surrounding lithologic units to increase the hydraulic connection of the GHB with the underlying lithologic units. The depth of the zone of increased hydraulic conductivity was based on the bathymetry data for each lake.

Table 5.1 Lakes Assigned within the Groundwater Flow Model

Lake/Watercourse	Assigned Water Surface Elevation (m amsl)
Martin Lake	268
Gerry Lake	268
Jack Lake	274
Sutherland Lake	275
Mel Lake	275
Zed Lake	283
Unnamed Lake (West Stockpile)	270
Unnamed Lake (south of Zed Lake)	279

5.2.3.1.3 Watercourses

Rivers and streams are simulated in the model domain and are presented on Figure A.6. These watercourses were simulated using the MODFLOW River package (RIV) to simulate the interaction between surface water and groundwater and to allow the prediction of groundwater contributions to baseflow and surface water contributions to the groundwater flow system. Three parameters are required to simulate these interactions: the stage (e.g., elevation) of the water level in the watercourse, the elevation of the bottom of the watercourse, and the conductance of the streambed materials.

The locations of the watercourses were based on data from the Ontario Hydro Network in Ontario Geohub (MNR 2023). The stages of the watercourses were assigned an elevation equivalent to the ground surface topography determined from LiDAR DEM (where available) or PDEM (2019).

The depth of water in each watercourse was assigned based on data from hydrological monitoring stations where possible or assumed to be 0.5 or 1 m where no data were available, mainly for watercourses distal from the PA. The depth of the Mattagami River was assigned as 10 m. The depth was then used to estimate the bottom elevation using the stage for each watercourse.

The conductance term was determined based on the hydraulic conductivity of the streambed sediments, the thickness of the sediments, the width of the watercourse, and the length of the watercourse within each model cell. Watercourses were assigned widths based on data from hydrological monitoring stations, stream order, and from observations from aerial photographs. The hydraulic conductivity was assigned based on sediment analyses from sampling locations along the rivers within the PA as presented in Appendix C of this report. Streambed thicknesses were assumed to be 1 m thick. The length of the mapped watercourse feature within each cell was determined using pre-processing software. The hydraulic conductivity of the streams was adjusted during the model calibration.

5.2.4 Distribution of Hydrogeological Parameters

Hydraulic conductivity values were assigned to the model based on the hydrostratigraphic units as defined in the conceptual model (Section 5.1). These values were assigned based on a combination of field-testing data and/or literature values. Each hydrostratigraphic unit was assumed to be uniform and isotropic. Bedrock hydraulic conductivity was assumed to be constant with depth. This uniform representation of bedrock is a conservative approach that results in higher predicted mine inflow rates, compared with assuming lower bedrock hydraulic conductivities with depth. Hydraulic conductivity values were refined during model calibration as described in Section 5.2.5, below.

5.2.5 Groundwater Flow Model Calibration

5.2.5.1 Calibration Methodology

The process of model calibration involves the adjustment of model parameter values to match field-measured values within a pre-established range based on the conceptual model. The groundwater flow model was calibrated to available measured groundwater levels within the LSA/RSA and simulated river flows were compared to estimated baseflow.

Eighty-one monitoring well and private well groundwater elevations (from the MECP water well record database) are available for calibration purposes. Thirty-eight of these wells are located in the PA and 43 of the wells are located distant from the PA, many of them by several tens of kilometres. Many of these distant wells included water level data that were not contemporaneous to the PA wells, and assessment of the accuracy of the data was not possible. As such, those wells were weighted at 10% for calibration analysis, compared to the full 100% weighting applied to the 38 wells in the PA where the data are considered representative and reliable for use in evaluating the quality of the model calibration. The locations of the monitoring wells used for model calibration are shown on Figure A.7.

Steady-state model calibration was conducted using an iterative approach. Model calibration was assessed by comparing model-predicted water levels to measured water levels at groundwater monitoring wells. Model input parameters were adjusted between each simulation test (model run) to achieve better agreement between predicted and measured values. Each simulation test included only one model input parameter adjustment per test to enable a more effective evaluation of the calibration for each adjustment.

Model input parameters adjusted throughout the calibration process included hydraulic conductivity of hydrostratigraphic units, groundwater recharge, and hydraulic conductivity for the GHB and RIV boundary conditions. Following each iterative revision, the success of the calibration was quantitatively evaluated against established criteria as well as qualitative representation of the regional groundwater surface.

5.2.5.2 Calibration to Water Levels

The range in observed groundwater elevations was 49.5 m across the 81 calibration points. The calibration was considered successful if the primary calibration criteria (absolute residual mean, residual standard deviation, and Root Mean Square (RMS) error) were each less than 4.95 m, or, when normalized, 10% of the range of observed groundwater elevations. Calibration criteria for normalized residual standard deviation, normalized RMS, and normalized absolute residual mean were also set at 10%. The RMS error is usually regarded as the best measure of fit between observed and simulated water levels (Anderson and Woessner 1991). Spitz and Moreno (1996) suggest 10% as a possible RMS criterion, with the exact degree of acceptable model error being dependent on several factors including the location, number, and accuracy of observation points. Several regulatory agencies have established similar criteria:

- The British Columbia Ministry of Environment guidance for groundwater modelling states, “Generally, [normalized] RMSE under 10 percent is good in many models, and under 5% is very good in terms of average residual fit.” (Wels et al. 2012).
- The Nevada Division of Environmental Protection Bureau of Mining Regulation and Reclamation (US) guidance for groundwater flow models states, “A commonly used, if somewhat arbitrary, criterion to suggest a “good” calibration is a normalized root-mean-squared error of less than 10% for regional-scale groundwater models.” (Newman, 2018).
- The Australian Government modeling guidelines state the scaled RMS is a useful descriptor of goodness of fit and a target of 5 to 10% is suggested (Barnett et al. 2012).

The observed and predicted groundwater elevations for each target, along with the weighted and non-weighted residual are presented in Table 5.2.

Table 5.2 Groundwater Flow Model Residuals

Well Name	Model Layer	Model Area	Weighting	Groundwater Elevation (m amsl)		Residual (m) (Observed – Predicted Groundwater Elevation)	
				Observed	Predicted	Unweighted	Weighted
				1600159	4	LSA/RSA	10%
1600179	5	PA	100%	265.38	267.03	-1.64	-1.64
1600180	3	LSA/RSA	10%	243.78	247.47	-3.69	-0.37
1600710	4	LSA/RSA	10%	279.66	280.41	-0.75	-0.07
1600712	6	LSA/RSA	10%	277.59	280.33	-2.74	-0.27

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Well Name	Model Layer	Model Area	Weighting	Groundwater Elevation (m amsl)		Residual (m) (Observed – Predicted Groundwater Elevation)	
				Observed	Predicted	Unweighted	Weighted
1600713	2	LSA/RSA	10%	277.82	280.37	-2.55	-0.25
1600714	1	LSA/RSA	10%	289.44	284.06	5.38	0.54
1600717	1	LSA/RSA	10%	285.97	267.29	18.67	1.87
1600762	7	LSA/RSA	10%	255.73	256.17	-0.44	-0.04
1600790	4	LSA/RSA	10%	273.68	271.65	2.03	0.20
1601515	2	LSA/RSA	10%	249.16	238.44	10.72	1.07
1601660	5	LSA/RSA	10%	251.14	240.56	10.58	1.06
1601746	5	LSA/RSA	10%	260.03	244.10	15.92	1.59
1602153	4	LSA/RSA	10%	255.63	249.28	6.36	0.64
1602159	7	LSA/RSA	10%	247.02	244.14	2.88	0.29
1602207	7	LSA/RSA	10%	241.22	244.81	-3.59	-0.36
1602357	5	LSA/RSA	10%	261.69	247.62	14.07	1.41
1602567	8	LSA/RSA	10%	261.04	249.11	11.92	1.19
1603047	5	LSA/RSA	10%	277.54	278.95	-1.41	-0.14
1603056	6	LSA/RSA	10%	276.42	255.00	21.42	2.14
1603201	3	LSA/RSA	10%	283.14	277.44	5.70	0.57
1603376	6	LSA/RSA	10%	242.43	236.76	5.67	0.57
1603418	4	LSA/RSA	10%	255.64	248.83	6.81	0.68
1603611	3	LSA/RSA	10%	288.00	292.33	-4.33	-0.43
1603617	9	LSA/RSA	10%	257.13	248.97	8.16	0.82
1603745	8	LSA/RSA	10%	263.57	249.66	13.91	1.39
1604700	8	LSA/RSA	10%	272.35	270.15	2.20	0.22
1604875	6	LSA/RSA	10%	267.57	243.18	24.39	2.44
1604893	8	LSA/RSA	10%	256.45	240.38	16.07	1.61
1604991	5	LSA/RSA	10%	251.79	240.63	11.15	1.12
1605066	9	LSA/RSA	10%	266.04	249.25	16.79	1.68
1605067	10	LSA/RSA	10%	269.64	250.04	19.60	1.96
1605068	10	LSA/RSA	10%	269.64	250.04	19.60	1.96
1605181	4	LSA/RSA	10%	259.88	247.67	12.22	1.22
1605672	1	LSA/RSA	10%	290.75	287.24	3.51	0.35
1605811	5	LSA/RSA	10%	278.66	283.40	-4.74	-0.47
5902374	2	LSA/RSA	10%	289.39	301.42	-12.04	-1.20
7042392	6	LSA/RSA	10%	264.67	266.25	-1.58	-0.16

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Well Name	Model Layer	Model Area	Weighting	Groundwater Elevation (m amsl)		Residual (m) (Observed – Predicted Groundwater Elevation)	
				Observed	Predicted	Unweighted	Weighted
7115154	1	LSA/RSA	10%	283.33	277.30	6.02	0.60
7132455	5	LSA/RSA	10%	262.98	243.34	19.64	1.96
7150165	4	LSA/RSA	10%	279.16	295.22	-16.07	-1.61
7185741	5	LSA/RSA	10%	262.61	249.49	13.13	1.31
7233144	6	LSA/RSA	10%	263.39	248.42	14.97	1.50
7286671	9	LSA/RSA	10%	271.42	279.61	-8.18	-0.82
CR19-14	5	PA	100%	269.80	268.34	1.45	1.45
CR21-142	4	PA	100%	270.05	269.41	0.65	0.65
CR21-161B	3	PA	100%	270.75	270.15	0.60	0.60
CR22-203A	5	PA	100%	271.07	273.96	-2.89	-2.89
CR22-211	5	PA	100%	267.80	268.84	-1.05	-1.05
CR22-260	7	PA	100%	269.82	269.26	0.56	0.56
CR22-262A	3	PA	100%	271.17	270.87	0.30	0.30
CR23-306	8	PA	100%	272.58	272.31	0.27	0.27
CR23-307	8	PA	100%	269.21	270.00	-0.79	-0.79
CR-BS-B1	6	PA	100%	272.55	273.69	-1.14	-1.14
CR-BS-B2	3	PA	100%	272.83	273.68	-0.85	-0.85
CR-BS-C1	5	PA	100%	272.04	272.92	-0.88	-0.88
CR-BS-C2	2	PA	100%	274.20	272.93	1.27	1.27
CR-BS-C3	4	PA	100%	273.95	272.92	1.03	1.03
CR-BS-C4	6	PA	100%	269.56	272.93	-3.37	-3.37
CR-BS-D1	6	PA	100%	270.81	273.95	-3.14	-3.14
CR-BS-D2	3	PA	100%	272.55	273.96	-1.41	-1.41
DP7-23	1	PA	100%	268.48	268.76	-0.28	-0.28
HG-BH-01	5	PA	100%	269.36	266.33	3.03	3.03
HG-BH-03	4	PA	100%	269.10	265.94	3.16	3.16
NWR-BH-01	4	PA	100%	266.91	269.71	-2.80	-2.80
OP-BH-01	5	PA	100%	268.30	264.18	4.12	4.12
OP-BH-06	4	PA	100%	270.18	270.64	-0.46	-0.46
PF-BH-02	4	PA	100%	269.25	268.29	0.96	0.96

Well Name	Model Layer	Model Area	Weighting	Groundwater Elevation (m amsl)		Residual (m) (Observed – Predicted Groundwater Elevation)	
				Observed	Predicted	Unweighted	Weighted
SOS-BH-02	4	PA	100%	270.19	266.91	3.28	3.28
TSF-BH-01A	5	PA	100%	270.53	273.84	-3.31	-3.31
TSF-BH-06	5	PA	100%	270.20	272.27	-2.07	-2.07
TSF-BH-11	5	PA	100%	270.02	272.97	-2.95	-2.95
TSF-BH-15A	3	PA	100%	269.33	276.87	-7.54	-7.54
TSF-BH-15B	2	PA	100%	270.22	276.87	-6.65	-6.65
TSF-BH-16	4	PA	100%	274.73	273.21	1.52	1.52
TSF-BH-22	4	PA	100%	271.05	267.60	3.45	3.45
TSF-BH-26A	5	PA	100%	269.11	267.62	1.49	1.49
TSF-BH-26B	3	PA	100%	269.08	267.60	1.48	1.48
TSF-BH-30	4	PA	100%	278.37	276.37	2.00	2.00
TSF-BH-34	5	PA	100%	281.12	277.85	3.27	3.27
WOS-BH-01	4	PA	100%	268.55	262.84	5.71	5.71

A plot of the predicted versus observed groundwater levels is shown on Figure A.8 , with wells with a full weighting of 100% labelled as high reliability while wells with a weighting of 10% labelled as lower reliability. A line of perfect fit (e.g., a line having a slope of 1.0) is shown for comparison. Predicted groundwater levels that match the observed groundwater levels exactly will fall on this line. As shown on Figure A.8 and in Table C.1 (Appendix C of this report), there is generally good agreement with the simulated and measured water level targets. A summary of calibration statistics for the calibrated groundwater flow model is provided in Table 5.3.

Table 5.3 Groundwater Flow Model Calibration Statistics

Calibration Criterion	Value
Minimum Unweighted Residual (m)	-7.54
Maximum Unweighted Residual (m)	5.71
Number of Observations	81
Range in Observations (m)	49.53
Residual Mean (m)	0.31 (1%)
Absolute Residual Mean (m)	1.53 (3%)
Residual Std. Deviation (m)	2.05 (4%)
Sum of Squares (m ²)	348.83
RMS Error (m)	2.08 (4%)

The predicted groundwater elevation contours in the PA are presented on Figure A.9 along with the observed groundwater elevation for each calibration target within the figure boundary.

5.2.5.3 Calibration to Baseflow

Baseflow separation was conducted for historical flows at the selected regional Water Survey of Canada stations as part of the Regional Hydrology Assessment as discussed in the Surface Water Resources Baseline Report (Appendix B.6 of the Impact Statement). The regional average baseflow per area of 0.0035 m³/s/km² was used to estimate baseflow for each of the four primary rivers in the groundwater flow model. Estimated baseflow is presented in Table 5.4 along with simulated baseflow from the groundwater flow model. The table demonstrates that the simulated baseflow is lower than the estimated baseflow by a factor of 6 to 11. This is to be expected given the LSA/RSA is located within the Northern Clay Belt and till while the regional stations from which the average baseflow per area was calculated are not within the clay belt. Lower baseflow is to be expected given predominantly clay is present at the surface within the LSA/RSA.

Table 5.4 Estimated and Predicted Baseflow

River	Watershed Area in Model (km ²)	Estimated Baseflow (based on regional average baseflow) (m ³ /s)	Predicted Baseflow (from groundwater flow model) (m ³ /s)
North Muskego	418	1.5	0.13
Mattagami	1134	4.0	0.70
North Driftwood	383	1.3	0.15
Buskegau	649	2.3	0.29

5.2.5.4 Calibrated Model Parameters

The values of the hydrogeologic parameters that were estimated from the calibration process are presented in Table 5.5. The calibrated hydraulic conductivities for the various hydrostratigraphic units are generally within the ranges expected for the materials based on measured and literature values, as these ranges were set as part of the calibration process. Modelled glaciolacustrine and till hydraulic conductivity values exceeded the initially expected range. These higher hydraulic conductivity values were necessary to balance the need for adequate recharge volumes to reach the underlying aquifer in this local area of the Northern Clay Belt. The higher values for these two units were considered defensible to effectively simulate the relatively broad distribution of small ponds, waters, and wetter soils across the area (too small to simulate as discrete bodies) that allow vertical hydraulic communication from the surface to groundwater.

The groundwater recharge rates for the calibrated model were 14.6 mm/year for surficial clay and till, and 40.2 mm/year for the eskers. The calibrated hydraulic conductivity for lakebed sediments (used to calculate the conductance term for the GHB cells) is 4.6×10^{-7} m/s. The calibrated hydraulic conductivities for the riverbed sediments (used to calculate the conductance terms for the RIV cells) in the North Driftwood River ranges from 1.6×10^{-5} to 3.3×10^{-5} m/s. The calibrated hydraulic conductivity for the riverbed sediments for other rivers is 2.3×10^{-5} m/s, which is within the range of hydraulic conductivity for the samples collected within the North Driftwood River.

Table 5.5 Parameter Values from Calibrated Model

Hydrostratigraphic Unit	Calibrated Hydraulic Conductivity		Conceptual Model Horizontal Hydraulic Conductivity Range (m/sec)
	Horizontal (m/sec)	Vertical (m/sec)	
Glaciolacustrine Clay Deposits	1.2×10^{-5}	1.2×10^{-6}	1×10^{-11} to 1×10^{-8}
Till	5.8×10^{-6} to 2.3×10^{-5}	5.8×10^{-7} to 2.3×10^{-6}	1×10^{-8} to 1×10^{-6}
Glaciofluvial Deposits	5.8×10^{-5} to 1.7×10^{-4}	5.8×10^{-6} to 1.7×10^{-5}	1×10^{-7} to 1×10^{-4}
Eskers	1.7×10^{-4}	1.7×10^{-5}	1×10^{-7} to 1×10^{-3}
Dike	1.2×10^{-6}	1.2×10^{-6}	8×10^{-12} to 7×10^{-6}
Intrusives	1.2×10^{-7}	1.2×10^{-7}	8×10^{-12} to 7×10^{-6}
Metasedimentary Rocks	5.8×10^{-8}	5.8×10^{-8}	8×10^{-12} to 7×10^{-6}
Metavolcanic Rocks	5.8×10^{-8}	5.8×10^{-8}	8×10^{-12} to 7×10^{-6}
Ultramafic	1.0×10^{-8}	1.0×10^{-9}	8×10^{-12} to 7×10^{-6}
Lakebed Sediments	4.6×10^{-7}		1×10^{-8} to 4×10^{-6}
Riverbed Sediments, North Driftwood River	1.6×10^{-5} to 3.3×10^{-5}		3×10^{-7} to 3×10^{-4}
Riverbed Sediments, other than North Driftwood River	2.3×10^{-5}		3×10^{-6} to 2×10^{-3}

5.2.5.5 Mass Balance

The mass balance (i.e., sum of groundwater inflows to outflows) from the calibrated groundwater flow model is presented in Table 5.6. The sum of inflow and sum of outflow is within -0.02% and well below the acceptability criteria of 1% as recommended by Reilly and Harbaugh (2004).

