Environmental and Social Impact Assessment for the Troilus Mine Project

GROUNDWATER QUALITY

LIST OF TABLES

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Acronyms and abbreviations

Ag	Silver
AMD	Acid Mine Drainage
Al	Aluminum
As	Arsenic
B	Boron
Ba	Barium
Be	Beryllium
Bi	Bismuth
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CCME	Canadian Council of Ministers of the Environment
Cd	Cadmium
Co	Cobalt
CPC	Quality criteria for the prevention of contamination of aquatic organisms
CPTF	Quality criteria for the protection of fish-eating terrestrial fauna
Cr	Chromium
Cu	Copper
AAC	Quality criterion for the protection of aquatic life - acute impact
CAC	Quality criterion for the protection of aquatic life - chronic impact
DRASTIC	D (Static water depth), R (Aquifer recharge), A (Aquifer), S (Soil), T (Terrain), I (Impact of vadose zone), C (Hydraulic conductivity (m/d))
DW	Drinking water
ESIA	Environmental and Social Impact Assessment
Fe	Iron
GCC	Grand Council of the Crees
Hg	Mercury
IAA	Impact Assessment Act
JBNQA	James Bay and Northern Quebec Agreement
K	Potassium
LSA	Local Study Area
Li	Lithium
LPRR	Land Protection and Rehabilitation Regulation
LQE	Environmental Quality Act
MELCCFP	Ministry of the Environment, the Fight against Climate Change, Wildlife and Parks
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
MW	Monitoring Well
Na	Sodium
Ni	Nickel
NBC	Natural background content
NQIA	Northern Quebec Inuit Association
OD	Dissolved Oxygen
ORP	Oxidation-Reduction Potential
PAHS	Polycyclic aromatic hydrocarbons
Pb	Lead
PDA	Project Development Area
PH	Petroleum hydrocarbons
PZ	Piezometer
RSA	Regional Study Area
REAFIE	Regulation respecting the supervision of activities in relation to their impact on the environment
MDMER	Metal and Diamond Mining Effluent Regulation
RSW	Resurgence in Surface Water
Sb	Antimony
Se	Selenium
Si	Silicon
Sn	Tin
Sr	Strontium
SRA	Species at Risk Act
Te	Tellurium
Th	Thorium
Ti	Titanium
Tl	Thallium
U	Uranium
V	Vanadium
VC	Valued Component
Zn	Zinc

14. Groundwater Quality

14.1 Scope of Assessment

14.1.1 Regulatory and Policy Setting

Troilus Gold (Troilus) Troilus mining project is located in the Eeyou Istchee James Bay territory in Northern Quebec. As such, it is governed by the James Bay and Northern Quebec Agreement (JBNQA), signed in 1975 between the governments of Canada and Quebec, the Grand Council of the Crees (GCC) and the Northern Quebec Inuit Association (NQIA).

Among other things, the JBNQA divides the territory into Category I, II and III lands. Category I lands are reserved for the exclusive use of the Crees, while Category II lands, contiguous to Category I lands, are part of the Québec public domain, where the Crees have exclusive hunting, fishing and trapping rights.

The Troilus mining project site lies within the territory of the Regional Government of Eeyou Istchee James Bay. More specifically, the site is located on the territory of the Cree community of Mistissini, on Category III lands. According to the JBNQA, Category III lands are public lands that are part of the domain of the State. On Category III lands, First Nations have the right to hunt, fish and trap, without permit, without bag limits and at any time, subject to the principle of conservation (COMEX, 2022). Mining rights on these Category III lands belong to the provincial government. However, given the interactions of the site's groundwater with surface water under federal jurisdiction, the design and construction of the project will also have to comply with applicable federal regulations.

Legislation applicable to groundwater includes the following acts, regulations, policies and guidelines.

14.1.1.1 Provincial Regulatory Context

Environmental Quality Act

The Environmental Quality Act (LQE) requires mining projects to obtain authorizations in compliance with regulations. The main regulations and policies applicable to the groundwater component of the Troilus project are as follows:

- Water Withdrawal and Protection Regulation;
- Regulation respecting the quality of drinking water;
- Land Protection and Rehabilitation Regulation;
- Soil protection and contaminated land rehabilitation policy;
- Groundwater Catchment Regulation;
- Regulation respecting industrial depollution attestations.

Directive 019 on the mining industry

Under this directive, the Regulation respecting the regulation of activities based on their impact on the environment (REAFIE) specifies the activities subject to ministerial authorization, as well as the information and documents required for such an application. Depending on the case, this may include a groundwater monitoring program, a hydrogeological study or a detailed groundwater environmental monitoring program. Note that a new version of Directive 019 (MDDEP, 2012) was published on February 13, 2025, but it does not apply to this project due to the assessment process already underway.

14.1.1.2 Federal Regulatory Context

At the federal level, the Troilus project is subject to the Impact Assessment Act (IAA), given that anticipated ore production exceeds 5,000 t/d (Designated Concrete Activities Regulations (SOR/2019-285).

The project is also subject to the Metal and Diamond Mining Effluent Regulations (MDMER) under the Fisheries Act, which governs the discharge of mining effluent into natural waters. In terms of hydrogeology, this regulation imposes strict standards for the quality of surface and groundwater that may be affected by mining activities and may require authorization for tailings deposition or effluent discharge into water bodies.

Furthermore, any potential alteration of groundwater or surface water impacting aquatic habitats is also covered by section 35 of the Fisheries Act, which prohibits the harmful alteration, disruption or destruction of fish habitat without authorization.

Finally, should critical habitats of protected aquatic species be identified, the Species at Risk Act (SRA) could impose additional protection measures.

14.1.1.3 Regional Regulatory Context

A Certificate of Non-Compliance is required by the regional government of Eeyou Istchee James Bay for the development of a groundwater well. This permit authorizes the withdrawal of groundwater or surface water and is required for any project that plans to draw water above certain thresholds. It is essential for a mine project, since water is required for various activities such as drainage, ore processing and domestic uses related to temporary installations. No water catchment facility can be legally built or operated without this permit, which must be obtained before work begins. The form requires a precise description of the intake structure, the anticipated water volumes, pumping methods and potential environmental impacts. This permit is often part of a broader environmental assessment for a mining project and may include strict conditions for the protection of water and wildlife.

14.1.2 Influence of Consultation and Engagement

Table 14.1 presents a summary of key information, Indigenous knowledge and concerns for the groundwater quality project based on the various consultations carried out as part of the environmental and social impact assessment (ESIA).

Table 14.1 Summary of key information, Indigenous knowledge and concerns for the project related to groundwater quality

Theme	Key information, Indigenous knowledge and concerns	Influence on the Assessment	Where information is addressed in the ESIA
Preservation of groundwater resources	Concerns shared by Cree First Nations and land users to secure drinking water supplies and monitor drinking water quality for local users	Relocation of camps located within the project footprint outside the project's radius of influence on groundwater.	Chapter 14

14.1.3 Potential Impacts, Pathways and Measurable Parameters

The assessment of the project's potential impacts on groundwater quality was carried out considering concerns raised by stakeholders, including local communities, Cree communities and regulatory agencies. These concerns relate primarily to the preservation of groundwater quality for domestic and ecological uses.