Table 5.6 Mass Balance for Calibrated Groundwater Flow Model

	Inflows (m ³ /day)	Outflows (m ³ /day)
General Head Boundary Cells	80,245	86,460
River Cells	25,077	133,423
Recharge	114,608	
Total	219,931	219,884
Inflows – Outflows		47
Percent Discrepancy		0.02%

5.2.6 Model Calibration Sensitivity Analysis

A sensitivity analysis was performed to quantify the uncertainty in estimated parameters, hydraulic stresses, and boundary conditions used to develop the calibrated steady state groundwater flow model, consistent with the approach described in Anderson and Woessner (1992). For this sensitivity analysis, iterative changes were applied to recharge, esker hydraulic conductivity, overburden hydraulic conductivities, bedrock hydraulic conductivity, and river/lake conductance values. Modelled changes for each of these parameters were constrained to reasonable and foreseeable values for each parameter/condition; tests were not performed for parameters outside of expected ranges. Specific modifications for each of the 12 sensitivity scenarios are presented in Table 5.7, below.

Table 5.7 Summary of Sensitivity Analysis Runs

Parameter	Sensitivity Test Parameter Change
Recharge	0.5 x calibrated value
	2.0 x calibrated value
Esker Hydraulic Conductivity	0.2 x calibrated value
Overburden Hydraulic Conductivity	0.5 x calibrated value
	2.0 x calibrated value
	Upper bound values for material ¹
Bedrock Hydraulic Conductivity	0.25 x calibrated value
	0.5 x calibrated value
	1.5 x calibrated value
	Reduction with depth to 1x10 ⁻¹¹ m/s ²

Parameter	Sensitivity Test Parameter Change
River and Lakebed Conductance	0.1 x calibrated value
	2.0 x calibrated value
<p>Notes:</p> <p>Reasonable and foreseeable upper bound values were used for each overburden lithostratigraphic unit, from 1×10^{-5} m/s for glaciolacustrine clay sediments to 5×10^{-4} m/s for eskers.</p> <p>Bedrock hydraulic conductivity gradually reduced from 1×10^{-7} m/s in model layers 6 to 8 to 1×10^{-11} m/s in model layers 21 to 25</p>	

The sensitivity tests were evaluated using the same 81 calibration points that were used to assess the steady state calibration. Model performance and associated calibration statistics for each sensitivity test are presented in Table 5.8.

Table 5.8 Sensitivity Analysis Calibration Statistics

Calibrated Model Parameter Multiplier	Calibrated Model	Recharge		Esker Hydraulic Conductivity	Overburden Hydraulic Conductivity			Bedrock Hydraulic Conductivity				River/Lakebed Conductance	
	-	0.5x	2.0x	0.2x	0.5x	2.0x	Upper Bound Values for Material ¹	0.25x	0.5x	1.5x	Reduction with depth to 1×10^{-11} m/s ²	0.1x	2.0x
Residual Mean (m)	0.31	0.86	-0.72	0.1	-0.7	0.67	0.41	0.27	0.28	0.32	0.26	0.25	0.31
Absolute Residual Mean (m)	1.5	1.6	2	1.5	2	1.5	1.6	1.5	1.5	1.5	1.5	1.5	1.5
Residual Standard Deviation (m)	2.1	1.9	2.6	2.1	2.6	1.9	2.1	2.1	2.1	2.0	2.1	2.1	2.1
Sum of Squares (m ²)	349	366	597	360	590	342	356	354	352	347	355	348	349
RMS Error (m)	2.1	2.1	2.7	2.1	2.7	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Minimum Residual (m)	-7.5	-7.1	-8.5	-7.8	-8.4	-7.2	-7.4	-7.6	-7.6	-7.5	-7.6	-7.7	-7.5
Maximum Residual (m)	5.7	5.9	5.4	5.7	5.4	5.6	5.7	5.7	5.7	5.7	5.7	5.6	5.7
Mass Balance Error (%)	0.02	-0.50	0.13	0.02	-0.01	0.01	0.01	0.002	0.008	0.004	0.010	0.03	0.02

Notes:

Reasonable and foreseeable upper bound values were used for each overburden lithostratigraphic unit, from 1×10^{-5} m/s for glaciolacustrine clay sediments to 5×10^{-4} for eskers.

Bedrock hydraulic conductivity gradually reduced from 1×10^{-7} m/s in model layers 6-8 to 1×10^{-11} m/s in model layers 21-25

5.2.6.1 Sensitivity to Recharge

The sensitivity analysis consisted of two scenarios where the recharge rate was adjusted as 100% increase and a 50% decrease from the calibrated baseline recharge value. The range in recharge rate used in this sensitivity scenario is considered conservative as climate change forecasts for Timmins, Ontario are in the range of 16% to 21% increase in precipitation for the next 20 to 50 years, respectively, under a high emissions scenario (ClimateData.ca 2024).

When the recharge rate is decreased by 50%, the residual mean is increased by 177% (predicted heads are decreased on average). When the recharge rate is increased by 100%, the residual mean decreases by 332% (the predicted heads are increased on average), indicating the model results are more sensitive to increased recharge than lowered recharge. The sensitivity scenarios for recharge rates indicate that the calibrated model provides an appropriate representation of recharge compared to the tested upper and lower range values (Table 5.8).

5.2.6.2 Sensitivity to Overburden and Bedrock Hydraulic Conductivity

The esker hydraulic conductivity was decreased in a sensitivity scenario to examine the calibration quality if the esker is assumed to be less conductive than typical hydraulic conductivities used to represent these coarser features. The esker sensitivity scenario focused on a decrease in hydraulic conductivity since the calibrated value is already at the high end of the expected range. The sensitivity scenario result indicates the steady state model calibration is sensitive to the lower value to simulate the esker's hydraulic conductivity. Reducing the hydraulic conductivity of the esker reduced groundwater discharge (baseflow) to the lakes within the esker which resulted in higher water levels near the lakes compared to baseline. The higher water levels near the lakes resulted in higher predicted inflow to the pit.

Two sensitivity scenarios were performed wherein the hydraulic conductivity of the overburden units was iteratively raised and lowered by two and by half, respectively. A third sensitivity scenario was run where the hydraulic conductivity of each overburden hydrostratigraphic unit was set at the high end of the expected range as presented in Section 5.2.5.4. The results indicate the model is sensitive to these parameter changes and the calibrated values were maintained. A 50% global decrease in overburden hydraulic conductivity results in over a 300% decrease in the mean residual (an increase in predicted heads on average). A global increase in overburden hydraulic conductivity of 100% results in an increase in mean residual of over 100% (a decrease in predicted heads on average). Increasing the overburden hydraulic conductivity to the high end of the expected values results in an increase in the mean residual of approximately 30% (a decrease in predicted heads on average).

Sensitivity scenarios for the bedrock hydraulic conductivity included four iterative tests: decreasing the values globally by 75% and 50%, increasing the values globally by 150%, and reducing the values gradually from 1×10^{-7} m/s in model layers 6 to 8 to 1×10^{-11} m/s in model layers 21 to 25. The model was relatively insensitive to reducing hydraulic conductivity with depth resulting in a 16% decrease in residual mean (an increase in predicted heads on average). The calibrated values for bedrock hydraulic conductivity were maintained for predictive modelling and analysis as the calibrated values provide higher

mine inflow rates and thus a more conservatively protective analysis with respect to the Project water balance.

5.2.6.3 Sensitivity to River and Lakebed Conductance

River and lakebed conductance values were lowered by an order of magnitude and doubled in two iterative sensitivity scenarios to examine model effects at either end of a reasonable range of values. The model was sensitive to decreases in conductance with a reduction of one order of magnitude resulting in an approximately 20% decrease in residual mean (an increase in predicted heads on average). Increasing the conductance by a factor of two did not result in a change in average predicted heads. The calibrated values for these conductances were maintained for predictive modelling and analysis as parameters that would provide a conservatively protective analysis.

5.2.7 Groundwater Flow Model Application

Starting with the baseline scenario represented by the calibrated groundwater flow model, the following modifications were completed to simulate operation and passive closure phases of mine development. The construction phase of the Project was not simulated for groundwater since dewatering activities are anticipated to be short term (e.g., temporary dewatering for construction of foundations for site infrastructure) and within the first one to two metres below shallow groundwater table.

5.2.7.1 Open Pit Progression

Initially, two zones of the Open Pit will be developed: the Main Zone and the East Zone. By the end of the operations phase 2, there will be some overlap between the boundaries of the two zones. The footprint of each zone is presented on Figure A.1. The Main Zone will be approximately 3,400 m by 1,700 m, with a depth of approximately 690 m bgs. The East Zone will be approximately 3,800 m by 1,500 m with a depth of approximately 615 m bgs. Open Pit extents are considered approximate at the cessation of mining operations and subject to refinement during detailed design and approval processes.

The East Zone will be mined to provide material to be used for construction until the end of Year 3. Development of the Main Zone will commence in Year -2 and continue until Year 17. The TMF will begin operations in Year 1 and will be used to store tailings until the end of Year 17. Mining of the East Zone will recommence in Year 9 and continue until Year 30. Tailings generated between Years 18 and 30 will be stored in the Main Zone. Following the full development of the East Zone, tailings will be stored in the East Zone.

To evaluate the effects of groundwater inflows to the Open Pit, the calibrated groundwater flow model was modified to include the extent and depth of the Open Pit for three specified stages of development and one stage of closure as discussed below:

- Year -1: representing early stage of pit development during construction.
- Year 17: representing an intermediate development state of the Open Pit when the Main Zone is developed to its full depth of approximately 690 m bgs.

- Year 30: representing the end of mining and when both the Main Zone and East Zone are developed to their full depths of approximately 690 and 615 m bgs, respectively. Tailings storage in the Main Zone of the Open Pit will have reached a top elevation of approximately 120 m amsl.
- Passive closure: representing the formation of pit lakes above the impounded tailings in the Main and East Zone of the Open Pit. The top elevation of tailings stored in the Main and East Zone of the Open Pit are approximately 120 and -14 m amsl, respectively.

For each flow model scenario, model cells that were intersected by the walls or floor of an Open Pit were identified and assigned as a seepage face boundary condition in the model. The seepage face was assigned using the MODFLOW Drain package (DRN) at these locations. Model cells that were located above the drain cells within the footprint of the Open Pit were set as inactive cells. The conductance of the drain cells was specified based on the hydraulic conductivity of the overburden or bedrock in the cells multiplied by the width, length, and thickness of the cell.

Each of the three Open Pit development stages (i.e., Years -1, 17, and 30 of mine life) and the passive closure pit lakes were simulated in the model as separate steady-state model runs. The simulations of Years -1, 17, and 30 of mine life and passive closure pit lakes were conducted by modifying the calibrated baseline model and completing separate model runs with the results compared to the baseline conditions. The results from each steady-state simulation were not used as input to the next simulation. While each stage of Open Pit development is essentially a “snapshot” in time, the approach of completing separate steady-state model runs provides predictions of effects which represent the groundwater condition which could be created by each development stage if each stage were to exist in perpetuity.

This approach of completing separate steady-state model runs provides higher inflow rates in the earlier stages of Open Pit development than would have been predicted by completing one single steady-state model run for the end of life of mine (Year 30). While increased inflows due to storage in the aquifer material and the slightly higher hydraulic gradients during the initial dewatering period may be expected, the use of the multiple steady-state model runs is expected to reduce this potential effect, and the model will provide a long-term representation of groundwater inflows over the life of mine.

5.2.7.2 Open Pit Filling by Groundwater

The groundwater inflow to the Open Pit after dewatering is terminated was simulated to provide estimated groundwater inflow rates for use in the water balance model. The Main Zone and East Zone of the Open Pit will be backfilled with tailings to elevations of 120 and -14 m amsl, respectively, and will be flooded to form pit lakes. Groundwater inflow for each of the two zones of the Open Pit was simulated in a steady-state model run by adjusting the stage of the drain cells representing the seepage faces. The pit lakes will discharge naturally at an elevation of approximately 272.5 m amsl through spillways with overland drainage to the North Driftwood River (from the Main Zone) and the West Buskegau River (from the East Zone). The stage of the water level forming pit lakes was specified at 25 to 50 m intervals above the top elevation of tailings in the East Zone of the Open Pit to the spillway elevation of 272.5 m amsl.

5.2.7.3 Impoundment Facility and East and West Stockpiles

Rock, clay, and till will be stored in an Impoundment Facility to be developed north of the Main Zone of the Open Pit. The East and West Stockpiles for processing will be located east and west of the Open Pit, respectively. The locations of the Impoundment Facility and East and West Stockpiles are shown on Figure A.1.

For each stage of development modelled, the recharge rate within the footprints of the Impoundment Facility and the East and West Stockpiles is equal to the baseline rate of 15 mm/year. This is a conservative assumption as there is time required for the Impoundment Facility and East and West Stockpiles to equilibrate to precipitation (“wet-up”) to allow steady state infiltration. In the closure phase of the Project, the Impoundment Facility benches and plateaus will be rehabilitated with a vegetated cover to promote runoff. The East and West Stockpiles will be depleted and revegetated.

Recharge through the Impoundment Facility and East and West Stockpiles has the potential to affect groundwater quality. The MODFLOW volumetric tracking tool, FlowSource, was used in forward mode to predict the discharge location and flux of water recharging the groundwater flow system from beneath the Impoundment Facility and East and West Stockpiles. FlowSource is a software tool that calculates the volume and proportion of water in every groundwater model cell that reaches a predefined destination (Black and Foley 2013). The defined destinations were designated as each river and lake in the model along with the Open Pit. Separate simulations were completed in which the source cells were defined as the Impoundment Facility and the East and West Stockpiles. As local seepage to ditches in the vicinity of the Impoundment Facility was not accounted for in the groundwater flow model, some groundwater discharge rates to surface water receivers may be overestimated which is a conservative assessment of effects for the groundwater receiving environment.

This analysis is conservative for the scenarios pre closure as the analysis is done using steady state model simulations, meaning the conditions if the model scenario were to exist in perpetuity. In reality, the length of time of each modelled phase of mine life is generally less than the shortest groundwater flow travel time that was calculated from the TMF to the nearest surface water receptor.

The FlowSource results were used to select the shortest travel path from the Impoundment Facility and Stockpiles to the nearest river or lake. Horizontal groundwater flow travel time along the shortest travel path was then estimated using Darcy’s Law (Fetter 1994) and theoretical porosity (Fetter 1994). Darcy’s Law is dependent on the hydraulic conductivity and predicted hydraulic heads in groundwater flow model layer one along the flow path. This provided a lower bound estimate on travel time in groundwater for seepage from the Impoundment Facility and Stockpiles to surface water.

5.2.7.4 Tailings Management Facility

The TMF is located in the southern portion of the PA as shown on Figure A.1. The groundwater flow model was used to predict the discharge location and flux of water recharging the groundwater flow system beneath the TMF. The TMF was simulated by adjusting the rate of recharge within the TMF footprint to be consistent with the predicted water balance for the TMF (Appendix I of the Impact Statement for more details). A recharge rate of 214 mm/year was applied within the TMF footprint for the Year 17 model which represents 33% of total precipitation. The increased recharge relative to surrounding area represents the excess process water conveyed to the facility as part of the tailings slurry and the resulting increased head within the tailings.

Following termination of operations at the TMF after Year 17, the tailings within the TMF will drain. The coarser areas (e.g., sands) of the TMF are expected to drain quickly, within the first 5 years following operations. Subsequently, the moderate-textured tailings (e.g., silts) are expected to continue to drain at a lower rate within the first 10 years following operations. Finally, after approximately 10 years following operations, the finest textured tailings (e.g., clays) are expected to continue to drain at a very slow rate compared to initial drainage rates. During active closure (after Year 17), the surface of the TMF will be revegetated to control erosion. The revegetation will involve the placement of a 0.15 m thick layer of growth media consisting of stripped overburden and/or organics. The growth media will be seeded with herbaceous plants. For the model scenarios which represent development stages where the TMF is closed (i.e., Year 30 and passive closure), the recharge rate within the footprint of the TMF is equal to the baseline recharge rate of 15 mm/year, similar to the recharge rate for the silt and clay in the till and surrounding lithologic units.

Recharge through the TMF has the potential to affect groundwater quality. The MODFLOW volumetric tracking tool, FlowSource, was used in forward mode to predict the discharge location and flux of water recharging the groundwater flow system from beneath the TMF. This analysis is conservative for the scenarios pre closure as the analysis is done using steady state model simulations, meaning the conditions if the model scenario were to exist in perpetuity. In reality, the length of time of each modelled phase of mine life is generally less than the shortest groundwater flow travel time that was calculated from the TMF to the nearest surface water receptor.

The FlowSource results were used to select the shortest travel path from the TMF to the nearest river or lake. Darcy's Law (Fetter 1994) and theoretical porosity (Fetter 1994) were used to estimate horizontal groundwater flow travel time along the shortest travel path based on the hydraulic conductivity and predicted hydraulic heads in model layer one. This provided a lower bound estimate on travel time in groundwater for seepage from the TMF to surface water.

5.2.7.5 Tailings Storage Within the Open Pit

Following the termination of operations at the TMF after Year 17, tailings generated between Years 18 and 30 will be stored in the Main Zone of the Open Pit. Following the full development of the East Zone pit, tailings will be stored in the East Zone of the Open Pit. The top elevations of tailings stored in the Main and East Zone of the Open Pits are approximately 120 and -14 m amsl, respectively.

The MODFLOW volumetric tracking tool, FlowSource, was used in forward mode to predict the discharge location and flux of water of groundwater flowing through the tailings impounded in the Main and East Zone of the Open Pit. This analysis is conservative for the scenarios pre closure as the analysis is done using steady state model simulations, meaning the conditions if the model scenario were to exist in perpetuity. In reality, the length of time of each modelled phase of mine life is generally less than the shortest groundwater flow travel time that was calculated from the TMF to the nearest surface water receptor.

The FlowSource results were used to select the shortest travel path from the impounded tailings to the nearest river or lake. Darcy's Law (Fetter 1994) and theoretical porosity (Fetter 1994) were used to estimate horizontal groundwater flow travel time along the shortest travel path based on the hydraulic conductivity and predicted hydraulic heads in model layer one. This provided a lower bound estimate on travel time in groundwater from the impounded tailings to surface water.

5.3 Predicted Groundwater Seepage Quality from Project Infrastructure

Baseline geochemical conditions, including the potential for metal leaching and acid rock drainage, were assessed by WSP (Appendix G of the Impact Statement [Crawford Geochemistry Characterization]) for 299 rock samples, 109 ore samples, 4 tailings samples, and 50 overburden samples. Humidity cell tests (HCTs) of five samples representing each ore and rock lithology were run for 99 weeks. The Water Quality Assessment (Appendix K of the Impact Statement) scaled the HCT results based on the composition of lithologies predicted for the Impoundment Facility, East and West Stockpiles, and the TMF. The quality of groundwater in contact with the tailings impounded within the Open Pit was assumed to be the same as the quality of seepage from the TMF. The results were used in this TDR to assess the quality of seepage from the Impoundment Facility, East and West Stockpiles, and the TMF; the quality of groundwater in contact with the tailings impounded within the Open Pit was compared to regulatory criteria and baseline conditions.

6 Groundwater Quantity Results

6.1 Baseline Conditions

The calibrated groundwater flow model described in Section 5.2 was used to predict the water table elevation and groundwater flow under baseline conditions. Figure A.9 shows the predicted average annual water table elevation under baseline conditions from the calibrated groundwater flow model. Groundwater is predicted to flow regionally to the north towards James Bay with localized flow toward the West Buskegau River, North Driftwood River, and Mattagami River.

The predicted groundwater discharge to the primary lakes and watercourses located within the groundwater flow model domain is presented in Table 6.1. The locations of surface water features are presented on Figure A.10. The predicted baseline groundwater discharge rates were used to quantify changes to groundwater discharging during the operation and passive closure phases as presented in Sections 6.2 and 6.4, respectively.

In Table 6.1, a positive value indicates groundwater discharging to the surface water feature (i.e., a gaining stream segment) and a negative value indicates that the surface water feature is recharging the groundwater flow system (i.e., a losing stream segment). Baseflow values presented in the table represent the groundwater contributions to the features, and do not include contributions from surface water storage.

Table 6.1 Estimated Groundwater Discharge to Surface Water Features – Baseline

Surface Water Feature	Predicted Groundwater Discharge Rate (m ³ /d) ¹
Jocko Creek	6,104
North Driftwood River	6,334
West Buskegau River	1,234
Unnamed Lake (South of Zed Lake)	1,054
Zed Lake	-1,620
Mel Lake	1,211
Sutherland Lake	-2,858
Jack Lake	350
Gerry Lake	6,444
Martin Lake	1,577
Unnamed Lake (West Stockpile)	58
Note:	
1. A negative number indicates that surface water is recharging groundwater at that reach/lake.	

6.2 Operations Phase

6.2.1 Operations Phase Year -1

The predicted average groundwater inflow into the East Zone of the Open Pit at the end of Year -1, when early dewatering of the Open Pit is required due to rock extraction to support site construction, is 2,700 m³/day, with 26% of this inflow from the overburden. The predicted change in water table elevation (drawdown) due to dewatering of the East Zone of the Open Pit at the end of Year -1 in comparison to baseline conditions is shown on Figure A.11. Dewatering of the East Zone of the Open Pit is predicted to lower the water table by a minimum of 1 m over an area extending 2 km to the east, 3 km to the west and south, and up to 7.5 km to the north of the Open Pit.

Table 6.2 presents the comparison of predicted groundwater discharge rates in baseline with predicted groundwater discharge rates at the end of Year -1. The highest reduction in predicted groundwater discharge rate in the rivers is predicted in the West Buskegau River as it is the closest of the three to the Open Pit. Jack Lake and Martin Lake have higher reductions in predicted groundwater discharge rates relative to the other lakes in the area but Jack, Martin, and Gerry Lakes should be considered as one system as they are directly connected by an upper reach of the North Driftwood River.

Table 6.2 Predicted Groundwater Discharge to Surface Water Features – Operations Year -1

Surface Water Feature	Predicted Groundwater Discharge Rate (m ³ /d)		
	Baseline ¹	Operations Year -1 ¹	Percent Increase (Decrease)
Jocko Creek	6,104	5,846	(4)
North Driftwood River	6,334	9,085	43
West Buskegau River	1,234	-202	(116)
Unnamed Lake (South of Zed Lake)	1,054	1,011	(4)
Zed Lake	-1,620	-1,705	(5)
Mel Lake	1,211	1,147	(5)
Sutherland Lake	-2,858	-3,161	(11)
Jack Lake	350	-304	(187)
Gerry Lake	6,444	4,731	(27)
Martin Lake	1,577	25	(98)
Unnamed Lake (West Stockpile)	58	62	7
Note:			
1. A negative number indicates that surface water is recharging groundwater at that reach/lake.			

6.2.2 Operations Phase Year 17

The predicted average groundwater inflow into the Open Pit at the end of Year 17, when the Main Zone is developed to full depth and development of the East Zone is ongoing, is 10,500 m³/day, with 2% of this inflow from the overburden. The predicted change in water table elevation (drawdown) due to dewatering of the Open Pit at the end of Year 17 in comparison to baseline conditions is shown on Figure A.12. The predicted 1 m drawdown contour as a result of Open Pit dewatering extends up to 3.2 km to the east, 3.9 km to the west, 2.5 km to the south, and 7.3 km to the north of the Open Pit. The predicted extent of drawdown to the south of the Open Pit is limited due to increased infiltration in the TMF footprint which results in mounding below the TMF. The area of mounding northwest of the Main Zone is due to the diversion of a portion of the North Driftwood River in Year 4. This portion of the North Driftwood River is estimated to receive 4,346 m³/day of groundwater discharge in baseline conditions that is not removed in the Year 17 model, resulting in a groundwater mound of approximately 1 m above baseline.

Table 6.3 presents the comparison of predicted groundwater discharge rates to surface water features in baseline with predicted groundwater discharge rates at the end of Year 17. The highest predicted reduction in groundwater discharge relative to baseline conditions were related to the diversion of a portion of the North Driftwood River in Year 4. The diversion results in changes to local groundwater levels which, in turn, results in a switch in Unnamed Lake (West Stockpile) from a lake which receives groundwater discharge to a lake which recharges groundwater.

Table 6.3 Predicted Groundwater Discharge to Surface Water Features – Operations Year 17

Surface Water Feature	Predicted Groundwater Discharge Rate (m ³ /d)		
	Baseline ¹	Operations Year 17 ¹	Percent Increase (Decrease)
Jocko Creek	6,104	7,797	28
North Driftwood River	6,334	848	(87)
West Buskegau River	1,234	2,243	82
Unnamed Lake (South of Zed Lake)	1,054	2,158	105
Zed Lake	-1,620	-842	48
Mel Lake	1,211	1,818	50
Sutherland Lake	-2,858	-2,235	22
Jack Lake	350	543	55
Gerry Lake	6,444	7,180	11
Martin Lake	1,577	2,340	48
Unnamed Lake (West Stockpile)	58	-255	(540)
Note:			
1. A negative number indicates that surface water is recharging groundwater at that reach/lake.			

6.2.3 Operations Phase Year 30

The predicted average groundwater inflow into the Open Pit at the end of Year 30, when the Main Zone and East Zone of the Open Pit are fully developed, is 9,400 m³/day, with 2% of this inflow from the overburden. While the footprint of the Open Pit is larger in Year 30 than Year 17, the groundwater inflow rate is higher at the end of Year 17 than Year 30 due to the presence of the TMF which provides enhanced recharge as described in Section 5.2.6.4. In Year 30, the TMF is rehabilitated with cover and vegetation and therefore the recharge rate is reduced compared to Year 17 when the TMF is operational. The change in water table elevation (drawdown) due to dewatering of the Open Pit at the end of Year 30 in comparison to baseline conditions is shown on Figure A.13. The predicted 1 m drawdown contour as a result of Open Pit dewatering extends up to 3.1 km east, 4 km west, 5.1 km south, and 9 km north of the Open Pit. The area of mounding northwest of the Main Zone is due to the diversion of a portion of the North Driftwood River in Year 4. This portion of the North Driftwood River is estimated to receive 4,346 m³/day of groundwater discharge in baseline conditions that is not removed in the Year 30 model, resulting in a groundwater mound of approximately 1 m above baseline.

Table 6.4 presents the comparison of predicted groundwater discharge rates in baseline with predicted groundwater discharge rates at the end of Year 30. The highest predicted reduction in net discharge from groundwater to a river was for the West Buskegau River due to its proximity to the Open Pit. With the exception of Unnamed Lake (West Stockpile), the model results indicate relatively small predicted changes in net flow from groundwater to the lakes. The switch in Unnamed Lake (West Stockpile) from a lake which receives groundwater discharge to a lake which recharges groundwater is related to the changes in local groundwater levels after the North Driftwood River is diverted.

Table 6.4 Predicted Groundwater Discharge to Surface Water Features – Operations Year 30

Surface Water Feature	Predicted Groundwater Discharge Rate (m ³ /d)		
	Baseline ¹	Operations Year 30 ¹	Percent Increase (Decrease)
Jocko Creek	6,104	6,115	0.2
North Driftwood River	6,334	569	(91)
West Buskegau River	1,234	-2,000	(262)
Unnamed Lake (South of Zed Lake)	1,054	1,087	3
Zed Lake	-1,620	-1,653	(2)
Mel Lake	1,211	1,192	(2)
Sutherland Lake	-2,858	-2,717	5
Jack Lake	350	240	(31)
Gerry Lake	6,444	5,966	(7)
Martin Lake	1,577	2,029	29
Unnamed Lake (West Stockpile)	58	-254	(538)
Note:			
1. A negative number indicates that surface water is recharging groundwater at that reach/lake.			

6.3 Open Pit Filling

The predicted rate of groundwater inflow to the Open Pit after the pits have been fully developed and dewatering has ceased is presented in Table 6.5. The predicted groundwater flow into the Open Pit once dewatering ceases is about 8,600 m³/day and decreases to about 1,400 m³/day once the stage of the pit lakes reach the design elevation of the spillways. The inflow of groundwater to the pit lakes at the design elevation of the spillways is predicted to be from the overburden.

Table 6.5 Predicted Open Pit Filling Rates in Closure

Water Level Elevation in Open Pit (m amsl)	Predicted Groundwater Inflow Rate into Open Pit (m ³ /d)
-14 (top of tailings in East Zone)	8,600
86	8,000
136	7,900
186	7,400
236	5,900
272.5 (spillway elevation)	1,400 (to spillways)

6.4 Passive Closure with Pit Lakes

The predicted steady-state flows from the flooded pit lakes to the east and west spillways in passive closure are 900 and 500 m³/day, respectively. The spillways control the stage of the pits in passive closure at 272.5 m amsl, which is approximately 7 m above to 3 m below the baseline groundwater elevation within the Open Pit. The predicted change in water table elevation (drawdown) in passive closure in comparison to baseline conditions is shown on Figure A.14. The area of mounding northwest of the Main Zone is due to the diversion of a portion of the North Driftwood River in Year 4. This portion of the North Driftwood River is estimated to receive 4,346 m³/day of groundwater discharge in baseline conditions that is not removed in the passive closure model, resulting in a groundwater mound of up to 25 m above baseline below the TMF. This mounding is present in the operations phase model results for the Year 17 and Year 30 scenarios (Figure A.12 and Figure A.13), but is smaller in extent and magnitude due to the lowering of the water table resulting from the dewatering of the Open Pit during mine operations.

Table 6.6 presents the comparison of predicted groundwater discharge rates in baseline with predicted groundwater discharge rates for the passive closure phase. The North Driftwood River diversion was maintained for the passive closure phase. In general, predicted groundwater discharge to surface water in passive closure is similar to baseline conditions before mine operations occurred. Martin Lake and the unnamed lake near the West Stockpile show an increase in groundwater discharge for passive closure. These lakes are located closest to the pit lakes where a spillway maintains the surface water elevation at approximately 272.5 m amsl which is approximately 5 to 8 m above the baseline groundwater elevation, resulting in groundwater mounding in this area. The groundwater mounding results in a greater horizontal hydraulic gradient toward the lake resulting in a higher than baseline predicted groundwater discharge

rate to the lake. For the remaining lakes, predicted groundwater discharge to the local lakes generally returned to baseline conditions.

Table 6.6 Predicted Groundwater Discharge to Surface Water Features – Post Closure

Surface Water Feature	Predicted Groundwater Discharge Rate (m ³ /d)		
	Baseline ¹	Passive Closure with Pit Lakes ¹	Percent Increase (Decrease)
Jocko Creek	6,104	6,230	2
North Driftwood River	6,334	2,160	(66)
West Buskegau River	1,234	1,788	45
Unnamed Lake (South of Zed Lake)	1,054	1,157	10
Zed Lake	-1,620	-1,584	2
Mel Lake	1,211	1,272	5
Sutherland Lake	-2,858	-2,627	8
Jack Lake	350	332	(5)
Gerry Lake	6,444	6,748	5
Martin Lake	1,577	2,809	78
Unnamed Lake (West Stockpile)	58	301	419
Note:			
1. A negative number indicates that surface water is recharging groundwater at that reach/lake.			

6.5 Prediction Confidence

The modelling was conducted using an EPM approach. As discussed in Section 5.2, this is appropriate based on the regional scale of the model and considering that flow was predicted to occur primarily through the shallow weathered bedrock which is highly fractured and, therefore, behaves like a porous medium. The groundwater flow modelling was conducted using a model calibrated to water levels and river baseflows to establish baseline conditions. Predictions made using the model are based on several conservatively protective assumptions to reduce the influence of uncertainty in the predictions. Therefore, the confidence in the predictions made using the model is considered high.

Conservatively protective parameters were applied in the model calibration and predictive analysis phases of the modelling investigations. Specifically, the model includes generally high hydraulic conductivity values applied uniformly throughout the entire depth of bedrock. The model did not represent reductions in hydraulic conductivity with depth that could occur due to lithostatic pressure, reduced fractures/connectivity, and reduced secondary porosity. Hydraulic conductivities for overburden hydrostratigraphic units were generally on the high end of the reasonable range of values for each unit or higher for some units (i.e., the surface glaciolacustrine deposits, and tills). Using higher hydraulic conductivity values in the calibrated model results in higher groundwater flow velocities and increased groundwater flow that may occur toward the pit. As such, this approach provided results that may be

considered conservatively high for predicting mine operation-related changes in groundwater elevations, mine inflow rates, and changes in net flows from groundwater to surface water features.

The characterization of the Main Regional Fault in the groundwater flow model was based on review of logs from four exploration boreholes which intersected the fault and the results of one packer test which straddled the fault. A refined understanding of the Main Regional Fault would improve the confidence in predictions of effects of the Project on groundwater quantity. Another approach to increasing confidence regarding the Main Regional Fault is to conduct a sensitivity analysis to determine the sensitivity of the predictions of increased hydraulic conductivity of the fault. Typically, the conduit flow package (CFP) is used with MODFLOW6 to simulate the faults as zones of higher hydraulic conductivity over a defined dimension that is smaller than the groundwater flow model grid cell size. However, MODFLOW6 has undergone upgrades and the software code for the CFP package is not currently compatible with the MODFLOW6 code. Discussions with the developers of the code to rectify the issue have been ongoing. Therefore, simulation of the regional fault within the groundwater flow model was not feasible. As the project continues into permitting additional testing of the fault will be completed and the feasibility of simulating the fault within the model will continue to be discussed with the developers to refine the understanding of the influence of the regional fault on the predictions of effects of the Project on groundwater.

A steady-state modelling approach was selected for the Open Pit dewatering as this provides a conservatively high estimate of groundwater drawdown at the end of Year 30 (when the maximum drawdown extent is predicted) and, as a result, the potential effects on groundwater levels and reductions in groundwater discharge to surface water receivers. Furthermore, the use of separate steady-state model runs to simulate dewatering is expected to provide an over-estimation of the effects on shallow and deep groundwater levels and corresponding changes in groundwater discharge rates to surface water features. The steady-state modelling approach provides average annual groundwater inflow rates and may “under predict” Project inflows in the early phases of Open Pit development. However, while increased inflows due to storage in the aquifer materials and the slightly higher hydraulic gradients may be expected during the initial dewatering period, this not expected to be an issue for the Project and the use of the multiple steady-state model runs reduces this potential effect. The model provides reliable long-term representation of groundwater inflows over the life of mine.

6.6 Model Predictions Sensitivity Analysis

The sensitivity of the model predictions to uncertainty in input parameters was assessed using the operations phase Year 17 groundwater flow model and adjusting key parameters to observe the changes in predicted groundwater inflow to the Open Pit, water table drawdown, and groundwater discharge to surface water features.

6.6.1 Inflow into Open Pit

Eleven sensitivity scenarios, each with a key input parameter(s) adjusted, were run to assess the effect on the predicted inflow into the Open Pit in Year 17. The results are summarized in Table 6.7.

Table 6.7 Sensitivity of Predicted Groundwater Inflow to Open Pit to Model Input Parameters

Parameter	Sensitivity Test Parameter Change	Operations Phase Year 17 Predicted Inflow to Open Pit (m ³ /day)
Base Case		10,500
Recharge	0.5 x calibrated value	9,400
	2.0 x calibrated value	10,600
Overburden Hydraulic Conductivity	0.5 x calibrated value	10,000
	Upper bound values for material ¹	19,000
Esker Hydraulic Conductivity	0.2 x calibrated value	11,500
Bedrock Hydraulic Conductivity	0.25 x calibrated value	9,100
	0.5 x calibrated value	10,100
	1.5 x calibrated value	12,500
	Reduction with depth to 1x10 ⁻¹¹ m/s ²	9,100
River and Lakebed Conductance	0.1 x calibrated value	10,800
	2.0 x calibrated value	14,100
Notes:		
1. Reasonable and foreseeable upper bound values were used for each overburden lithostratigraphic unit, from 1x10 ⁻⁵ m/s for glaciolacustrine clay sediments to 5x10 ⁻⁴ for esker sediments.		
2. Bedrock hydraulic conductivity gradually reduced from 1x10 ⁻⁷ m/s in model layers 6-8 to 1x10 ⁻¹¹ m/s in model layers 21-25.		