Mining operations, through pumping, dewatering, tailings storage and the use of chemicals, are a major factor likely to alter groundwater quality. The impact pathways identified include the mobilization of natural contaminants (such as heavy metals), infiltration of substances from mining activities (process water, leachates, hydrocarbons), and changes to the hydrogeological regime that can promote the migration of pollutants into aquifers.

The activities described in the previous paragraph may lead to contamination of groundwater, compromising its use for drinking water and the preservation of associated ecosystems. These impacts could disproportionately affect certain populations, in particular Cree community users who depend on these resources.

The risk of groundwater acidification associated with acid mine drainage (AMD), through the oxidation of sulphide minerals exposed to air and water, and the infiltration of acidic water from stockpiles or pits, can be removed from the risk analysis for this large-scale project. This decision is based on a number of technical elements, including geochemistry, presented in Chapter 5.2.3.

To quantify potential impacts, several measurable parameters have been selected, such as metal concentrations (arsenic, lead, cadmium, etc.), electrical conductivity, pH, nitrate and hydrocarbon concentrations, and the presence of contamination indicator bacteria. These indicators make it possible to objectively assess changes in groundwater quality and verify compliance with existing environmental and health standards.

Table 14.2 summarizes the potential impacts identified on groundwater quality, linking them to the various project phases (construction, operation, closure) and to the environmental monitoring parameters selected. These analyses will guide the implementation of appropriate mitigation and monitoring measures to minimize the risk of contamination and ensure responsible management of the resource.

Table 14.2 Potential impacts, impact pathways and measurable parameters for groundwater quality

Potential Impacts	Impact Pathways	Measurable Parameters and Unit of Measurement	Project Phase Concerned
Metal contamination	Mobilization of metals naturally present in rock during excavation and dewatering. Infiltration of contact water from piles or waste rock.	Concentration of arsenic, lead, cadmium, etc. (mg/l) Electrical conductivity (µS/cm) pH	Construction, operation and closure
Hydrocarbon contamination	Accidental leaks or spills of fuels, oils and lubricants. Infiltration through unprotected soils.	Total hydrocarbon concentration (mg/l) Odor/film visible in piezometers (m)	Construction, operation and closure
Nutrient or nitrate enrichment	Use of nitrate-based explosives and infiltration into aquifers. Discharge of partially treated wastewater.	Nitrate concentration (NO_3-) (mg/l) Electrical conductivity (µS/cm)	Construction and operation

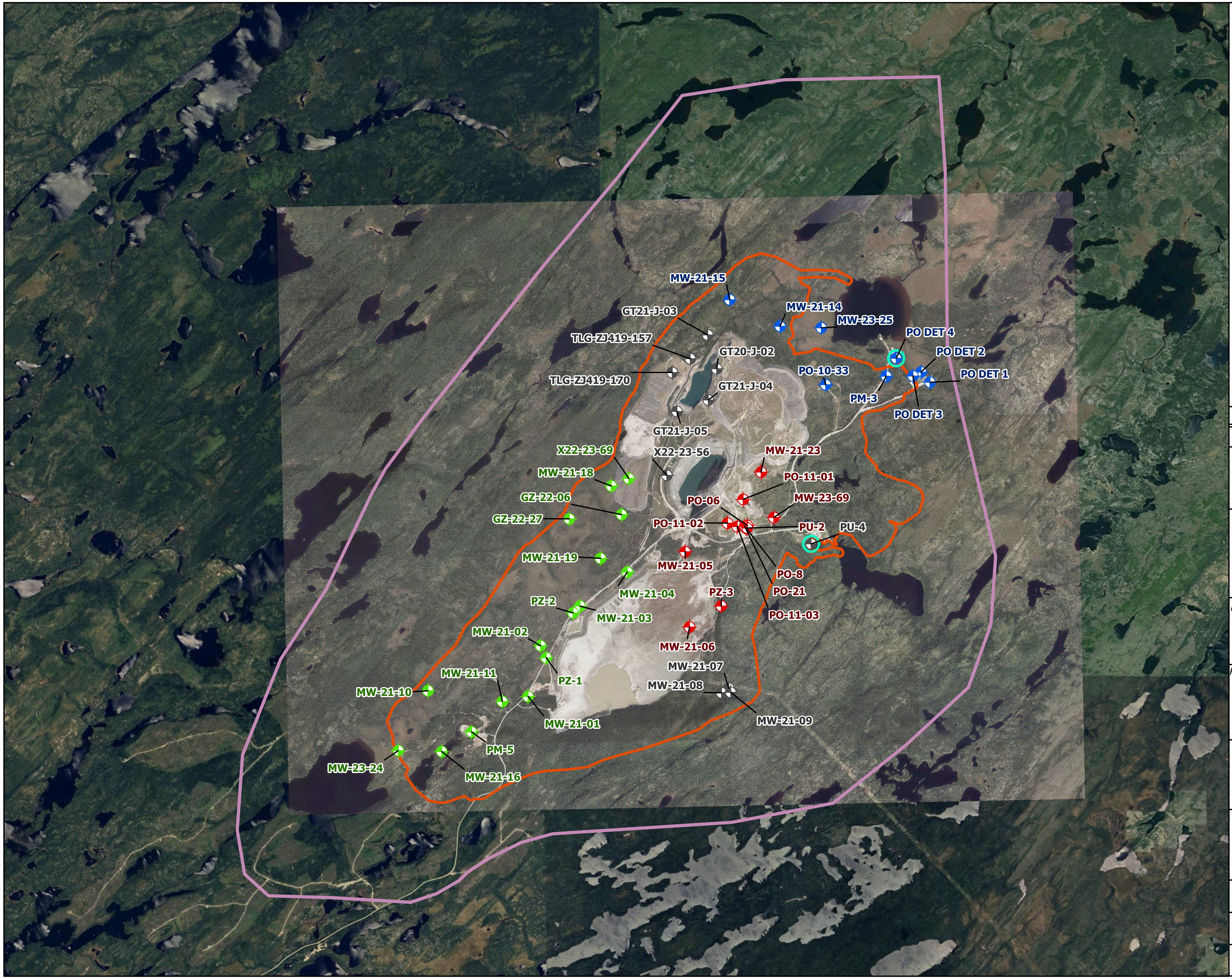
14.1.4 Boundaries

14.1.1.4 Spatial Boundaries

The study areas correspond to the spatial framework, to which are associated the sources of potential impacts on the groundwater quality of the receiving environment, as well as the assessment of project impacts. It comprises the Project Development Area (PDA), the Local Study Area (LSA) and the Regional Study Area (RSA). The PDA is defined for the entire project, and corresponds to the direct right-of-way of the planned infrastructure and mining activities. For groundwater quality, the LSA has been defined (Map 14.1) on the basis of the extent of the expected drawdown cone, i.e. the area in which groundwater pumping and drainage associated with mining activities could lead to a measurable drop in water table levels. This approach makes it possible to include areas where direct and indirect impacts on groundwater availability can be assessed with a sufficient degree of confidence, while considering the concerns of local stakeholders, notably Cree land users dependent on this resource.

The RSA was determined (Map 14.2) in conjunction with that used for the surface water assessment. This integrated approach ensures a consistent analysis of interactions between groundwater and watercourses, particularly in areas where aquifers feed wetlands and river systems.

The RSA also provides the framework for assessing cumulative impacts, taking into account past, present and foreseeable projects that may influence groundwater resources on a broader scale. Its scope has been defined to encompass areas where hydrogeological changes could have significant consequences for water uses, without diluting the analysis of project-specific impacts.



LÉGENDE / LEGEND

- Zone de développement du projet / Project development area
- Zone d'étude locale / Local Study Area
- Puits d'observation en amont de la zone minière / Monitoring Wells upstream of active mine area
- Puits d'observation dans la zone minière / Monitoring Wells within the active mine area
- Puits d'observation en aval de la zone minière / Monitoring Wells downstream of acitve mine area
- Autres puits d'observation / Other Monitoring Wells
- Puits d'eau potable / Potable Water Well

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RÉFÉRENCES/REFERENCES

Infrastructure proposées: 167040485_PublicationDonnes_Infrastructures_Poly, Stantec, 25 Janvier 2024
Carte de base: Bing 06 Juin 2023

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CLIENT

Troilus Gold Corp.

PROJET/PROJECT

Étude d'impact sur l'environnement et le milieu social pour le projet de mine Troilus / Environmental and Social Impact Assessement for the Troilus Mine Project

TITRE/TITLE

Zone d'étude locale et puits de suivis / Local Study Area and Monitoring Wells

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DESSINÉ / DRAWN M. Baker	Figure No. 14.1 — ED./REV. 1

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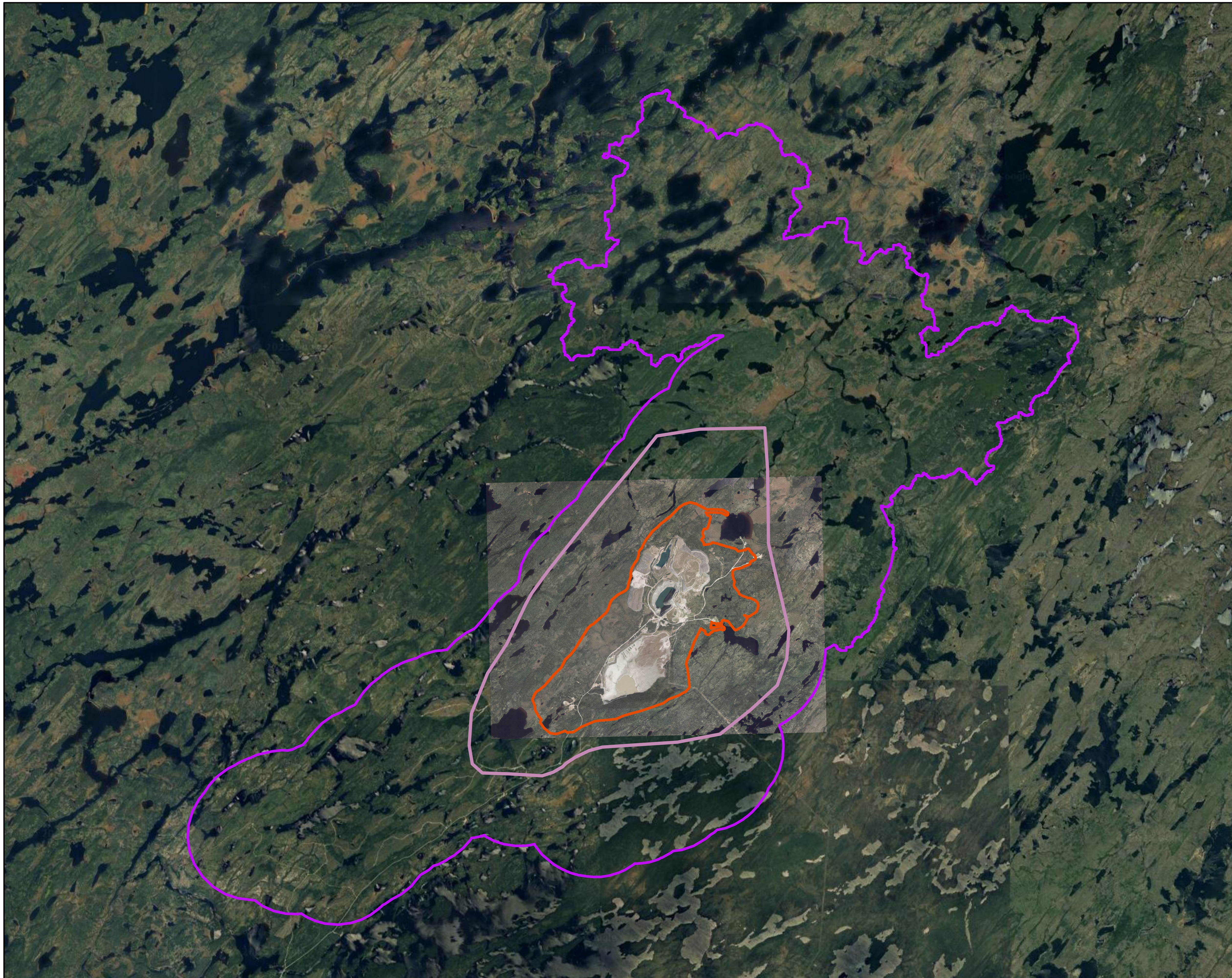

LÉGENDE / LEGEND

- Zone de développement du projet / Project development area
- Zone d'étude locale / Local Study Area
- Zone d'étude régionale / Regional Study Area

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RÉFÉRENCES/REFERENCES

ZDP, ZEL, ZER: BluMetric, 2025
Base Map: Bing, 06 June 2023

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CLIENT

Troilus Gold Corp.

PROJET/PROJECT

Étude d'impact sur l'environnement et le milieu social pour le projet de mine Troilus / Environmental and Social Impact Assessment for the Troilus Mine Project

TITRE/TITLE

Zone d'étude régionale / Regional Study Area

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14.1.1.5 Temporal Boundaries

The temporal boundary of the assessment includes all project phases from the start of construction through to the end of closure. Based on the current Project schedule, the project phases include:

- Construction (Year -3 to Year -1)
- Operations
  - Operations phase 1 (Year 1 to Year 21): milling with ore extraction
  - Operations phase 2 (Year 22): milling with no ore extraction
- Decommissioning and closure
  - Active closure (Year 22 to Year 24)
  - Passive closure (Year 24+)

Refer to Chapter 3 of the ESIA (Project Description) for a detailed description of the activities anticipated to occur during each phase.