The predicted rate of groundwater inflow to the Open Pit is moderately sensitive to reductions in recharge rate. Under wetter conditions (recharge is twice the calibrated value), predicted inflow increased by only 1%, and under dryer conditions (recharge is half the calibrated value), the predicted inflow decreased by 11%.

The predicted rate of groundwater inflow to the Open Pit is not sensitive to a global one half decrease in bulk hydraulic conductivity of the overburden materials. The predicted rate of groundwater inflow to the Open Pit was sensitive to a global increase of hydraulic conductivity to the highest reasonable values for each overburden unit applied in one single test simulation with a resulting increase in the predicted inflow of 81%.

The predicted rate of groundwater inflow to the Open Pit is moderately sensitive to a reduction in the hydraulic conductivity of the esker with an 80% reduction in hydraulic conductivity resulting in a 10% increase in predicted inflow. The reduction in the esker hydraulic conductivity was applied so that the hydraulic conductivity did not differ between the esker and surrounding overburden. The increase in pit inflow was attributed to the removal of a preferential groundwater flow pathway from the esker. Consequently, drawdown is more uniform and generally radial from the Open Pit, given the removal of the local zone of higher hydraulic conductivity of the esker that connected to the surficial lakes. A sensitivity scenario with increased esker hydraulic conductivity was not included as the calibrated value is already near the upper end of the expected range for esker materials.

The predicted rate of groundwater inflow to the Open Pit is moderately sensitive to changes in the hydraulic conductivity of the bedrock model layers. Reduction in hydraulic conductivity of 75% and 50% result in decreased predicted inflow into the Open Pit of 10% and 4%, respectively. An increase in hydraulic conductivity of 150% results in a 19% increase in predicted inflow to the Open Pit. A gradual reduction of four orders of magnitude in hydraulic conductivity in the bedrock from 1×10^{-7} m/s in the shallow rock to 1×10^{-11} m/s in the deepest rock at the base of the model resulted in a 13% reduction in the predicted inflow into the Open Pit.

The predicted inflow to the Open Pit is sensitive to increases in the hydraulic conductivity of the river and lakebed sediments. A doubling of the hydraulic conductivity river and lakebed sediments results in a 33% increase in the predicted rate of inflow of groundwater to the Open Pit. Decreasing the hydraulic conductivity of the river and lakebed sediments had a nearly negligible effect on predicted inflow to the Open Pit (less than 3% difference).

6.6.2 Water Table Drawdown

The predicted water table drawdown for the sensitivity runs which result in the largest decrease and increase in predicted inflows to the Open Pit (reduction of bedrock hydraulic conductivity with depth to 1×10^{-11} m/s and increasing of overburden hydraulic conductivity values to their upper bounds) are presented on Figure A.15 along with the base case Year 17 predicted drawdown.

Reducing the bedrock hydraulic conductivity with depth results in a smaller extent of water table drawdown (30% smaller in area) than the base case and increased water table mounding in the vicinity of the North Driftwood River Diversion. The extent of mounding associated with the TMF is largely unchanged as mounding is controlled by the hydraulic conductivity of the overburden immediately beneath the TMF, and not of the deeper bedrock.

Increasing the overburden hydraulic conductivity values to their upper bounds results in a similar extent of water table drawdown (3% larger in area) than in the base case as the overburden becomes a preferential pathway for groundwater flow to the Open Pit. The extent of mounding associated with the TMF is reduced as the lower hydraulic conductivity beneath the TMF allows for greater seepage to groundwater.

6.6.3 Discharge of Groundwater to Surface Water Features

The predicted groundwater discharge rates for the sensitivity runs which result in the largest decrease and increase in predicted inflows to the Open Pit (reduction of bedrock hydraulic conductivity with depth to 1×10^{-11} m/s and increasing of overburden hydraulic conductivity values to their upper bounds) are presented in Table 6.8.

Table 6.8 Predicted Groundwater Discharge to Surface Water Features – Operations Year 17 Sensitivity Cases

Surface Water Feature	Predicted Groundwater Discharge Rate – Operations Year 17(m ³ /d)		
	Base Case ¹	Decreasing Bedrock Hydraulic Conductivity with Depth ¹	Upper Bound Overburden Hydraulic Conductivity ¹
Jocko Creek	7,797	6,401	7,844
North Driftwood River	848	1,171	6,068
West Buskegau River	2,243	3,555	-2,025
Unnamed Lake (South of Zed Lake)	2,158	2,201	1,450
Zed Lake	-842	-778	-3,213
Mel Lake	1,818	1,856	1,877
Sutherland Lake	-2,235	-2,202	-3,365
Jack Lake	543	573	293
Gerry Lake	7,180	7,438	9,819
Martin Lake	2,340	2,587	2,453
Unnamed Lake (West Stockpile)	-255	-140	-70
Note:			
1. A negative number indicates that surface water is recharging groundwater at that reach/lake.			

For the surface water features assessed, reducing the bedrock hydraulic conductivity with depth results in an average 12% increase in groundwater discharge to surface water. The largest percentage changes to groundwater discharge rates for this sensitivity case are predicted to occur in the West Buskegau River and the Unnamed Lake (West Stockpile). For the surface water features assessed, increasing overburden hydraulic conductivity values to their upper bounds results in an average 9% decrease in groundwater discharge to surface water. The largest percentage changes to groundwater discharge rates for this sensitivity case are predicted to occur in the North Driftwood River and Zed Lake.

7 Groundwater Quality Results

7.1 Predicted Seepage Quality from Project Infrastructure

Seepage from the TMF, Impoundment Facility, and East and West Stockpiles has the potential to affect groundwater quality. The estimated seepage quality [see the Water Quality Assessment (Appendix K of the Impact Statement)] from the TMF, Impoundment Facility, and East and West Stockpiles, is presented in Table 7.1 which includes the 75th percentile, mean, and maximum concentrations for operations and closure. The TMF seepage quality is not predicted by in the Water Quality Assessment (Appendix K of the Impact Statement) to vary over the Project life span. The quality of groundwater in contact with tailings impounded in the East and West Zones of the Open Pit was assumed to be equal to the quality of seepage from the TMF as estimated in the Water Quality Assessment (Appendix K of the Impact Statement).

Table 7.1 Predicted Concentration of Groundwater Seepage from Project Components Compared to Baseline Concentrations

Parameter	Units	Criteria					Background Groundwater Quality (75 th percentile)		West Stockpile			East Stockpile			Impoundment Facility			TMF
		MDMER	PWQO (x10)	CWCG-FAL (x10)	GCDWQ	ODWQS	Bedrock	Overburden	75 th Percentile	Maximum	Mean	75 th Percentile	Maximum	Mean	75 th Percentile	Maximum	Mean	Constant
Ammonia (as N)	mg/L	n/v	n/v	27 ^{TBC2} L	n/v	n/v	2.84	2.17	0.17	0.18	0.11	0.12	0.14	0.08	0.16	0.25	0.1	2.28
Bromide	mg/L	n/v	n/v	n/v	n/v	n/v	0.9	0.148	16.03	16.7	11.58	11.8	13.7	8.76	11.2	11.2	6.41	1.5
Chloride	mg/L	n/v	n/v	1,200 ^L	≤250 ^D	250 ^I	0.88	3.81	71.63	74.6	52.29	53.8	62.2	39.61	81.5	121	44.2	282 ^{DI}
Fluoride	mg/L	n/v	n/v	1.2 ^L	1.5 ^E	1.5 ^F	0.12	0.28	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Nitrate (as N)	mg/L	n/v	n/v	30 ^L	10 ^E	10.0 ^F	-	-	23.55 ^{EF}	24.80 ^{EF}	16.12 ^{EF}	17.5 ^{EF}	20.3 ^{EF}	10.85 ^{EF}	23.1 ^{EF}	35.9 ^{EFL}	13.32 ^{EF}	5.2
Nitrite (as N)	mg/L	n/v	n/v	0.6 ^L	1 ^E	1.0 ^F	0.046	-	0.17	0.18	0.11	0.07	0.08	0.04	0.16	0.25	0.11	0.22
Sulfate	mg/L	n/v	n/v	n/v	≤500 ^D	500 ^I	2.98	5.25	141	147	102.98	106	122	77.95	326	326	187.37	282
Aluminum	µg/L	n/v	n/v	50/1,000 ^{VAR1} L	100 ^a D, 2,900 ^E	100 ^K	5.7	7.3	24.5	24.5	24.32	24.4	24.4	24.2	24.8	24.9	24.5	25.3
Antimony	µg/L	n/v	200 ^B	n/v	6 ^E	6 ^F	0.418	0.41	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	3.93
Arsenic	µg/L	100	50 ^B , 1,000 ^C	50 ^L	10 ^{ALARA} E	10 ^F	1.48	5.1	3.74	3.93	2.72	2.84	3.3	2.06	37 ^{EF}	37 ^{EF}	21.19 ^{EF}	1.12
Barium	µg/L	n/v	n/v	n/v	2,000 ^E	1,000 ^F	45.9	99.7	61.6	157	53.78	75.8	301	66.19	48.9	82.3	35.25	8.72
Beryllium	µg/L	n/v	110/11,000 ^{s3} C	n/v	n/v	n/v	-	0.02	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
Bismuth	µg/L	n/v	n/v	n/v	n/v	n/v	0.054	0.05	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Boron	µg/L	n/v	2,000 ^a B	15,000 ^L	5,000 ^E	5,000 ^F	40.8	38.5	1.24	1.46	0.92	0.97	1.21	0.7	12	12	6.57	282
Cadmium	µg/L	n/v	1/5 ^{s12} B, 2 ^C	0.9 ^{LTG} L	7 ^E	5 ^F	0.0128	0.04	0.04	0.04	0.03	0.03	0.04	0.02	0.1	0.1	0.06	0.01
Calcium	µg/L	n/v	n/v	n/v	n/v	n/v	66,100	88,600	2,592.5	2,680	2,103.6	2,180	2,370	1,790.41	72,300	82,200	59,044.19	1,460
Chromium	µg/L	n/v	n/v	n/v	50 ^E	50 ^F	3.95	5.03	10.07	14.2	9.87	10.07	11.6	7.48	0.70	0.70	0.70	3.30
Chromium (Hexavalent)	µg/L	n/v	10 ^C	10 ^L	n/v	n/v	-	-	13.63 ^{CL}	14.10 ^{CL}	9.77	9.97	11.5 ^{CL}	7.38	0.6	0.6	0.6	3.2
Chromium (Trivalent)	µg/L	n/v	89 ^C	89 ^L	n/v	n/v	-	-	0.1	0.10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cobalt	µg/L	n/v	9 ^B	n/v	n/v	n/v	0.438	0.56	0.72	0.75	0.52	0.54	0.62	0.4	1.21	1.21	0.7	0.92
Copper	µg/L	100	10/50 ^{s13} B, 50 ^C	20 ^{TBC1} L	≤1000 ^D , 2,000 ^E	1,000 ^I	0.825	2.12	8.01	8.32	5.84	5.99	6.93	4.42	15.3 ^B	15.3 ^B	8.77	1.00
Iron	µg/L	n/v	3,000 ^C	3,000 ^L	≤300 ^D	300 ^I	1,430 ^{DI}	4,450 ^{CDIL}	2.08	2.08	2.07	2.07	2.07	2.06	2.08	2.09	2.07	2.1
Lead	µg/L	80	10/30/50 ^{s15} B, 50/100/200/250 ^{s14} C	10 ^{TBC1} L	5 ^{ALARA} E	10 ^F	0.17	0.12	1.27	1.32	0.93	0.96	1.1	0.7	2.89	2.89	1.66	0.09
Lithium	µg/L	n/v	n/v	n/v	n/v	n/v	1.9	7.35	1.48	1.55	1.08	1.12	1.29	0.82	9.16	9.16	5.29	38.5
Magnesium	µg/L	n/v	n/v	n/v	n/v	n/v	54,000	27,500	91,025	93,500	74,128.57	75,400	82,700	63,079.49	62,800	71,400	48,786.05	182,000
Manganese	µg/L	n/v	n/v	4,300 ^{EQ4} L	≤20 ^D , 120 ^E	50 ^I	124 ^{DEI}	165 ^{DEI}	16.53	17.2	12.04	12.5	14.4	9.13	189 ^{DEI}	189 ^{DEI}	108.9 ^{DI}	69.5 ^{DI}
Mercury	µg/L	n/v	2 ^C	0.26 ^L	1 ^E	1 ^F	-	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Molybdenum	µg/L	n/v	400 ^B	730 ^L	n/v	n/v	3	11.2	5.38	5.59	3.92	4.03	4.66	2.97	23.3	23.3	13.44	28.4
Nickel	µg/L	250	250 ^C	250 ^{TBC1} L	n/v	n/v	4.96	3	18.55	19.3	13.53	13.9	16	10.24	10.2	10.2	5.78	17.2
Phosphorus	µg/L	n/v	300 ^{s4} B	n/v	n/v	n/v	210	142	42	42	42	42	42	42	0.72	1.9	0.67	19.5
Potassium	µg/L	n/v	n/v	n/v	n/v	n/v	2,650	3,680	287.75	299	233.49	243	263	198.75	13,100	14,900	10,739.77	2,930
Selenium	µg/L	n/v	1,000 ^C	10 ^L	50 ^E	50 ^F	0.73	0.36	1.33	1.38	0.96	0.99	1.14	0.73	2.16	2.16	1.24	2.94
Silver	µg/L	n/v	1 ^C	2.5 ^L	n/v	n/v	0.0162	0.205	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025
Sodium	µg/L	n/v	n/v	n/v	≤200000 ^D	200,000 ^g , 20,000 ^g	11,800	44,700 ^J	233	241	188.16	196	212	160.26	18,900	21,500 ^J	15,494.88	26,500 ^J

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7 Groundwater Quality Results
 September 30, 2024

Parameter	Units	Criteria					Background Groundwater Quality (75 th percentile)		West Stockpile			East Stockpile			Impoundment Facility			TMF
		MDMER	PWQO (x10)	CWCG-FAL (x10)	GCDWQ	ODWQS	Bedrock	Overburden	75 th Percentile	Maximum	Mean	75 th Percentile	Maximum	Mean	75 th Percentile	Maximum	Mean	Constant
Strontium	µg/L	n/v	n/v	n/v	7,000 ^E	n/v	392	452	115.5	121	84.32	86.4	99.9	63.8	431	431	248.52	9.6
Thallium	µg/L	n/v	3 _b ^B	8 ^L	n/v	n/v	-	-	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0575
Tin	µg/L	n/v	n/v	n/v	n/v	n/v	0.45	0.55	1.08	1.13	0.79	0.81	0.94	0.6	3.91	3.91	2.25	1.36
Titanium	µg/L	n/v	n/v	n/v	n/v	n/v	3.86	3.4	1.03	1.08	0.76	0.78	0.9	0.57	6.47	6.47	3.73	0.1
Tungsten	µg/L	n/v	300 _a ^B	n/v	n/v	n/v	0.175	0.88	1.60	1.66	1.16	1.19	1.38	0.88	3.54	3.54	2.04	7.54
Uranium	µg/L	n/v	50 _a ^B	150 ^L	20 ^E	20 ^F	0.16	1.17	10.63	11.1	7.78	8.03	9.26	5.89	23.4 ^{EF}	23.4 ^{EF}	13.47	0.01
Vanadium	µg/L	n/v	60 ^B	n/v	n/v	n/v	1.5	2.2	1.15	1.21	0.84	0.88	1.01	0.64	30.4	30.4	17.56	0.32
Yttrium	µg/L	n/v	n/v	n/v	n/v	n/v	-	-	0.28	0.29	0.21	0.21	0.25	0.16	0.64	0.64	0.37	0.07
Zinc	µg/L	400	200 ^B 300 ^C	70 _{Eq2} ^L	≤5000 ^D	5,000 ^I	202 ^{BL}	26.3	28.20	29.4	20.58	21.2	24.5	15.6	63.9	63.9	36.74	2.00

Notes:

MDMER Metal and Diamond Mining Effluent Regulations, Schedule 4, Maximum Authorized Monthly Mean Concentration

PWQO (x10) Provincial Water Quality Objectives of the Ministry of Environment and Energy (MOEE, 1999) (x10)

A PWQO Table 2 - Calculated (x10)

B PWQO Table 2 - Interim (x10)

C PWQO Table 2 (x10)

GCDWQ Health Canada (August 2024). Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

D Guidelines for Canadian Drinking Water Quality - Aesthetic Objectives/ Operational Guidelines

E Guidelines for Canadian Drinking Water Quality - Maximum Acceptable Concentration

O. Reg. 169/03 Ontario Drinking Water Quality Standards (January 1, 2018)

F Schedule 2 - Chemical Standards (expressed as a maximum acceptable concentration)

G Schedule 3 - Radiological Standards - Table 1 - Natural Radionuclides

H Schedule 3 - Radiological Standards - Table 2 - Artificial Radionuclides

I ODWS Table 4 - Chemical/Physical Objectives and Guidelines, Aesthetic Objectives

J ODWS Table 4 - Medical Officer of Health Reporting Limit

K ODWS Table 4 - Chemical/Physical Objectives and Guidelines, Operational Guidelines

CCME Canadian Council of Ministers of the Environment

L Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Life - Freshwater Aquatics Long Term x 10

6.5^A Concentration exceeds the indicated standard.

15.2 Measured concentration did not exceed the indicated standard.

<0.50 Laboratory reporting limit was greater than the applicable standard.

<0.03 Analyte was not detected at a concentration greater than the laboratory reporting limit.

n/v No standard/guideline value.

- Parameter not analyzed / not available.

a^B This Interim PWQO was set for emergency purposes based on the best information readily available. Employ due caution when applying this value.

a^D This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants; it does not apply to naturally occurring aluminum found in groundwater. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.

ALARA as low as reasonably achievable

b This Interim PWQO is currently under development. The value is subject to change upon publication by MOE.

d Where both nitrate and nitrite are present, the total of the two should not exceed 10 mg/L (as nitrogen).

EQ2 The long-term CWQG is for dissolved zinc and is calculated using the following equation: $CWQG = \exp(0.947[\ln(\text{hardness mg}\cdot\text{L}^{-1})] - 0.815[\text{pH}] + 0.398[\ln(\text{DOC mg}\cdot\text{L}^{-1})] + 4.625) \times 10$. The value in the table is for surface water of 50 mg CaCO₃·L⁻¹ hardness, pH of 7.5 and 0.5 mg·L⁻¹ DOC. The CWQG equation is valid between hardness 23.4 and 399 mg CaCO₃·L⁻¹, pH 6.5 and 8.13 and DOC 0.3 to 22.9 mg·L⁻¹.

EQ4 The long-term CWQG is found using the look-up table (see Table 5) or the CWQG and benchmark calculator is Appendix B of CCME (2019). The value in the table is for surface water of 50 mg/L hardness and pH of 7.5. The CWQG table is valid between hardness 25 and 670 mg/L and pH 5.8 and 8.4.

g The aesthetic objective for sodium in drinking water is 200 mg/L. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.

h When sulfate levels exceed 500 mg/L, water may have a laxative effect on some people.

j High levels (above 500 mg/L) can cause physiological effects such as diarrhea or dehydration.

LTG The CWQG for cadmium (i.e. long-term guideline) of 0.09 µg·L⁻¹ x 10 is for waters of 50 mg CaCO₃·L⁻¹ hardness. The CWQG for cadmium is related to water hardness (as CaCO₃): When the water hardness is > 0 to < 17 mg/L, the CWQG is 0.04 µg/L x 10; at hardness ≥ 17 to ≤ 280 mg/L, the CWQG is calculated using this equation $(CWQG (\mu\text{g/L}) = 10^{(0.83(\log[\text{hardness}]) - 2.46)}) \times 10$; At hardness > 280 mg/L, the CWQG is 0.37 µg/L x 10.

s3 The PWQO for beryllium is hardness dependent. If hardness <75 mg/L than PWQO is 0.011 mg/L. For hardness > 75 mg/L, PWQO is 1.1 mg/L.

s4 Applies to Phosphorus, total. PWQO is 0.03 mg/L for rivers and streams, 0.02 mg/L for lakes, and 0.01 mg/L for lakes naturally below this value.

s12 The interim PWQO for cadmium is hardness dependent. If hardness <100 mg/L than PWQO is 0.0001 mg/L. For hardness >100 mg/L, PWQO is 0.0005 mg/L.

s13 The interim PWQO for copper is hardness dependent. If hardness <20 mg/L than PWQO is 0.001 mg/L. For hardness >20 mg/L, PWQO is 0.005 mg/L.

s14 PWQO for lead is alkalinity dependent. For alkalinity <20 mg/L, PWQO is 0.005 mg/L. For alkalinity between 20-40 mg/L, PWQO is 0.01 mg/L. For alkalinity between 40-80 mg/L, PWQO is 0.02 mg/L. For alkalinity >80 mg/L, PWQO is 0.025 mg/L.

s15 Interim PWQO for lead is hardness dependent. For hardness <30 mg/L, interim PWQO is 0.001 mg/L. For hardness between 30-80 mg/L, interim PWQO is 0.003 mg/L. For hardness >80 mg/L, interim PWQO is 0.005 mg/L.

TBC1 Value is minimum value available. Sample-specific value to be calculated (equation).

TBC2 Calculated using pH=7.5 and temperature = 10 (geomean in overburden=7.0 and 7.3, respectively), then the present guideline values (mg/L NH₃) can be converted to mg/L total ammonia-N by multiplying the corresponding guideline value by 0.8224.

VAR1 Variable, 5 µg/L if pH < 6.5 and 100 µg/L if pH > 6.5

Background groundwater quality was consistently elevated relative to the regulatory criteria for iron, manganese and sodium. Elevated concentrations of these parameters are typical of groundwater in Ontario and are reflective of the natural mineralization and geochemical processes in the area. Concentrations in bedrock were also found to be elevated relative to the regulatory criteria for zinc, which is considered atypical for a groundwater system. Instrumentation installed within monitoring wells may have resulted in elevated zinc; equipment adjustments will be made, and future sampling may confirm the cause of elevated zinc concentrations.

As presented in Table 7.1, the following trends were observed when comparing water quality in seepage from the TMF, Impoundment Facility, and East and West Stockpiles to relevant regulatory criteria:

East and West Stockpiles

- Seepage from the East and West Stockpiles is not predicted to exceed MDMER criteria.
- Seepage from the East and West Stockpiles may exceed the ODWQS and/or the GCDWQ for nitrate.
- Seepage from the East and West Stockpiles may exceed 10 x PWQO and 10 x CWQG-FAL for Hexavalent Chromium. Hexavalent chromium was not measured in the baseline groundwater monitoring programs, however the 75th percentile total chromium concentrations in the baseline data for overburden and bedrock were approximately 50% below the predicted seepage concentrations. As hexavalent chromium comprises a portion of total chromium, the hexavalent chromium concentrations from the East and West Stockpile are not likely to exceed the 75th percentile baseline concentration and the baseline concentrations are not predicted to exceed 10 x PWQO or 10 x CWQG-FAL.

TMF

- Seepage from TMF is not predicted to exceed MDMER criteria.
- Seepage from the TMF may exceed the ODWQS and/or the GCDWQ aesthetic guidelines for chloride. The predicted seepage concentration of chloride from the TMF is two to three orders of magnitude higher than the 75th percentile baseline concentrations in bedrock and overburden.
- Seepage from the TMF may exceed the ODWQS and GCDWQ aesthetic guidelines for manganese. The GCDWC health-based criteria, the Maximum Acceptable Concentration, is not predicted to be exceeded. The predicted seepage concentration of manganese from the TMF is approximately 50% of the 75th percentile baseline concentrations in overburden and bedrock which also exceed the aesthetic ODWQS and GCDWQ criteria.
- Seepage from the TMF may exceed the ODWQS Medical Officer of Health reporting limit for sodium. The predicted seepage concentration of sodium from the TMF is approximately 45% lower than the 75th percentile baseline concentration in overburden which also exceeds the ODWQS Medical Officer of Health reporting limit. The predicted seepage concentration of sodium from the TMF is approximately double the 75th percentile baseline concentration in bedrock which does not exceed the ODWQS Medical Officer of Health reporting limit.

Impoundment Facility

- Seepage from the Impoundment Facility is not predicted to exceed MDMER criteria.
- Seepage from Impoundment may exceed the ODWQS, GCDWQ, and/or the 10 x CWQG-FAL criteria for nitrate. The maximum predicted seepage concentration of nitrate from the Impoundment Facility is approximately 20% higher than the 10 x CWQG-FAL criteria. The predicted 75th percentile seepage concentration of nitrate from the Impoundment Facility is not predicted to exceed the 10 x CWQG-FAL criteria.
- Seepage from the Impoundment Facility may exceed the ODWQS and/or the GCDWQ for arsenic. The predicted 75th percentile seepage concentration of arsenic from the Impoundment Facility is approximately an order of magnitude higher than the 75th percentile baseline concentration in bedrock and overburden. Baseline concentrations do not exceed regulatory criteria.
- Seepage from the Impoundment Facility may exceed the 10 x PWQO (interim) criteria for copper but not the 10 x CWQG-FAL criteria. The CWQG-FAL criteria is based on newer science than the 10 x PWQO (interim) criteria. The predicted 75th percentile seepage concentration of copper from the Impoundment Facility is approximately one order of magnitude higher than the 75th percentile baseline concentrations in overburden and bedrock. Baseline concentrations do not exceed regulatory criteria.
- Seepage from the Impoundment Facility may exceed the ODWQS and the GCDWQ aesthetic and health-based criteria for manganese. The predicted seepage concentration of manganese from the Impoundment Facility is of the same order of magnitude as the 75th percentile baseline concentrations in bedrock and overburden, which also exceed the ODWQS and the GCDWQ aesthetic and health based criteria.
- Seepage from the Impoundment Facility may exceed the ODWQS Medical Officer of Health reporting limit for sodium. The predicted seepage 75th percentile concentration for sodium in seepage from the Impoundment Facility is approximately 50% lower than the 75th percentile baseline concentration in overburden which also exceeds the ODWQS Medical Officer of Health reporting limit. The predicted seepage concentration of sodium from the Impoundment Facility is approximately double the 75th percentile baseline concentration in bedrock which does not exceed the ODWQS Medical Officer of Health reporting limit.
- Seepage from the Impoundment Facility may exceed the ODWQS and/or the GCDWQ for uranium. Baseline concentrations do not exceed regulatory criteria.

7.2 Predicted Fate of Groundwater Flow from Project Infrastructure

The fate of seepage through the TMF, Impoundment Facility, and East and West Stockpiles and of groundwater in contact with the tailings impounded in the East and West Zones of the Open Pits, was estimated using FlowSource in forward mode to predict the discharge location and flux of water recharging the groundwater flow system from each source. Predicted flows below 1 m³/d are not tabulated. There are no known groundwater uses within the flow path of the predicted seepage from

Project Infrastructure to the receiving environment. The assessment of the effect of the quality and fate of groundwater seepage from Project infrastructure on the surface water receiving environment is presented in the Surface Water Resources Assessment (Appendix C.5 of the Impact Statement).

7.2.1 Fate of Seepage – Operations Year 17

The fate of seepage through the TMF, Impoundment Facility, and East and West Stockpiles under the groundwater flow condition representative of operations Year 17 is presented in Table 7.2 and Figure A.16.

Table 7.2 Predicted Fate of Seepage From TMF, Impoundment Facility, and Stockpiles – Representing Steady State Conditions of Operations Year 17 Mine Plan

Surface Water Feature	Predicted Groundwater Discharge Rate of Seepage Originating from Project Infrastructure (m ³ /d)		
	TMF	Impoundment Facility	Stockpiles
Jocko Creek	2,256	-	-
North Driftwood River	-	194	-
West Buskegau River	2,090	105	-
Unnamed Lake (South of Zed Lake)	1,503	-	-
Zed Lake	43	-	-
Mel Lake	1,099	-	-
Sutherland Lake	155	-	-
Jack Lake	58	-	-
Gerry Lake	1,453	-	-
Martin Lake	-	-	-
Unnamed Lake (West Stockpile)	-	-	-
Open Pit	4,427	843	324
Note: - Groundwater flows greater than 1 m ³ /d are not predicted from the Project infrastructure to the surface water feature			

The lower bound on predicted horizontal groundwater flow travel times of groundwater seepage from Project infrastructure to rivers or lakes are as follows:

- approximately 60 years from the TMF to Gerry Lake
- approximately 150 years from the Impoundment Facility to the North Driftwood River
- groundwater from seepage from the Stockpiles is not predicted to discharge to modeled rivers or lakes

As the lower bounds on predicted horizontal groundwater flow travel times of groundwater seepage from the TMF, Impoundment Facility, and Stockpiles to rivers or lakes are greater than 17 years, seepage is not predicted to reach a receiver during the period of mine life represented by the Year 17 model.

7.2.2 Fate of Seepage – Operations Year 30

The fate of seepage through the TMF, Impoundment Facility, and East and West Stockpiles, and of groundwater in contact with tailings impounded in the Open Pit under the groundwater flow condition representative of operations Year 30 is presented in Table 7.3 and Figure A.17.

Table 7.3 Predicted Fate of Seepage From TMF, Impoundment Facility, Stockpiles, and Tailings Impounded in Open Pit – Representing Steady State Conditions of Operations Year 30 Mine Plan

Surface Water Feature	Predicted Groundwater Discharge Rate of Seepage Originating from Project Infrastructure (m ³ /d)			
	TMF	Impoundment Facility	Stockpiles	Tailings Impounded in Open Pit
Jocko Creek	-	-	-	-
North Driftwood River	-	87	-	-
West Buskegau River	-	49	-	-
Unnamed Lake (South of Zed Lake)	64	-	-	-
Zed Lake	-	-	-	-
Mel Lake	2	-	-	-
Sutherland Lake	-	-	-	-
Jack Lake	-	-	-	-
Gerry Lake	-	-	-	-
Martin Lake	-	-	-	-
Unnamed Lake (West Stockpile)	-	-	-	-
Open Pit	840	1,051	323	1,981
Note: - Groundwater flows greater than 1 m ³ /d are not predicted from the Project infrastructure to the surface water feature.				

The lower bound on predicted horizontal groundwater flow travel times of groundwater seepage from Project infrastructure to rivers or lakes are as follows:

- approximately 60 years from the TMF to Gerry Lake
- approximately 220 years from the Impoundment Facility to the North Driftwood River
- groundwater from seepage from the Stockpiles and within the impounded tailings is not predicted to discharge to modeled rivers or lakes

As the lower bounds on predicted horizontal groundwater flow travel times of groundwater seepage from the TMF, Impoundment Facility, and Stockpiles to rivers or lakes are greater than 30 years, seepage is not predicted to reach a receiver during the period of mine life represented by the Year 30 model.

7.2.3 Fate of Seepage – Passive Closure with Pit Lakes

The fate of seepage through the TMF and Impoundment Facility, and of groundwater in contact with tailings impounded in the pit lakes once steady-state conditions have been realized is presented in Table 7.4 and Figure A.18. In passive closure, the East and West Stockpiles are depleted, graded, and revegetated.

Table 7.4 Predicted Fate of Seepage From TMF, Impoundment Facility, Tailings Impounded in Pit Lakes – Passive Closure

Surface Water Feature	Predicted Groundwater Discharge Rate of Seepage Originating from Project Infrastructure (m ³ /d)		
	TMF	Impoundment Facility	Tailings Impounded in Pit Lakes
Jocko Creek	-	-	-
North Driftwood River	-	538	-
West Buskegau River	-	435	-
Unnamed Lake (South of Zed Lake)	208	-	-
Zed Lake	-	-	-
Mel Lake	58	-	-
Sutherland Lake	2	-	-
Jack Lake	-	-	-
Gerry Lake	528	-	-
Martin Lake	16	-	1
Unnamed Lake (West Stockpile)	12	5	4
Open Pit	69	256	54
Note: - Groundwater flows greater than 1 m ³ /d are not predicted from the Project infrastructure to the surface water feature.			

The lower bound on predicted horizontal groundwater flow travel times of groundwater seepage from Project infrastructure to rivers or lakes are as follows:

- approximately 150 years from the TMF to Gerry Lake
- approximately 60 years from the Impoundment Facility to the West Buskegau River
- approximately 920 years from the impounded tailings to Martin Lake

7.3 Prediction Confidence

The effects to groundwater quality as a result of the Project are based on field data and geochemical characterization of overburden, ore, rock, and tailings. Prediction confidence in groundwater quality effects is high, as reductions in groundwater discharge to the natural environment did not consider collection within the contact water collection system for the ore stockpile and Impoundment Facility. Including the effect of the contact water collection system result in further reductions in loading to the natural environment. Furthermore, conservative estimates of groundwater recharge beneath the ore stockpile and Impoundment Facility are applied in the groundwater modelling, which overestimate the loadings to groundwater.

The prediction of concentrations in groundwater at the point of discharge to the receiving environment did not consider physical flow processes, such as dispersion and diffusion, and chemical processes, such as adsorption, precipitation, and dissolution along the groundwater flow path of the travel time to reach the ultimate receptor. These processes will result in reductions in groundwater concentrations along the groundwater flow path, and therefore represents a conservative approach to estimating loading to the natural environment.

Furthermore, the groundwater quality assessment does not consider the effect of timing for infrastructure development (i.e., when the Impoundment Facility is in place) or the groundwater travel time in calculating the mass loading to the environment (seepage quality multiplied by groundwater discharge rate). This will result in a conservative prediction of the mass loading in early phases of the Project (i.e., operations) and provide a better representation of long-term water quality through closure, although still a very conservative prediction.

8 Follow-Up and Monitoring

The primary effect on groundwater quantity and flow is a lowering of the water table as a result of dewatering the Open Pit during construction and operations and, to a lesser extent, during closure when the Open Pit refills. The effect on groundwater quality is an increase in concentrations of parameters in seepage (as noted in Section 7.2) from the Impoundment Facility, East and West Stockpiles, TMF, and tailing impounded within the Open Pit to groundwater.

Canada Nickel proposes additional field studies with findings to be incorporated into a refined groundwater flow model to refine the prediction of effects of the Project on groundwater quantity and quality to support the permitting process. Canada Nickel will also develop a follow-up and monitoring program to monitor groundwater levels and groundwater quality at key Project locations. Monitoring data from these locations will be used to verify and confirm the predicted effects of the Project on groundwater and to meet regulatory requirements related to specific permits or conditions of approval.

8.1 Additional Field Studies

The following additional field studies are proposed to support an update to the groundwater flow model:

- Additional hydraulic testing to refine the understanding of the hydrogeological properties of the Main Regional Fault.
- Drilling of boreholes and installation of monitoring wells within the footprint of the Impoundment Facility, TMF, and Stockpiles; along the proposed realignment channel of the North Driftwood River; and within the regionally mapped boundaries of the esker.
- Completion of geophysics to characterize hydrostratigraphy between discrete drilling locations in select areas.
- A pumping test in the footprint of the Open Pit to refine estimates of hydraulic conductivity.

8.2 Monitoring Methods

Prior to and during construction, a detailed groundwater monitoring program will be developed and implemented, building on the baseline monitoring program, to confirm potential changes in groundwater associated with future mine operation. The monitoring program for groundwater will be developed based on regulatory requirements for both quantity and quality.

- The type of monitoring equipment, selection of monitoring stations, frequency of sample collection, and duration of the program will be based on federal and provincial guidelines and consultation with government agencies. However, it is anticipated that the monitoring program will generally comprise the following key elements:
 - Water quantity (flow rate and total daily volume) of dewatering water in accordance with PTTW and ECA requirements.