14.1.5 Residual Impacts Characterization

Table 14.3 presents the characterization of residual impacts on groundwater quality.

Table 114.3 Characterization of residual impacts on groundwater quality

Characterization	Description	Quantitative Measure or Definition of Qualitative categories
Direction	The long-term trend of the residual impact	**Positive** - a residual impact that causes measurable parameters to evolve in a favorable direction for the VC relative to the baseline. **Adverse** - a residual impact that causes measurable parameters to evolve in an unfavorable direction for the VC in relation to the baseline. **Neutral** - no net change in measurable parameters for the VC compared with the baseline.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No measurable change** - no measurable change in impact can be observed. **Low** - a measurable change, but applicable quality criteria will not be exceeded **Moderate** - a measurable change, but applicable quality criteria may be exceeded. **High** - a measurable change, but applicable quality criteria will be exceeded.

Characterization	Description	Quantitative Measure or Definition of Qualitative categories
Geographic extent	The geographic area in which a residual impact occurs	**PDA** - residual impacts are limited to the PDA **LSA** - residual impacts extend to the LSA **RSA** - residual impacts extend to the RSA
Timing	Considers when the residual impact is expected to occur, where relevant to the VC.	**No sensitivity** - The impact does not occur during a critical life stage (e.g., outside fish spawning or elk calving periods, or periods of cultural activity), or the timing chosen does not affect the VC. **Moderate sensitivity** - The impact may occur during an insensitive period of a critical life stage. For many species, this is the beginning (e.g. several days before nesting for birds) or the end (e.g. periods when birds have fledged, but remain close to their nests) of the critical period. **High sensitivity** - Impact occurs at a critical life stage (e.g. fish spawning or bird nesting period) or during culturally significant activities (e.g. plant harvesting or holiday season).
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual impact can no longer be measured or otherwise perceived	**Short term** - the residual impact is limited to the duration of the construction phase (<3 years). **Medium-term** - residual impact extends to the end of life of the project (25 years) **Long term** - residual impact extends beyond the life of the project (>25 years)
Frequency	Identifies the frequency of the residual impact and its occurrence over the course of the project or a specific phase.	**Single event** **Multiple irregular event** - occurs at irregular intervals **Multiple regular event** - occurs at regular intervals **Continuous** - occurs continuously
Reversibility	This refers to whether a measurable parameter or VC can return to its initial state after project activity has ceased.	**Reversible** - the residual impact is likely to be reversed after completion of the activity and reclamation. **Irreversible** - the residual impact is unlikely to be reversed.

14.1.6 Significance Definition

The significance of residual impacts is determined by the following thresholds:

- **Negligible or low**: Impacts on groundwater quality are considered negligible or low when they result in a minimal, localized, infrequent and short-term variation in physico-chemical parameters (pH, metals, contaminants, etc.), without exceeding regulatory thresholds or natural background concentrations. Changes are reversible, with no significant impact on human or ecosystem uses. Mitigation measures are effective in maintaining water quality close to reference conditions.
- **Moderate :** A moderate impact results in measurable but partially reversible alteration of groundwater quality, with occasional exceedances of water quality thresholds in certain areas or at certain times. This may temporarily affect the use of certain wells, or result in limited degradation of quality for dependent ecosystems. The impact remains geographically limited, but requires increased monitoring and corrective measures to limit its scope. Sensitive users may perceive a drop in quality, but without compromising their safety.
- **High:** Impacts are considered high when contamination is significant, persistent or irreversible, far exceeding groundwater quality standards, with high concentrations of pollutants (heavy metals, hydrocarbons, nitrates, etc.). The impact is widespread in space and time, difficult to mitigate, and compromises domestic uses, particularly for Cree communities. Water quality becomes inadequate for vulnerable ecosystems, and mitigation or restoration measures are complex, uncertain or costly.

14.2 Existing Conditions

14.2.1 Methods

The description of pre-development groundwater quality conditions, i.e. prior to mine construction in 1996, is based on the hydrological and hydrogeological study carried out by Geocon (1993) as part of the original Troilus Mine project.

The description of existing groundwater quality conditions at the site is based on data from the biannual (summer and fall) monitoring of environmental groundwater quality carried out by Troilus between 2018 and 2022 (Troilus database), and then by WSP in 2022 and 2023 (WSP 2024a and WSP 2024b). These data include groundwater chemistry results and piezometric level measurements from 35 observation wells installed at the Troilus mine site (in and around the pit areas). The locations of these wells are shown on Map 14.1.

The parameters analyzed are as follows, including those recommended by Directive 019 (MDDEP, 2012):

- Anions: bromides, chlorides, fluorides and sulfates;
- Nitrogen compounds: ammoniacal nitrogen, total nitrogen, nitrates and nitrites;
- Cyanide compounds: cyanates, cyanides and thiocyanates;
- Inorganic compounds: total phosphorus, sulfides, total solids, suspended solids, orthophosphates, alkalinity, total hardness;

- Thiosulfates;
- PH (petroleum hydrocarbons) C_{10}-C_{50};
- PAH (polycyclic aromatic hydrocarbons);
- BTEX (benzene, toluene, ethylbenzene, xylenes);
- Total and dissolved metals (Al, Sb, Ag, As, Ba, Be, Bi, B, Cd, Cr, Cr III, Cr VI, Co, Cu, Sn, Fe, Li, Mg, Mn, Hg, Mo, Ni, Pb, K, Se, Si, Na, Sr, Te, Tl, Th, Ti, U, V, Zn);
- Radionuclides;
- Physico-chemical parameters, measured in situ and in the laboratory (pH, ORP (oxidation-reduction potential), turbidity, DO (dissolved oxygen)).

14.2.1.1 Groundwater Quality Criteria

The MELCCFP potability criteria of 1983 and 1985, and the Canadian Water Quality Guidelines of the Canadian Council of Ministers of the Environment (CCME) were used to determine groundwater quality during the pre-project phase (Entraco, 1991 in Geocon, 1993).

Under existing conditions, and considering that groundwater at the study site has as potential receptors surface water and drinking water supply wells (for the needs of the mine), the following criteria have been retained for the evaluation of groundwater analytical results:

- MELCCFP (2021) Resurgence in Surface Water Criteria (RSW[1]) for environmental monitoring wells;
- Criteria in Appendix V of the Regulation respecting the protection and rehabilitation of lands (RPRL) for environmental monitoring wells;
- Drinking water (DW) criteria (MELCCFP, 2021) for drinking water supply wells.