- Monitoring groundwater levels in monitoring wells to document changes in level and flow in response to Open Pit dewatering, filling of the pit in early closure, and changes in recharge due to Project components (e.g., TMF). Groundwater levels will be monitored using a combination of manual and automated monitoring methods with the frequency and approach modified throughout the life of the Project. During initial periods of monitoring, it is anticipated that automated monitoring will be implemented to confirm initial water level responses to dewatering. As effects on groundwater levels are confirmed, monitoring may be transitioned to manual methods or discontinued at locations where no effects are observed.
- Monitoring groundwater and surface water levels at drive-point piezometers in the vicinity of key surface water features to document changes in groundwater and surface water interactions in response to Open Pit dewatering and changes in recharge due to Project components (e.g., TMF).
- Monitoring groundwater quality at monitoring wells located upgradient, cross-gradient, and downgradient of the Impoundment Facility, East and West Stockpiles, TMF, and Open Pit to document potential changes in groundwater quality.
- Groundwater quality samples from monitoring wells will be collected annually with a subset of monitoring wells monitored in spring, summer, and fall during construction, operations, and decommissioning/closure with the frequency progressively reduced based on monitoring results and Project phase. Winter groundwater sampling may not be feasible as the monitoring wells may be frozen and not possible to sample. Groundwater quality samples will be analyzed for general chemistry parameters and select dissolved metals.
- Groundwater quality monitoring results will be compared with applicable regulatory standards set out in GCDWQ, ODWQS, and Project-specific regulatory approvals.
- Monitoring groundwater levels and quality in background monitoring wells.
- A water well survey will be completed within and adjacent to the LSA to confirm known groundwater users in the vicinity of the PA by validating the MECP WWR and PTTW database review presented in Section 4.

8.3 Monitoring Locations and Frequencies

Groundwater monitoring locations will be reviewed at regular intervals. Monitoring locations/stations may be added or removed from the monitoring program in accordance with their utility in monitoring the effects of the Project on groundwater.

Monitoring locations will be maintained until the location is no longer required. If a monitoring location/station is no longer required but is identified as part of a regulatory approval, it will only be removed from the monitoring program once the required amendments are approved.

9 Conclusions

The primary effect on of the Project on groundwater quantity and flow is a lowering of the water table as a result of dewatering the Open Pit during construction and operations and, to a lesser extent, during closure when the Open Pit refills. The largest drawdown extent is predicted to occur at the end of Year 30 representing the end of mining when both the Main Zone and East Zone of the Open Pit are developed to their full depths. The predicted 1 m drawdown contour as a result of Open Pit dewatering at the end of Year 30 extends up to 3.1 km east, 4 km west, 5.1 km south, and 9 km north of the Open Pit.

The maximum rate of groundwater inflow to the Open Pit is predicted to occur at the end of Year 17 when the Main Zone is developed to full depth, development of the East Zone is ongoing, and immediately prior to closure of the TMF. The predicted rate of groundwater inflow to the Open Pit at the end of Year 17 is approximately 10,500 m³/day.

Due to lowering of the water table, surface water features closest to the Open Pit are predicted to generally experience a reduction in groundwater discharge during the construction and operations phases. The presence of enhanced recharge through the TMF prior to its closure is predicted to result in a groundwater mound and an associated increase in groundwater discharge to surface water features in proximity to the TMF.

In general, predicted groundwater discharge to surface water in passive closure is similar to baseline conditions before mine operations occurred. Martin Lake and the unnamed lake near the West Stockpile are predicted to increase in groundwater discharge for passive closure. These lakes are located closest to the pit lakes where a spillway maintains the surface water elevation at approximately 272.5 m amsl which is approximately 5 to 8 m above the baseline groundwater elevation, resulting in groundwater mounding in this area. The predicted steady-state groundwater flows from the flooded pit lakes to the east and west spillways in passive closure are 900 and 500 m³/day, respectively.

Seepage from the TMF is not predicted to exceed MDMER but is predicted to exceed the ODWQS and/or the GCDWQ aesthetic guidelines for chloride and manganese, and the Medical Officer of Health reporting limit for sodium. Concentrations of manganese above the ODWQS and/or GCDWQ are typical of baseline groundwater quality.

Seepage from the Impoundment Facility is not predicted to exceed MDMER but is predicted to exceed the ODWQS and/or the GCDWQ for arsenic, manganese, uranium, and nitrate, and the Medical Officer of Health reporting limit for sodium. Seepage from the Impoundment Facility is also predicted to exceed the 10 x PWQO (interim) criteria for copper, but not the 10 x CWQG-FAL criteria. Concentrations of arsenic and manganese above the ODWQS and/or the GCDWQ are typical of baseline groundwater quality.

Seepage from the East and West Stockpiles is not predicted to exceed MDMER, the ODWQS, or the GCDWQ for the parameters analyzed. Seepage from the East and West Stockpiles may exceed 10 x PWQO and 10 x CWQG-FAL for Hexavalent Chromium.

The fate of groundwater recharging beneath the mine infrastructure was predicted using the groundwater flow model. For groundwater recharge originating at the TMF during operations of the TMF is predicted to discharge predominantly to the Open Pit as well as Jocko Creek, West Buskegau River, an Unnamed Lake (South of Zed Lake), and Gerry Lake. Once the TMF is rehabilitated (after Year 17), recharge through the TMF is reduced and groundwater recharge originating at the TMF is predicted to discharge predominantly to an Unnamed Lake (south of Zed Lake) and Gerry Lake with a minor component of discharge to the Open Pit and other watercourses. Groundwater recharge originating at the Impoundment Facility is predicted to predominantly discharge to the Open Pit and an unnamed lake (West Stockpile), North Driftwood River, and/or West Buskegau River during operations with discharge to the North Driftwood River, West Buskegau River, and the Open Pit in closure. The majority of recharge originating beneath the stockpiles is predicted to be captured by the Open Pit with the majority of recharge through the impounded tailings in the Open Pit predicted to remain within the Open Pit (90%).

Canada Nickel will develop a follow-up and monitoring program to monitor groundwater levels and groundwater quality at key Project locations. Monitoring data from these locations will be used to verify and confirm the predicted effects of the Project on groundwater and to meet regulatory requirements related to specific permits or conditions of approval.

10 References

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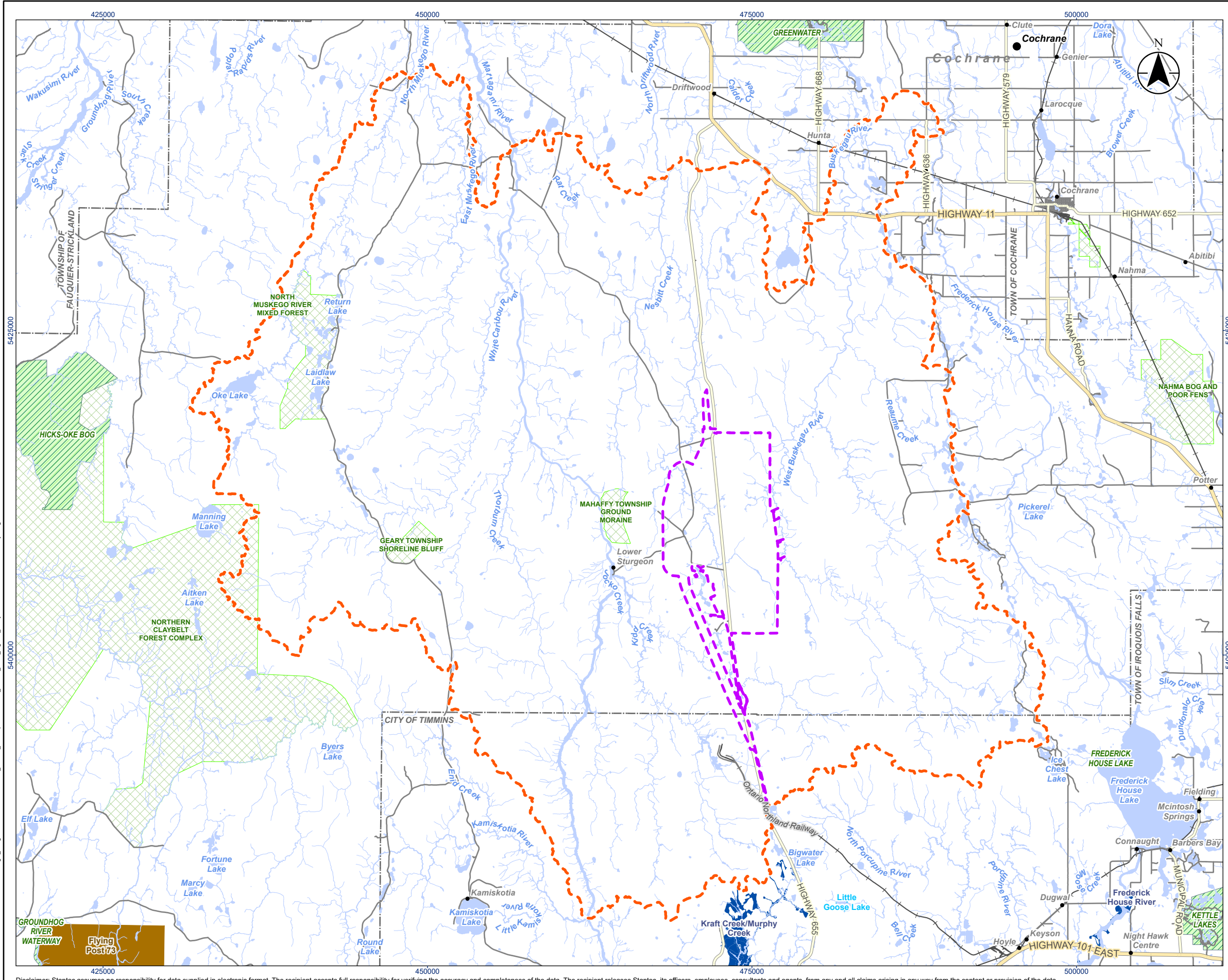
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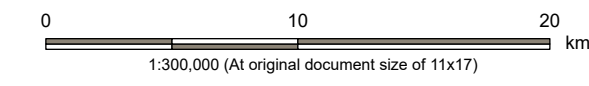
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Appendices

Appendix A Figures

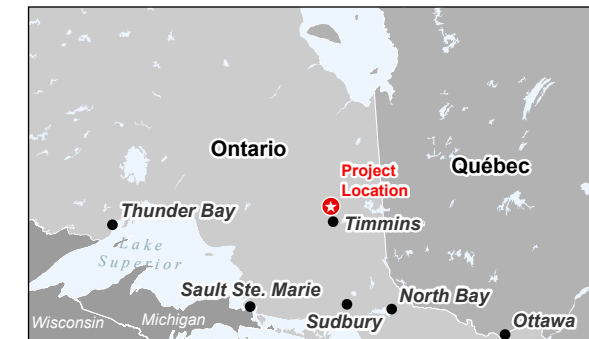


- Legend**
-  Project Area
 -  Local/Regional Study Area
- Base Features**
-  Expressway / Highway
 -  Major Road
 -  Minor Road
 -  Railway
 -  Watercourse
 -  Waterbody
 -  Municipal Boundary - Lower Tier
 -  First Nation Reserve
 -  Conservation Reserve (Regulated)
 -  Provincial Park
 -  Wetland, Provincially Significant
 -  Wetland, Other Evaluated



Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © King's Printer for Ontario, 2023.

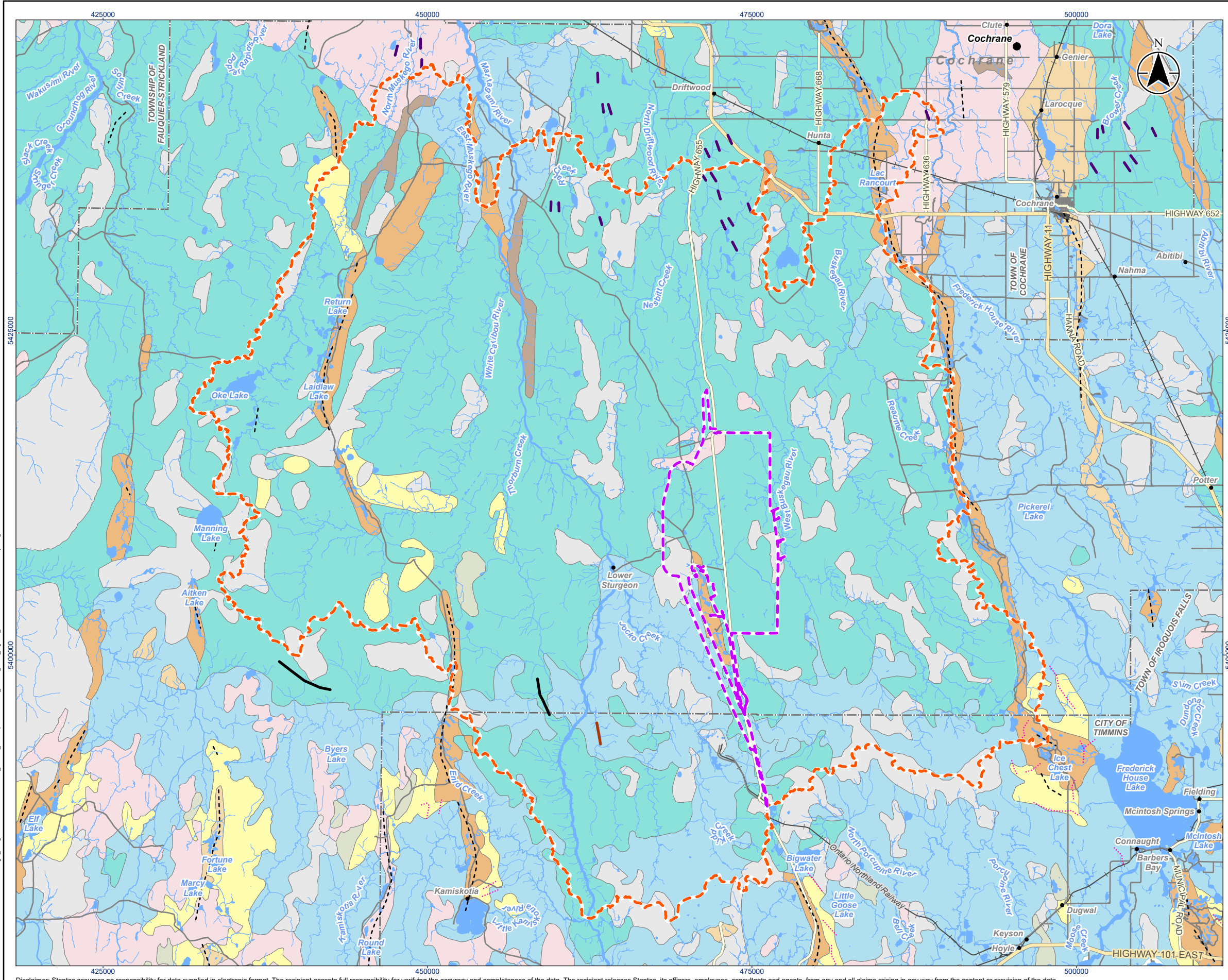


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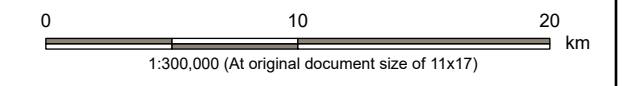
Client/Project: Canada Nickel Company (CNC)
 Crawford Nickel Project

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- Legend**
- Project Area
 - Local/Regional Study Area
 - Expressway / Highway
 - Major Road
 - Minor Road
 - Railway
 - Watercourse
 - Waterbody
 - Municipal Boundary - Lower Tier
- Surficial Geology**
- Beach, bar or spit
 - Drumlin or area of drumlins
 - Esker or area of eskers; direction of flow know or assumed
 - Terrace escarpment (abandoned shore bluff)
 - Trend of end moraine crest
 - 1: Bedrock
 - 18: Till
 - 21: Till, fine-grained
 - 22: Glaciofluvial Ice (Esker)
 - 23: Glaciofluvial Outwash deposits
 - 24: Glaciolacustrine deposits
 - 25: Glaciolacustrine deposits
 - 31: Fluvial deposits
 - 32: Organic deposits
 - 33: Lakes



- Notes**
1. Coordinate System: NAD 1983 UTM Zone 17N
 2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © King's Printer for Ontario, 2023.
 3. Ontario Geological Survey, 1997. Quaternary geology, seamless coverage of the province of Ontario: Ontario Geological Survey, Data Set 14.