Certain metal criteria were adjusted based on the hardness measured in Lake A (PE43), which is considered the site's groundwater receiving environment.

The MELCCFP has also established alert thresholds for groundwater, corresponding to a concentration above which there is reason to apprehend a loss of the resource and a risk of impact on health, uses and the environment. For a site located upstream of a water body, the MELCCFP imposes a threshold equal to 50% of the RSW criteria value. As the study site is located less than 1 km from several streams and lakes, a 50% alert threshold was applied.

[1] Criteria for groundwater resurgence into surface water are established on the basis of the surface water quality criteria to which dilution is assigned. The value adopted for each parameter corresponds to the lowest of the following four values: 1) AAC: quality criterion for the protection of aquatic life - acute impact; 2) 100 x AAC: quality criterion for the protection of aquatic life - chronic impact; 3) 100 x CPC (O): quality criterion for the prevention of contamination of aquatic organisms, except for toxic, persistent and bioaccumulable substances, for which CPC (O) is used directly; 4) CPTF: quality criterion for the protection of fish-eating terrestrial fauna.

14.2.1.2 Determination of Metal Levels under Existing Conditions and Temporal Trends

Existing metal levels in groundwater were calculated for each given parameter from a minimum of eight sample analysis results from at least three observation wells, over at least two sampling programs, in accordance with Directive 019 (MDDEP, 2012). The calculated values provide an initial concentration representative of the existing environment prior to redevelopment.

To study changes in the concentration of analyzed parameters in groundwater, the analytical results obtained were subjected to the Mann-Kendall test (MELCCFP, 2017), which identifies temporal trends.

The Mann-Kendall test was applied to all groundwater analytical results between 2005 and 2023. These results are drawn from various sampling programs carried out either by Troilus or by consultants, in wells installed on the study site.

14.2.2 Pre-Mine Conditions

Groundwater quality at the Troilus project site was assessed using a single groundwater sample collected in 1991 by Entraco from a former borehole intended as a drinking water supply for the Troilus-Frotet camp (Geocon, 1993). This sample, analyzed for total metals and other inorganic parameters, as well as for the main organic and bacteriological parameters (coliforms and streptococci), complied with potability criteria at the time. The complete table of analyses carried out on the site's groundwater in 1991 can be found in Appendix II of the Geocon (1993) report.

14.2.3 Existing Conditions

The environmental quality of groundwater is assessed by chemical analysis of groundwater samples for the parameters recommended by Directive 019 (MDDEP, 2012). For mine sites, the presence or absence of potential groundwater receptors determines the applicable quality criteria.

The concentrations of chemical parameters measured in the laboratory and the values of physico-chemical parameters measured in situ or at an accredited laboratory as part of WSP's monitoring (2022-2023) are used as a reference for groundwater quality at the Troilus site prior to the start of planned mining activities. Monitoring results for 2022 and 2023 are detailed in WSP's annual monitoring reports (WSP, 2024a and 2024b), available in Appendices G1.10 and G.1.11.

14.2.3.1 Summary of Groundwater Analytical Results

The observation wells selected for groundwater quality monitoring are located upstream and downstream of the tailings storage facility, upstream and downstream of the mine site (mined pit area), in the former industrial area, and downstream of the in-trench landfill (see Map 14.1).

Considering the results of sampling programs from 2018 to 2023, the following observations can be made:

- Groundwater in wells located upstream and downstream of the mine site is naturally acidic, with an average pH of around 6.5, with several wells showing a pH below 6. The wells located in the former industrial area and the camp zone, on the other hand, have a neutral pH, with an average of 7.3;
- The electrical conductivity of groundwater is generally lower upstream of the PDA (south-west) than downstream (north-east) of the former industrial zone;
- Exceedances of EC comparison criteria or Appendix V of the RPRL for groundwater in the supply wells Camp Well (PU-4), PO-DET-4 and PU-2 (WSP, 2024a and 2024b) were observed in some of these wells for at least one of the following parameters: dissolved metals (arsenic, manganese) and ammoniacal nitrogen. For information purposes, RSW comparison criteria were also exceeded for copper and sulfides (expressed as H_2S) in wells that could be used for water supply. It should be noted that only PU-4 and PO-DET-4 are drinking water supply wells;
- An exceedance of the alert threshold with no exceedance of the RSW groundwater comparison criteria was observed in one of the wells that could be used for water supply, for zinc and sulfides (expressed as $S^{2-)}$;
- Exceedances of Appendix V of the RPRL comparison criteria for groundwater in environmental monitoring wells were observed for toluene and dissolved metals (manganese and nickel);
- RSW comparison criteria were exceeded in environmental monitoring wells for the following parameters: sulfides (expressed as H_2S and S^{2-}) and dissolved metals (silver, cadmium, copper, manganese, mercury and zinc);
- Exceedances of the alert threshold without exceeding the RSW groundwater comparison criteria were observed in some environmental monitoring wells for the following parameters: dissolved metals (silver, cobalt, copper and zinc), total phosphorus and sulfides (expressed as $S^{2-)}$;
- In general, exceedances of groundwater quality criteria are concentrated in topographically depressed areas, notably in the middle of the site, where the old pits and natural dewatering zones are located. Conversely, wells MW-21-14 (located in unconsolidated deposits) and MW-23-25 (drilled in bedrock), located regionally downstream of the mine site, show no exceedances, indicating attenuation of concentrations with distance and limited dispersion across the site.

The other parameters comply with the comparison criteria and their respective alert thresholds, where applicable.

Analytical results from Troilus monitoring in 2018 to 2021 are compiled in Appendix G1.12, and results from WSP monitoring in 2022 and 2023 in Appendices G1.10 and G.1.11.

The exceedances of EC and RSW criteria observed in groundwater samples collected as part of monitoring between 2018 and 2023 are presented in Tables 14.4 and 14.5 for wells in unconsolidated deposits and in bedrock, respectively.

Table 14.4 Summary of exceedances of DW and RSW criteria in groundwater - wells installed in unconsolidated deposits

Observation Well	Sampling Date									
	Sept-19	May-20	Sep-20	May-21	Sep-21	May -22	Jul-22	Sep-Oct 2022	May-23	Oct-23
MW-21-01							H_2S >DW	H_2S >RSW	Mn>DW	Mn>DW
MW-21-03							H_2S >RSW		Mn>RSW	Cd and Mn>RSW
							NH_4> DW	NH_4> DW		
MW-21-04							H_2S >RSW	H_2S >RSW	Mn>RSW	Mn>RSW
							NH_4> DW	NH_4> DW		
MW-21-06							Al, Mo, $NH_4$and H_2S >DW	Al, Mo, $NH_4$and H_2S >DW	Al and Mo >DW	Al, As and Mo >DW
MW-21-08									As>DW	As >DW
MW-21-14										Hg>RSW
MW-21-15									Zn>RSW	
MW-21-16							Al>DW	Al>DW	Al and As >DW	Al and As >DW
MW-21-19								Zn>RSW		
MW-21-23							NH_4> DW	$NH_4$and H_2S > DW	Mn>DW	Mn>DW
PM-3					Cu>RSW	NH_4> DW		Hg>RSW		
PM-5		NH_4> DW	Mn and NH_4> DW		Mn and NH_4> DW	NH_4> DW		NH_4> DW		
					Cu>RSW			Hg>RSW		
PO-10-33							Cu and Zn >RSW	Cu and Zn >RSW	Cu and Zn >RSW	Cu and Zn >RSW
									Al and Mn >DW	Al and Mn >DW
PO-11-01							Al>DW			
							Cu and Zn >RSW			
PO-11-02							Zn >RSW		Cu >RSW	
PO-DET-4							Cu >RSW	Cu >RSW	Cu >RSW	Cu >RSW

Observation Well	Sampling Date									
	Sept-19	May-20	Sep-20	May-21	Sep-21	May -22	Jul-22	Sep-Oct 2022	May-23	Oct-23
PZ-1	As>DW	NH_4> DW	NH_4> DW	As>DW	As and NH_4>DW	NH_4> DW		As and NH_4>DW		
		Mn>RSW	Mn>RSW	Mn>RSW	Mn>RSW	Mn>RSW		Hg and Mn>RSW		
PZ-2	As>DW	Al,As,Mn and NH_4> DW	Mn and NH_4> DW	As, Mn and NH_4>DW	Mn and NH_4>DW	Mn and NH_4>DW		Mn and NH_4>DW		
								Hg>RSW		
PZ-3		Al>DW	Al>DW	Al and NH_4>DW	Al>DW	Al>DW				
					Cu>RSW					

Table 14.5 Summary of exceedances of DW and RSW criteria in groundwater - wells installed in bedrock

Observation well	Sampling date											
	May-18	Sep-18	Sep-19	May-20	Sep-20	May-21	Sep-21	May -22	Jul-22	Sep-Oct 2022	May-23	Oct.-23
MW-21-02									NH_4> DW		As>DW	As>DW
MW-21-05									H_2S >DW	H_2S >DW	As>DW	As and Mn>DW
MW-21-07									H_2S >DW			
MW-21-10										$NH_4$and H_2S > DW		As>DW
PO-8	Cu and Zn>RSW	Cu and Zn>RSW	Cu and Zn>RSW	Cu and Zn>RSW	Cu and Zn>RSW	Cu and Zn>RSW	Cu and Zn>RSW			Cd, Cu, Hg, Mn and Zn>RSW		
				Mn >DW	Mn and NH_4>DW	Mn >DW	Mn and NH_4>DW			Ni >DW		
PO-21				NH_4>DW	NH_4>DW	CN>RSW	Cr,Cu,Pb and Se >RSW	Pb and Se >RSW	NH_4>DW	U >RSW		Mn >DW
						NH_4>DW	Cd>DW	NH_4>DW		Sb and Mn >DW		
PU-2									NH_4>DW	NH_4>DW	As and Mn >DW	As and Mn >DW
Camp well (PU-4)											As >DW	As >DW

DW: "Drinking water" criteria from Guide d'intervention - Protection des sols et réhabilitation des terrains contaminés (MELCCFP, 2021).

RSW: "Resurgence in surface water" criteria from the Intervention guide - Soil Protection and Rehabilitation of Contaminated Land (MELCCFP, 2021).

Not sampled

Sampled, no exceedances based on parameters analyzed during various programs

14.2.3.2 Determination of Existing Metal Levels

According to the analyses carried out, the following parameters could exceed the RSW criterion or its alert threshold in certain wells: copper, mercury and zinc. For aluminum and arsenic, the concentrations obtained show that levels could exceed drinking water criteria.

The results obtained are presented in Table 14.6, in which the calculated levels are compared with groundwater quality criteria.

Table 14.6 Calculation of existing metal levels in groundwater

Parameters	Lithological units / Existing concentrations (mg/l)	
	Unconsolidated deposits	Bedrock
Aluminum	**0.1200**	0.0175
Arsenic	**0.0004**	**0.0025**
Boron	0.01	0.14
Cadmium	0.0001	0.0001
Calcium	76	162
Chromium	0.0004	0.0003
Cobalt	0.0046	0.0121
Copper	**0.0088**	**0.0049**
Iron	1.693	1.705
Lithium	0.005	0.005
Magnesium	7.42	6.06
Manganese	**0.2305**	**0.2585**
Mercury	**0.0000119**	**0.0000915**
Molybdenum	0.0003	0.0091
Nickel	0.0035	0.0057
Lead	0.00006	0.00005
Potassium	14.0488	14.7125
Silicon	11.6	15.9
Sodium	14.2125	19.4913
Zinc	**0.1019**	**0.0513**

100: Calculated NBC value > RSW criterion

100 : Calculated NBC value > RSW criterion alert threshold

100 NBC value calculated > Criterion/recommendation Drinking water

14.2.3.3 Trends in Groundwater Quality

Table 14.7 below shows the parameters for which a significant trend has been observed between 2005 and 2023. These trends are indicated according to whether they are increasing or decreasing, and according to whether the well is located near, hydraulically upstream of or downstream from existing mining infrastructure (mine site including pits, waste rock pile and tailings storage facility used in former mining operations).

Thus, most parameters showing a significant trend in the Mann-Kendall test show an overall downward trend, with the notable exception of iron and magnesium in pits located hydraulically upstream of the pits, but downstream of the tailings storage facility. A possible upward trend is also observed for beryllium and uranium in the industrial zone.

Table 14.7 Summary of significant trends in the Mann-Kendall test between 2005 and 2023

Parameters	Trends			
	Sector 1	Sector 2	Mine site	Global
Fluorides				
Nitrates				
Nitrites				
Ammoniacal nitrogen				
Chlorides				
Available cyanides				
Total alkalinity				
Total Kjeldahl nitrogen				
pH				
Conductivity				
Suspended matter				
Petroleum hydrocarbons C_{10}-C_{50}				
Dissolved arsenic				
Dissolved beryllium				
Dissolved cadmium				
Dissolved cobalt				
Dissolved copper				
Dissolved iron				
Dissolved lithium				
Dissolved magnesium				
Dissolved manganese				
Dissolved mercury				
Dissolved molybdenum				
Dissolved nickel				
Dissolved potassium				

Parameters	Trends			
	Sector 1	Sector 2	Mine site	Global
Dissolved lead	[green]			[green]
Dissolved silicon	[green]		[yellow]	[green]
Dissolved sodium			[green]	
Dissolved titanium	[yellow]	[yellow]		[yellow]
Dissolved uranium			[orange]	
Dissolved zinc	[yellow]			[yellow]

Legend

[white]	No significant trend
[red]	Upward trend, with negligible risk of false positives
[orange]	Upward trend, with non-negligible risk of false positives
[green]	Downward trend, with negligible risk of false positives
[yellow]	Downward trend, with non-negligible risk of false positives

14.2.3.4 DRASTIC Vulnerability

The vulnerability of the bedrock aquifer was assessed using the DRASTIC method (Aller et al., 1987), which determines the susceptibility of groundwater to be affected by contamination originating directly from the surface.