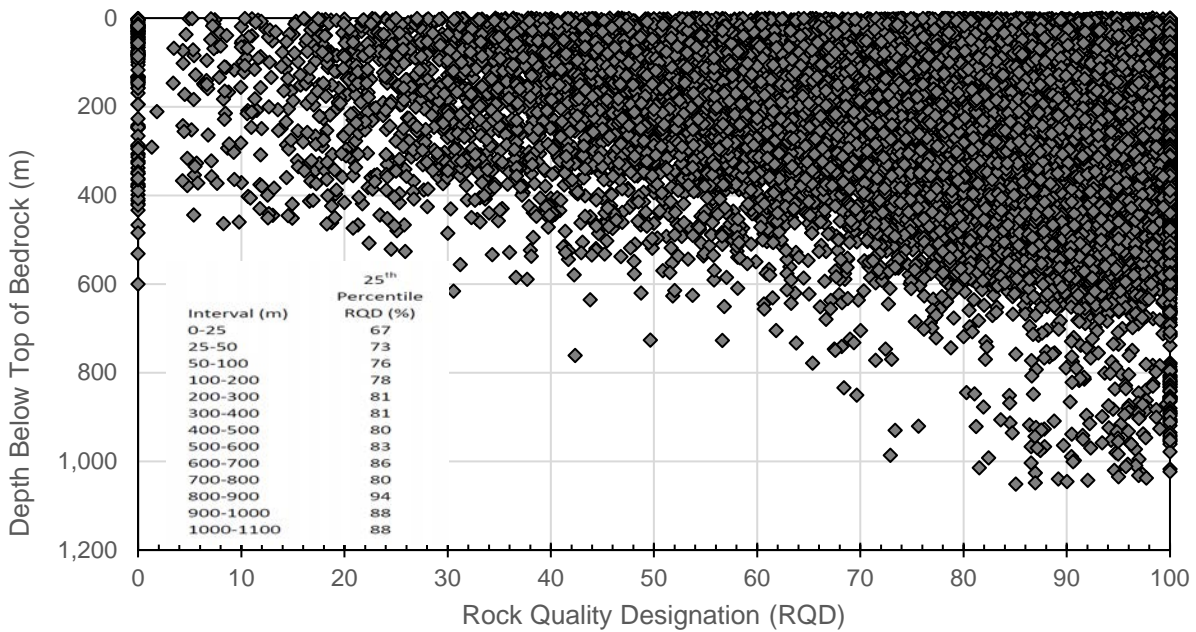
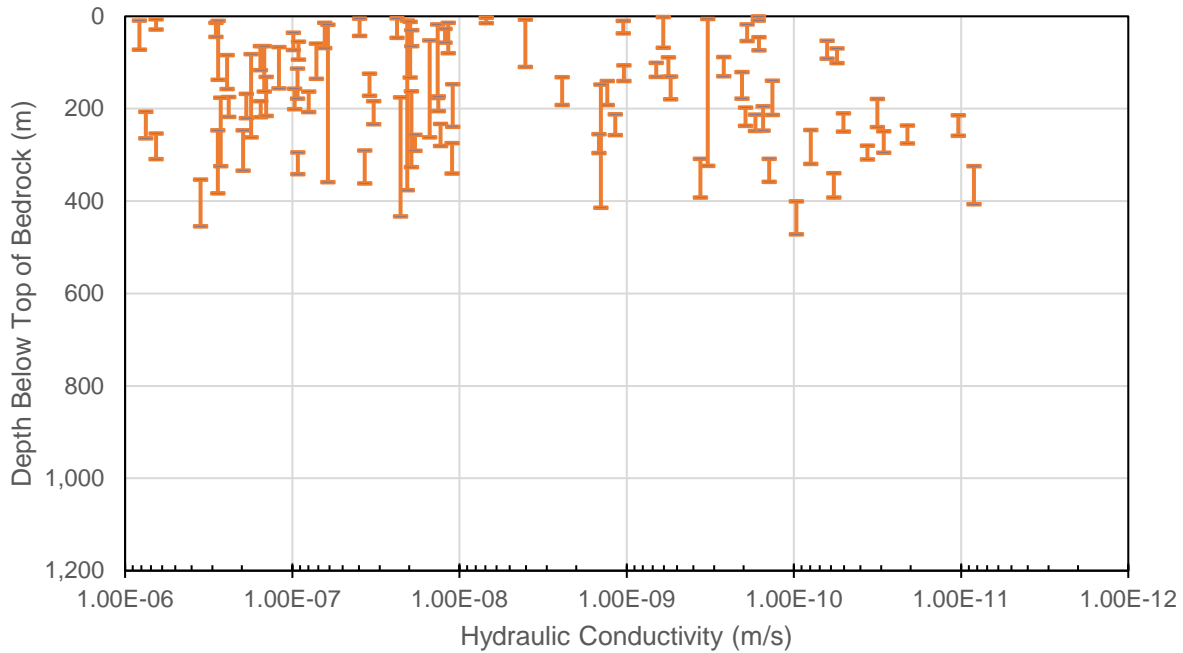
Project Location: Timmins, Ontario
 160930456 REVA
 Prepared by toghlan on 2024-09-10

Client/Project: Canada Nickel Company (CNC)
 Crawford Nickel Project

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Hydraulic Conductivity of Bedrock



Client/Project

Canada Nickel Company (CNC)
Crawford Nickel Project

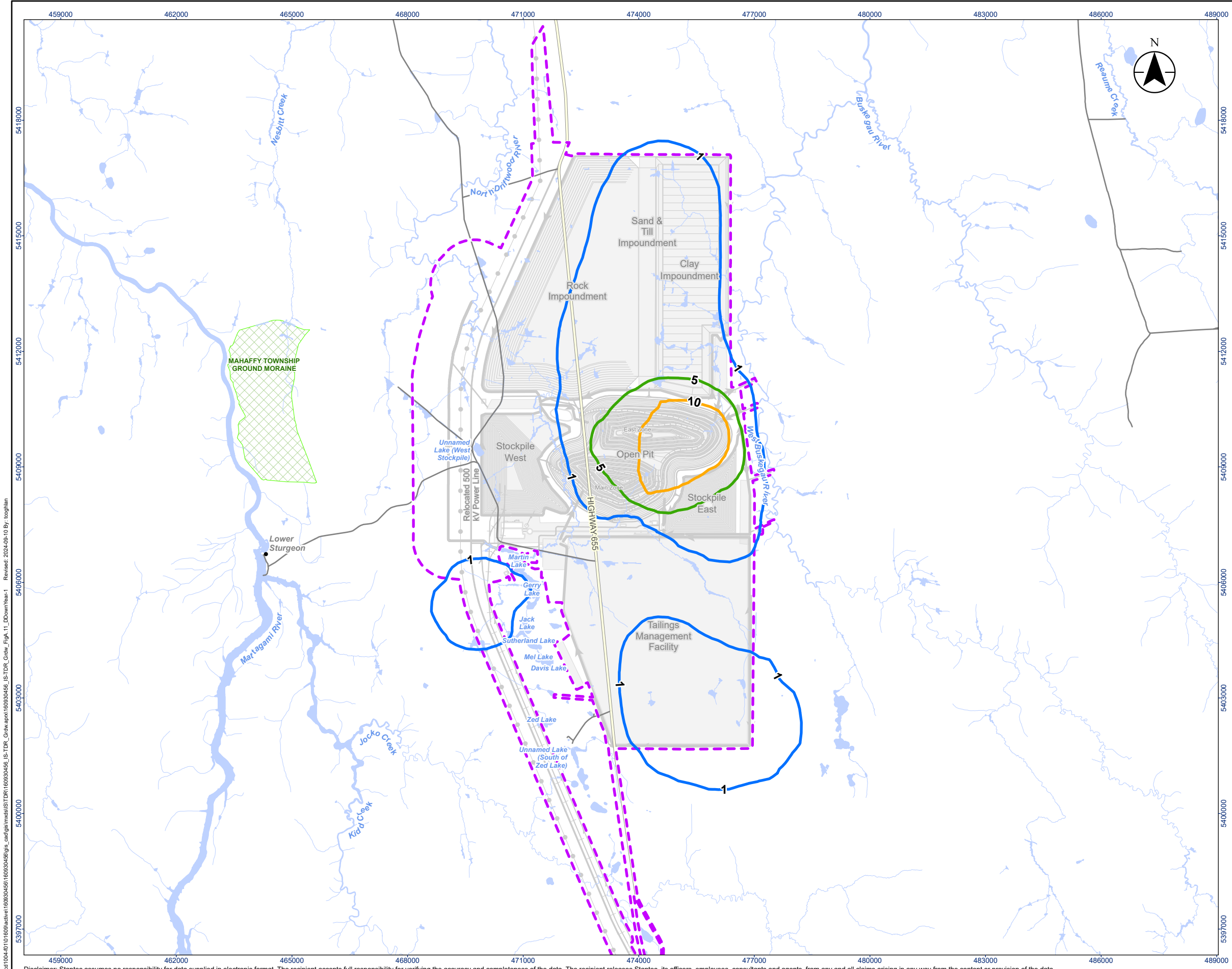
Figure No.

A.5






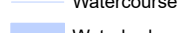
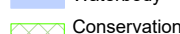
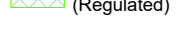
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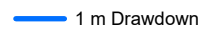
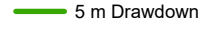
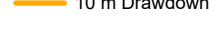
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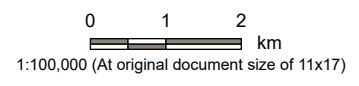


Legend

Project Area
 Project Area

Base Features
 Major Road
 Minor Road
 Watercourse
 Waterbody
 Conservation Reserve (Regulated)

Drawdown Contours
 1 m Drawdown
 5 m Drawdown
 10 m Drawdown



- Notes**
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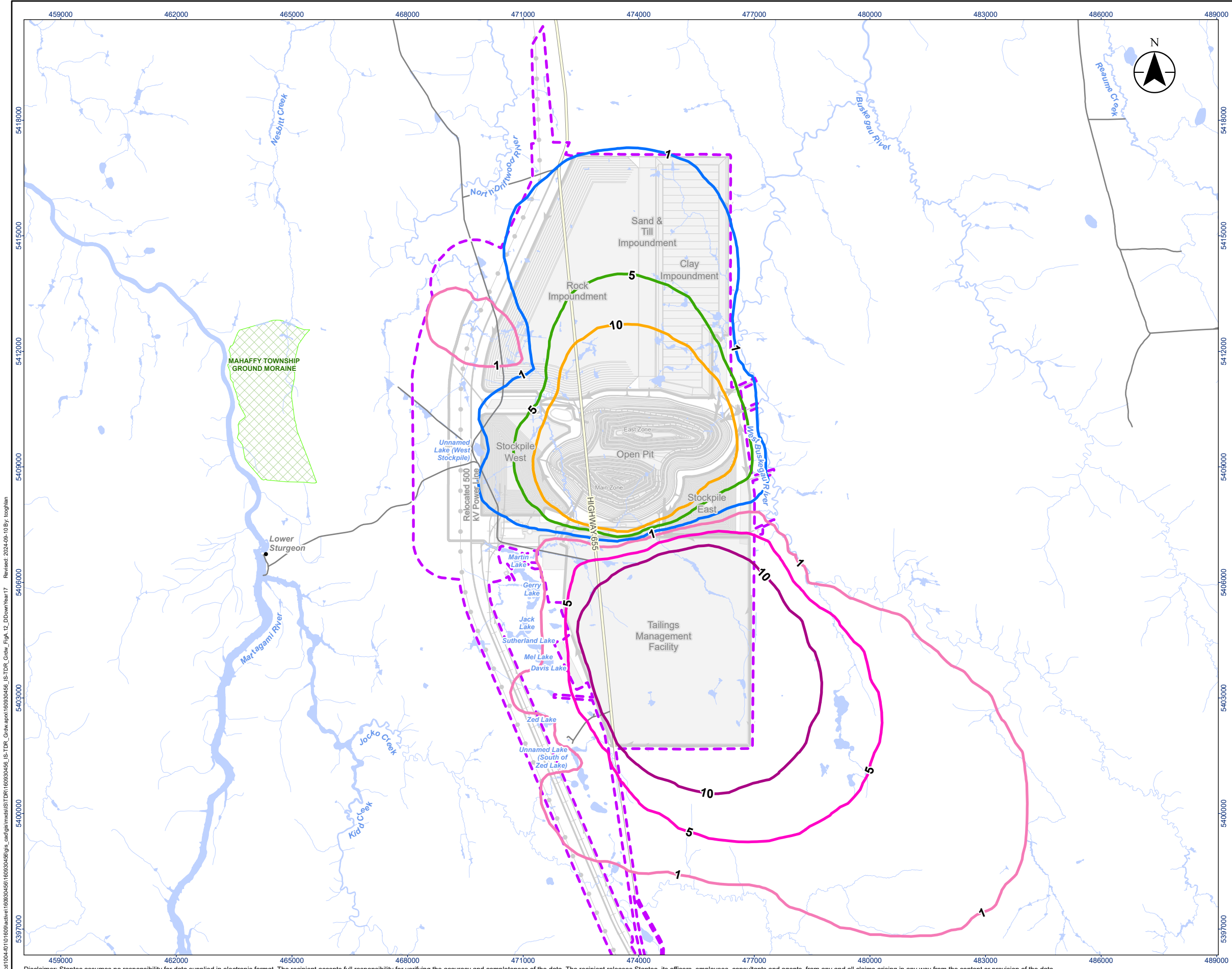
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 Prepared by toghlan on 2024-09-10

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 Canada Nickel Company (CNC)
 Crawford Nickel Project


Figure No.
A.11


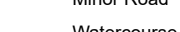

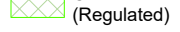

Title
Predicted Groundwater Table Drawdown - Operations Phase Year -1

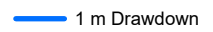
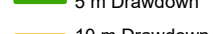

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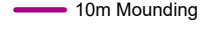



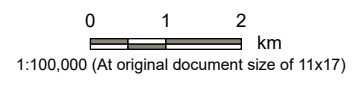
Legend

Project Area
 Project Area

Base Features
 Major Road
 Minor Road
 Watercourse
 Waterbody
 Conservation Reserve (Regulated)

Drawdown Contours
 1 m Drawdown
 5 m Drawdown
 10 m Drawdown

Mounding Contours
 1 m Mounding
 5 m Mounding
 10m Mounding



Notes
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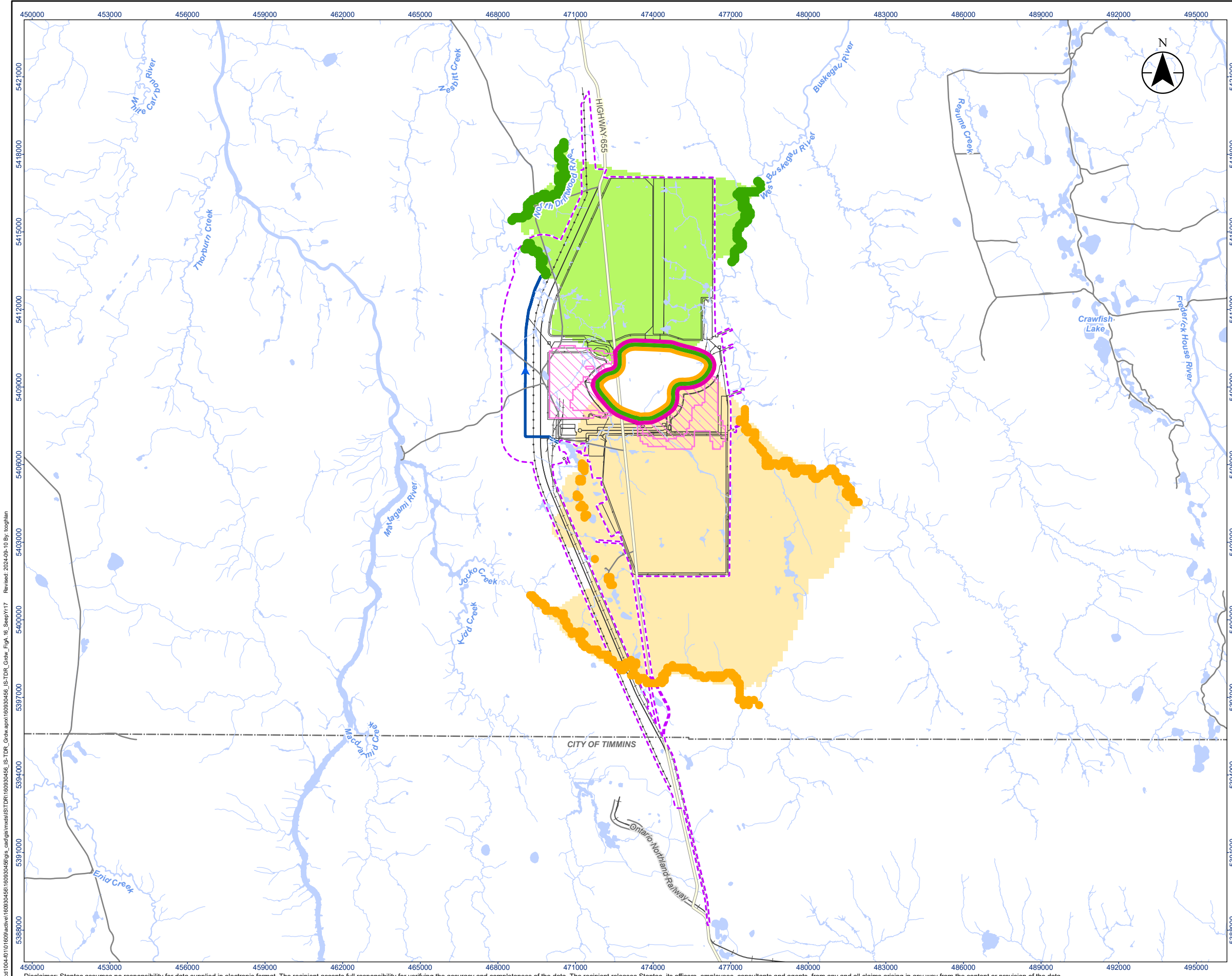


Project Location: Timmins, Ontario
 160930456 REVA
 Prepared by toghlan on 2024-09-10

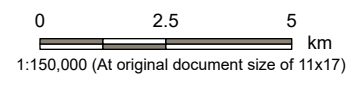
Client/Project: Canada Nickel Company (CNC)
 Crawford Nickel Project

Figure No.: **A.12**
 Title: **Predicted Groundwater Table Drawdown - Operations Phase Year 17**

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- Legend**
- Project Area
 - Base Features**
 - Major Road
 - Minor Road
 - Railway
 - Watercourse
 - Waterbody
 - Municipal Boundary - Lower Tier
 - North Driftwood Diversion Channel
 - Discharge of Seepage from TMF
 - Discharge of Seepage from Impoundment Facility
 - Discharge of Seepage from Stockpiles
 - Groundwater Seepage from TMF
 - Groundwater Seepage from Impoundment Facility
 - Groundwater Seepage from Stockpiles



Notes

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Project Location: Timmins, Ontario
 160930456 REVA
 Prepared by tooghlan on 2024-09-10

Client/Project: Canada Nickel Company (CNC)
 Crawford Nickel Project

Figure No. **A.16**
 Title **Fate of Seepage to Groundwater - Operations Phase Year 17**

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 Revised: 2024-09-10 By: tooghlan

Appendix B Water Quality Assessment Checklist

APPENDIX A | WATER QUALITY ASSESSMENT CHECKLIST

This checklist can be used to verify that the main components of a water assessment have been completed. It is helpful to include this checklist with the IS (or equivalent document) to show where the components of the water quality assessment are located in the document. This is especially helpful if the components are located in more than one section of the document.

OVERALL	
✓	Item
✓	1. Worked examples are included for calculations, if a quantitative risk assessment was completed.
✓	2. Units are clearly stated and consistent (or conversion calculations are included as appropriate).
✓	3. All potential human receptors, with particular attention, if applicable, to Indigenous peoples who use the land, are clearly identified and their potentially increased exposure to sources of water contamination is characterized
✓	4. Assumptions are clearly stated and justified (modelling of worst-case scenarios, etc.).
✓	5. Principles of minimizing impacts are considered (e.g., not polluting up to guidelines). This concept includes identifying mitigation measures to minimize increases in concentrations of contaminants as a result of project activities.
✓	6. Cumulative scenarios and effects are considered
✓	7. The water quality section (as required) of the follow-up program is described.