The acronym DRASTIC corresponds to the seven physical and hydrogeological parameters considered in calculating vulnerability indices: depth of water table, recharge, nature of aquifer environment, soil type, slope of land, nature of vadose zone and hydraulic conductivity of aquifer. A numerical value between 1 and 5 reflects the degree of influence of each of these parameters or their weight in the calculation of indices.

A rating ranging from 1 to 10, defined in terms of value intervals, is associated with each parameter.

The calculation of the DRASTIC index thus corresponds to the sum of the scores assigned to the various parameters, multiplied by their respective weights:

DRASTIC index = (D1*D5) + (R*R4) + (A3*A3) + (S1*S2) + (T5*T1) + (I6*I5) + (C1* C3)

Index values can vary between 23 and 226.

The higher the value, the greater the vulnerability (risk of impact on groundwater in the event of contamination). The DRASTIC method is based on the following three conditions of application:

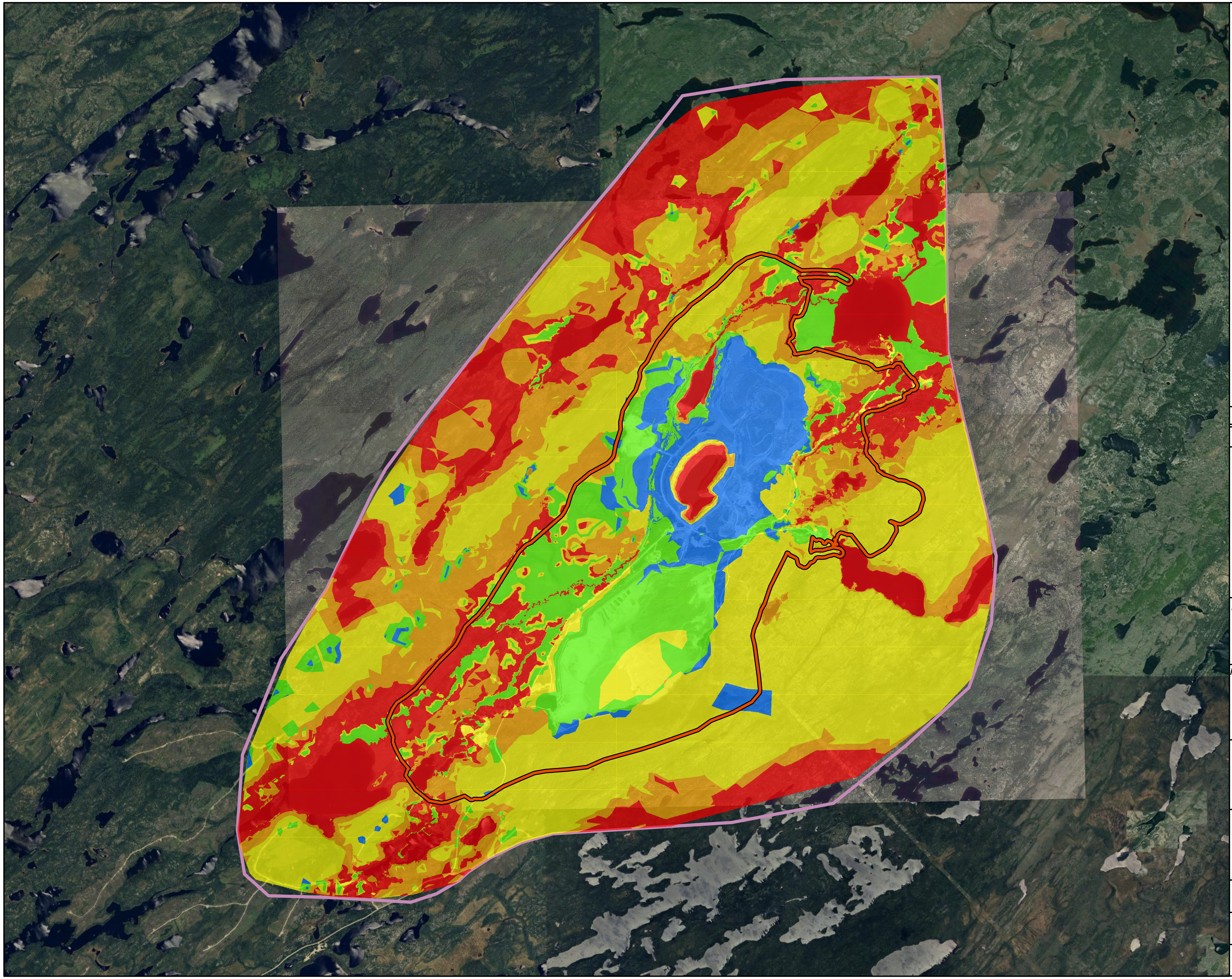
1) Sources of contamination are at the ground surface (this excludes underground sources);
2) The nature of the contaminant is not considered, but it is mobile in the soil in dissolved phase;
3) Contaminants can only reach the water table by vertical infiltration (underground flow is not taken into account).

The calculation of the DRASTIC index for each parameter was carried out using the results of studies carried out on the site. Table 14.8 shows the DRASTIC index for each parameter, and Map 14.3 shows the distribution of the index at the site.

Table 14.8 Source of information by parameter in the DRASTIC index

Description	Source of information
Static water depth (**D**)	Hydrogeological modeling (BluMetric, February 2025)
Net annual recharge (**R**)	Hydrogeological modeling (BluMetric, February 2025)
Aquifer environment (**A**)	Hydrogeological modeling (BluMetric, February 2025)
Soil type (**S**)	Unconsolidated deposits (Golder, 2022)
Terrain slope (%) (**T**)	Lidar (MRN, 2021)
Impact of vadose zone (**I**)	Unconsolidated deposits (Golder, 2022)
Hydraulic conductivity (m/d) (**C**)	Average 23.2 m/d (Various sources)

Groundwater vulnerability levels for the bedrock aquifer range from very low (46) to very high (180). The most vulnerable zones are located mainly in the topographic highlands at the northwestern edge of the LSA, northeast of Lake Amont (PE2) and south of Lake A (PE43).