DRINKING WATER SOURCES

✓	Item	Section in IA
N/A	<p>8. All sources used for drinking water are identified in the IA study areas (project, local and regional) including:</p> <ul style="list-style-type: none"> <input checked="" type="checkbox"/> Source water intakes for DWTP(s) and/or sources from which water is consumed directly (e.g., wells) and their distance from the project; <input checked="" type="checkbox"/> Whether all sources of drinking water have been identified; <input checked="" type="checkbox"/> The responsibility/jurisdiction for DWTP(s) in the IA study area (municipal/provincial/territorial/federal). 	N/A
✓	<p>9. Information is included on whether there are predicted or measured changes to source water quality due to project activities (includes spills and accidents, where relevant).</p> <p>If yes, the following is included:</p>	Groundwater Assessment (Appendix C.4)
✓	<p>a. A comprehensive list (including quantitative information) of potential organic, inorganic and microbial contaminants, as well as their physical characteristics.</p>	
✓	<p>b. A comparison of predicted or measured changes in individual parameters to appropriate guidelines or standards.</p>	
N/A	<p>c. A conclusion with respect to the ability of DWTP(s) to address the predicted or measured changes in water quality.</p>	
N/A	<p>d. Information on how managers of DWTP(s) will be informed of any predicted or measured changes in source water quality.</p>	
N/A	<p>e. If the province or territory is responsible for managing the DWTP(s), confirmation from the appropriate authority of changes to the drinking water treatment protocol associated with predicted or measured changes to source water parameters.</p>	



PRIVATE WELLS		
✓	Item	Section in IA
✓	<p>10. Information is included on whether there are any private wells in the IA study area.</p> <p>If so, a discussion is included on whether any changes to the quality of the well water are likely due to project activities (including spills and accidents).</p>	Groundwater Assessment (Appendix C.4)
N/A	11. If changes to well water quality are predicted or measured as a result of project activities, the following is included:	
N/A	a. A comprehensive list (including quantitative information) of predicted organic, inorganic and microbial contaminants, as well as their physical characteristics.	
N/A	b. A comparison of individual parameters to appropriate guidelines or standards—for both the baseline case and predicted future concentrations during project construction, operation and decommissioning, and in the event of accidents/ malfunctions (as applicable).	
N/A	c. Details on how well owners will be notified of potential changes in water quality.	

RECREATIONAL WATER QUALITY

✓	Item	Section in IA
✓	12. All water bodies that are currently being used or may be used in the future for recreational purposes—and which may be affected by project activities—are identified, and a characterization of recreational activities in affected water bodies (swimming, canoeing, fishing, etc.) is included.	Social Conditions VC Chapter (Chapter 22)
✓	13. Information is included on whether there are predicted or measured changes to recreational water quality due to project activities (includes spills and accidents, where relevant). If so, the following is included:	Surface Water Resources Assessment (Appendix C.4)
✓	a. A comprehensive list (including quantitative information) of predicted or measured microbial, organic, and inorganic contaminants, as well as their physical characteristics.	
✓	b. A comparison of predicted or measured changes in individual parameters to appropriate guidelines or standards (provincial or territorial standards or the GCRWQ, which also apply on federal lands and First Nation reserves south of the 60 th parallel).	
✓	c. As the GCRWQ do not include guidelines for specific chemical parameters, in the case of chemical contamination, a comparison of predicted changes in individual parameters to appropriate guidelines or standards, as determined in consultation with the responsible authorities.	

NEED FOR AN HHRA

✓	Item	Section in IA
✓	14. Are there predicted exceedances of any provincial or territorial standards or federal guidelines after the application of mitigation measures? If so, it is suggested that an HHRA for the drinking or recreational water pathway be completed for contaminants.	Chapter 21 Assessment of Potential Effects on Health Appendix C.7 Human Health and Ecological Risk Assessment

Appendix C Grain Size Analysis

Table C-1
Grain Size Analysis
Crawford Nickel Project

Surface Water Feature	Date	Grain Size at which 10% is finer	Grain size at which 60% is finer	% passing .06mm sieve	Hazen Coefficient	Uniformity Index ¹	Porosity ²	Hydraulic Conductivity					
		(mm)	(mm)	%	(-)	(-)	(-)	(m/sec)					
		d ₁₀	d ₆₀	P ₂	C	C _u = d ₆₀ /d ₁₀	n=0.255(1+0.83 ^{C_u})	Hazen ³	Beyer ³	Kozeny-Carmen ³	Wang ³	Kaubisch ⁴	Geometric Mean
Gerry Lake	10/19/2022	0.01	0.05	65.8	-	5.2	0.35	N/A	N/A	N/A	N/A	N/A	N/A
Gerry Lake	10/19/2022	0.01	0.07	55.0	-	5.8	0.34	N/A	N/A	N/A	N/A	2.1E-09	2.1E-09
Gerry Lake	10/19/2022	0.01	0.05	65.9	-	5.3	0.35	N/A	N/A	N/A	N/A	N/A	N/A
Gerry Lake	10/27/2021	0.03	0.28	17.0	-	8.2	0.31	N/A	N/A	N/A	N/A	3.3E-06	3.3E-06
Gerry Lake	10/27/2021	0.07	0.29	9.1	-	4.4	0.37	N/A	1.0E-04	2.4E-05	4.6E-05	N/A	4.8E-05
Gerry Lake	10/27/2021	0.15	1.83	4.1	80	12.1	0.28	1.8E-04	4.1E-04	4.5E-05	1.2E-04	N/A	1.4E-04
Jack Lake	10/22/2022	0.07	0.14	9.2	-	2.1	0.43	N/A	1.2E-04	4.7E-05	8.2E-05	N/A	7.7E-05
Jack Lake	10/22/2022	0.03	0.12	18.8	-	4.3	0.37	N/A	N/A	4.6E-06	N/A	N/A	4.6E-06
Jack Lake	10/22/2022	0.02	0.24	31.2	-	10.3	0.29	N/A	N/A	1.2E-06	N/A	1.4E-07	4.2E-07
Martin Lake	10/19/2022	0.02	0.06	60.2	-	2.8	0.41	N/A	N/A	4.0E-06	N/A	N/A	4.0E-06
Martin Lake	10/19/2022	0.01	0.04	68.7	-	4.8	0.36	N/A	N/A	N/A	N/A	N/A	N/A
Martin Lake	10/19/2022	0.01	0.05	70.2	-	5.0	0.35	N/A	N/A	N/A	N/A	N/A	N/A
Martin Lake	10/27/2021	0.07	0.31	8.4	-	4.4	0.37	N/A	1.2E-04	2.8E-05	5.2E-05	N/A	5.6E-05
Martin Lake	10/27/2021	0.03	0.25	18.0	-	7.5	0.32	N/A	N/A	N/A	N/A	2.6E-06	2.6E-06
Martin Lake	10/27/2021	0.07	0.34	8.3	-	4.7	0.36	N/A	1.2E-04	2.7E-05	5.1E-05	N/A	5.5E-05
North Driftwood River	10/23/2021	0.06	0.28	10.6	-	4.9	0.36	N/A	N/A	N/A	3.5E-05	N/A	3.5E-05
North Driftwood River	10/23/2021	0.04	0.29	13.4	-	6.5	0.33	N/A	N/A	N/A	N/A	7.8E-06	7.8E-06
North Driftwood River	10/23/2021	0.04	0.27	14.5	-	6.6	0.33	N/A	N/A	N/A	N/A	5.9E-06	5.9E-06
North Driftwood River	10/20/2021	0.09	0.28	4.5	-	3.0	0.40	N/A	2.1E-04	6.7E-05	9.1E-05	N/A	1.1E-04
North Driftwood River	10/20/2021	0.10	0.28	2.9	-	2.8	0.40	N/A	2.4E-04	8.2E-05	1.1E-04	N/A	1.3E-04
North Driftwood River	10/20/2021	0.11	0.28	1.1	80	2.7	0.41	9.1E-05	2.9E-04	1.0E-04	1.2E-04	N/A	1.3E-04
North Driftwood River	10/26/2022	0.01	0.06	60.3	-	4.9	0.36	N/A	N/A	N/A	N/A	N/A	N/A
North Driftwood River	10/23/2022	0.03	0.10	31.5	-	3.7	0.38	N/A	N/A	5.2E-06	N/A	N/A	5.2E-06
North Driftwood River	10/23/2022	0.02	0.07	54.6	-	3.4	0.39	N/A	N/A	2.8E-06	N/A	N/A	2.8E-06
North Driftwood River	10/23/2022	0.02	0.06	56.8	-	3.3	0.39	N/A	N/A	2.7E-06	N/A	N/A	2.7E-06
North Driftwood River	10/23/2021	0.09	0.28	4.6	-	3.0	0.40	N/A	2.1E-04	6.7E-05	9.1E-05	N/A	1.1E-04
North Driftwood River	10/23/2021	0.07	0.27	8.5	-	3.9	0.38	N/A	1.2E-04	3.1E-05	5.4E-05	N/A	5.8E-05
North Driftwood River	10/23/2021	0.08	0.28	7.5	-	3.6	0.39	N/A	1.5E-04	4.2E-05	6.6E-05	N/A	7.4E-05
North Driftwood River	10/17/2022	0.04	0.34	27.7	-	9.6	0.30	N/A	N/A	3.0E-06	N/A	2.9E-07	9.4E-07
North Driftwood River	10/17/2022	0.03	0.15	39.3	-	4.7	0.36	N/A	N/A	4.9E-06	N/A	N/A	4.9E-06
North Driftwood River	10/17/2022	0.02	0.08	50.3	-	3.8	0.38	N/A	N/A	3.0E-06	N/A	N/A	3.0E-06
North Driftwood River	10/22/2021	0.10	0.35	4.7	-	3.6	0.38	N/A	2.2E-04	6.3E-05	8.9E-05	N/A	1.1E-04
North Driftwood River	10/22/2021	0.08	0.34	7.5	-	4.2	0.37	N/A	1.5E-04	3.7E-05	6.2E-05	N/A	7.0E-05
North Driftwood River	10/22/2021	0.10	0.38	4.2	80	3.7	0.38	8.3E-05	2.5E-04	6.9E-05	9.5E-05	N/A	1.1E-04
North Driftwood River	10/21/2021	0.09	1.13	6.4	-	12.2	0.28	N/A	1.6E-04	1.7E-05	5.1E-05	N/A	5.1E-05
North Driftwood River	10/21/2021	0.11	1.25	5.5	80	11.8	0.28	9.1E-05	2.1E-04	2.3E-05	6.5E-05	N/A	7.3E-05
North Driftwood River	10/21/2021	0.13	1.56	4.3	80	11.9	0.28	1.4E-04	3.2E-04	3.5E-05	9.3E-05	N/A	1.1E-04
Sutherland Lake	10/21/2022	0.04	0.15	17.2	-	4.1	0.37	N/A	N/A	7.7E-06	N/A	N/A	7.7E-06
Sutherland Lake	10/21/2022	0.04	0.16	14.1	-	3.8	0.38	N/A	N/A	1.2E-05	N/A	N/A	1.2E-05
Sutherland Lake	10/21/2022	0.07	0.16	1.4	-	2.1	0.43	N/A	1.5E-04	6.0E-05	9.3E-05	N/A	9.4E-05
North Driftwood Tributary	10/18/2022	0.02	0.07	52.4	-	4.7	0.36	N/A	N/A	N/A	N/A	N/A	N/A
North Driftwood Tributary	10/18/2022	0.02	0.09	50.3	-	4.8	0.36	N/A	N/A	1.6E-06	N/A	N/A	1.6E-06
North Driftwood Tributary	10/19/2021	0.04	0.32	15.5	-	8.3	0.31	N/A	N/A	N/A	N/A	4.7E-06	4.7E-06
North Driftwood Tributary	10/19/2021	0.34	0.35	10.6	80	1.0	0.47	9.2E-04	3.5E-03	1.8E-03	N/A	N/A	1.8E-03
North Driftwood Tributary	10/19/2021	0.07	0.33	9.1	-	5.01	0.36	N/A	9.7E-05	2.1E-05	4.3E-05	N/A	4.4E-05
West Buskegau River	10/26/2021	0.10	0.28	3.7	-	2.9	0.40	N/A	2.3E-04	7.6E-05	1.0E-04	N/A	1.2E-04
West Buskegau River	10/26/2021	0.05	0.26	12.9	-	5.6	0.34	N/A	N/A	9.1E-06	N/A	8.8E-06	9.0E-06
West Buskegau River	10/26/2021	0.10	0.28	2.5	80	2.8	0.41	8.0E-05	2.6E-04	8.7E-05	1.1E-04	N/A	1.2E-04
West Buskegau River	10/24/2022	0.01	0.05	73.3	-	4.0	0.38	N/A	N/A	N/A	N/A	N/A	N/A

Table C-1
Grain Size Analysis
Crawford Nickel Project

Surface Water Feature	Date	Grain Size at which 10% is finer	Grain size at which 60% is finer	% passing .06mm sieve	Hazen Coefficient	Uniformity Index ¹	Porosity ²	Hydraulic Conductivity					
		(mm)	(mm)	%	(-)	(-)	(-)	(m/sec)					
		d ₁₀	d ₆₀	P ₂	C	C _u = d ₆₀ /d ₁₀	n=0.255(1+0.83 ^{C_u})	Hazen ³	Beyer ³	Kozeny-Carmen ³	Wang ³	Kaibisch ⁴	Geometric Mean
West Buskegau River	10/24/2022	0.01	0.05	68.3	-	4.3	0.37	N/A	N/A	N/A	N/A	N/A	N/A
West Buskegau River	10/24/2022	0.01	0.05	72.2	-	4.7	0.36	N/A	N/A	N/A	N/A	N/A	N/A
West Buskegau River	10/24/2022	0.03	0.10	38.0	-	3.4	0.39	N/A	N/A	5.6E-06	N/A	N/A	5.6E-06
West Buskegau River	10/24/2022	0.01	0.05	81.6	-	4.7	0.36	N/A	N/A	N/A	N/A	N/A	N/A
West Buskegau River	10/24/2022	0.02	0.06	58.5	-	3.2	0.40	N/A	N/A	2.8E-06	N/A	N/A	2.8E-06
West Buskegau River	10/25/2021	0.08	0.96	7.7	-	12.3	0.28	N/A	1.1E-04	1.2E-05	3.8E-05	N/A	3.7E-05
West Buskegau River	10/25/2021	0.18	4.29	5.2	80	23.8	0.26	2.6E-04	4.9E-04	4.6E-05	N/A	N/A	1.8E-04
West Buskegau River	10/25/2021	0.05	1.32	11.7	-	25.6	0.26	N/A	N/A	N/A	N/A	1.2E-05	1.2E-05
West Buskegau River	10/24/2021	0.05	1.31	11.5	-	24.9	0.26	N/A	N/A	N/A	N/A	1.3E-05	1.3E-05
West Buskegau River	10/24/2021	0.04	0.69	14.7	-	16.6	0.27	N/A	N/A	N/A	N/A	5.7E-06	5.7E-06
West Buskegau River	10/25/2021	0.07	1.77	8.6	-	25.5	0.26	N/A	7.1E-05	6.8E-06	N/A	N/A	2.2E-05
West Buskegau River	10/24/2021	0.30	1.96	1.9	80	6.6	0.33	7.1E-04	1.9E-03	3.2E-04	4.5E-04	N/A	6.7E-04
West Buskegau River	10/24/2021	0.21	1.65	4.6	80	8.0	0.31	3.4E-04	8.7E-04	1.3E-04	2.3E-04	N/A	3.0E-04
West Buskegau River	10/24/2021	0.27	2.63	4.2	80	9.7	0.30	5.9E-04	1.4E-03	1.8E-04	3.4E-04	N/A	4.7E-04

N/A The formula is not appropriate to use for grain size distribution of the sample

Hazen Formula:

$$K = C d_{10}^2$$

Where:

- K Hydraulic conductivity (cm/sec)
- d₁₀ Grain size at which 10% is finer (cm)
- C Coefficient as follows:

Very fine sand, poorly sorted	40-80
Fine sand with appreciable fines	40-80
Medium sand, well sorted	80-120
Coarse sand, poorly sorted	80-120
Coarse sand, well sorted	120-150

Applicability: where 0.1 < d₁₀ < 3.0 mm

Beyer Formula:

$$K = 6 \times 10^{-4} \frac{g}{v} \ln \left(\frac{500}{C_u} \right) d_{10}^2$$

Where:

- K Hydraulic conductivity (m/sec)
- g Gravitational acceleration (9.8 m/s²)
- v Kinematic viscosity of water (1.2 x 10⁻⁶ m²/s)
- d₁₀ Grain size at which 10% is finer (m)

Applicability: where 0.06 < d₁₀ < 0.6 mm AND C_u <= 20

Kozeny-Carmen Formula:

$$K = \frac{1}{180} \frac{g}{v} \left(\frac{n^3}{(1-n)^2} \right) d_{10}^2$$

Where:

- K Hydraulic conductivity (m/sec)
- g Gravitational acceleration (9.8 m/s²)
- v Kinematic viscosity of water (1.2 x 10⁻⁶ m²/s)
- d₁₀ Grain size at which 10% is finer (m)

Applicability: silt, sand, gravelly sand

Wang Et Al. Formula:

$$K = 2.9 \times 10^{-3} \frac{g}{v} \left(\log \frac{g d_{60}^3}{v^2} \right)^{-1} d_{10}^2$$

Where:

- K Hydraulic conductivity (m/sec)
- g Gravitational acceleration (9.8 m/s²)
- v Kinematic viscosity of water (1.2 x 10⁻⁶ m²/s)
- d₁₀ Grain size at which 10% is finer (m)
- d₆₀ Grain size at which 60% is finer (m)

Applicability: where 0.05 < d₁₀ < 0.83 mm, 0.09 < d₆₀ < 4.29 mm, AND 1.3 < C_u < 18.3%

Kaibisch Formula:

$$K = 10^{0.0005 P_2^2 - 0.12 P_2 - 3.59}$$

Where:

- K Hydraulic conductivity (m/sec)
- P₂ percent passing .06mm sieve

Applicability: where 5 < C_u < 400 AND 10% < P₂ > 60%

¹ Craig, R.F. 1992. "Soil Mechanics, Fifth Edition". Chapman and Hill.

² Vukovic, M., and Soro, A. 1992. "Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition"

³ Duffield, G.M. "Representative Values of Hydraulic Properties" http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm

⁴ Cai, Jialiang, Taute, Thomas, Hamann, Enrico, and Schneider, Michael. 2013. "An Integrated Laboratory Method to Measure and Verify Directional Hydraulic conductivity in Fine-to-Medium Sandy Sediments". Groundwater.