LÉGENDE / LEGEND

- Zone de développement du projet / Project development area
- Zone d'étude locale / Local Study Area

Indice DRASTIC / DRASTIC Index

- ≤ 76: Vulnérabilité très faible / Very Low Vulnerability
- 76 - 100: Vulnérabilité faible / Low Vulnerability
- 100 - 126: Vulnérabilité moyenne / Medium Vulnerability
- 126 - 150: Vulnérabilité élevé / High Vulnerability
- > 150: Vulnérabilité très élevé / Very High Vulnerability

RÉV.	DESCRIPTION	AA/MM/YY	BY	VERIF.
1				

RÉFÉRENCES/REFERENCES

ZDP, ZEL, DRASTIC: BluMetric, 2025
Base Map: Bing, 06 June 2023

NOTES

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N E S W

CLIENT

Troilus Gold Corp.

PROJET/PROJECT

Étude d'impact sur l'environnement et le milieu social pour le projet de mine Troilus / Environmental and Social Impact Assessement for the Troilus Mine Project

TITRE/TITLE

Indice DRASTIC / DRASTIC Index

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NO. PROJET / PROJECT NO.	*DATE*
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CONÇU / CHECKED	*RÉVISÉ / VERIFIED*
É. Hudon-Gagnon	C. Gardois
DESSINÉ / DRAWN	*Figure No.* / *ED./REV.*
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14.3 Project Interactions with Groundwater Quality

Table 14.9 lists the activities planned for each project phase, together with their potential impacts on groundwater quality. Anticipated interactions between project activities and potential impacts are identified by a check mark, while a dash indicates the absence of interactions. These interactions are discussed in detail in Section 14.4, in the context of pathways, project-specific mitigation measures, and residual impacts.

Table 14.9 Project interactions with groundwater quality

Physical Activities	Heavy Metal Contamination	Hydrocarbon Contamination	Nutrient or Nitrate Enrichment
Construction			
Labour, equipment and materials transport to the site.	-	-	-
Vehicles and equipment operation and maintenance within the PA.	–	✓	–
Tree cutting, vegetation clearing, soil stripping and earthworks.	✓	✓	✓
Handling and use of explosives, including blasting	–	✓	✓
Construction of temporary and permanent buildings, including wastewater treatment system and drinking water collection and distribution system.	–	✓	✓
Construction of mining infrastructures such as stockpiles, pits and the raising of tailings management facility.	✓	✓	✓
Construction of roads and preparation of construction surfaces including the crushing of material used for construction. Relocation of a section of the access road and power line.	–	–	–
Construction of water management systems including ditches, diversion channel, sedimentation ponds and the water treatment plant.	–	–	–
Dewatering of natural water bodies and pits, lowering water level in tailings management facility and management of contact water.	–	–	-
Diversion of Bibou Creek (CE2).	-	–	-
Management of waste materials, including hazardous waste.	✓	✓	✓
Purchases of goods and services.	–	–	–
Employment	–	–	–
Operations			
Labour, equipment and materials transport to the site.	–	–	–
Vehicles and equipment operation and maintenance within the PA.	–	✓	–
Handling and use of explosives, including blasting.	–	–	–
Ore extraction from pits including drilling and hauling of waste rock.	–	–	✓
Ore, waste rock and tailings storage.	–	✓	–

Physical Activities	Heavy Metal Contamination	Hydrocarbon Contamination	Nutrient or Nitrate Enrichment
Ore processing including conveyor, crushing, loading and hauling on site.	✓	-	-
Transportation of concentrate to a smelter or a wharf.	✓	–	✓
Management and treatment of water on the mine site and to the environment, including drainage and contact water.	✓	–	–
Progressive reclamation of disturbed areas.	✓	–	–
Management of waste materials, including hazardous waste.	✓	✓	✓
Purchases of goods and services.	–	–	–
Employment	–	–	–
Decommissioning and Closure			
Labour, equipment and materials transport to the site.	–	–	–
Vehicles and equipment operation and maintenance within the PA.	✓	✓	–
Decommissioning, dismantling and disposal of buildings and equipment.	–	–	–
Pits flooding, surface and groundwater management.	✓	–	✓
Reclamation of disturbed areas, including earthworks, placement of overburden and revegetation.	-	✓	–
Management of waste materials, including hazardous waste.	✓	✓	✓
Purchases of goods and services.	–	–	–
Employment	–	–	–
NOTES: ✓ = Potential interaction – = No interaction			

14.4 Assessment of Residual Impacts on Groundwater Quality

A residual impact is defined as the environmental impact that remains after the implementation of all reasonable and effective mitigation measures. In other words, it is the impact that remains despite all efforts to avoid, reduce or compensate for adverse impacts.

In the context of the mining project, several mining-related activities are likely to lead to an alteration in groundwater quality, mainly due to the mobilization of contaminants and changes in the groundwater flow regime.

Deep excavations, dewatering of open pits and waste rock disposal may expose geological formations containing naturally occurring metals such as arsenic, lead or cadmium. In the presence of water and oxygen, these metals can be mobilized and leach into aquifers, leading to localized or diffuse groundwater contamination.

In addition, there is a risk of hydrocarbon contamination in the event of accidental leaks or spills of fuels, oils or lubricants on unconfined areas. These substances could seep through unprotected soils and reach the water table, affecting the quality of water used locally.

Furthermore, the use of nitrate-containing explosives, combined with possible discharge of partially treated wastewater, could lead to nutrient enrichment or nitrate contamination. This would be a particular issue for shallow aquifers or aquifers connected to drinking water sources.

Changes to the groundwater flow regime, caused by pumping, drainage or filling, could encourage the migration of contaminants in new or unforeseen directions, notably through potential connections between shallow and deep aquifers. This redistribution of flows could transport pollutants to sensitive areas, such as vulnerable ecosystems.

Finally, certain development practices, such as soil sealing or modification of natural drainage, could influence the quality of aquifer recharge. By limiting the infiltration of precipitation, these modifications could concentrate contaminants on the surface and reduce the natural attenuation process in the soil, thereby increasing the risk of groundwater contamination.

14.4.1 Metal Contamination

14.4.1.1 Project Pathways

Construction

Several activities planned as part of the mining project present a risk of groundwater contamination by metals. These metals, naturally present in geological formations, could be mobilized as a result of physical or chemical disturbances in the environment. The main pathways associated with certain stages of the project are detailed below.

During the deforestation, vegetation removal, soil striping and earthmoving phases, superficial soils are exposed and disturbed, favouring the alteration of minerals and the mobilization of metals present in geological horizons. Increased exposure of the substrate to atmospheric agents such as air and rainwater could accelerate the oxidation of metallic minerals, resulting in the release of certain elements into solution. In addition, erosion of exposed soils could generate runoff laden with fine particles containing metals, likely to infiltrate locally into aquifer systems.

Another major source of contamination is the construction of mining infrastructure, notably pits and tailings storage facility. These structures expose large surfaces of fragmented or processed rock, often rich in sulfide minerals. Their alteration, particularly by oxidation, could generate acid mine drainage (AMD), which increases the solubility of many metals such as arsenic, lead and copper. If not properly captured and treated, this acidic water could infiltrate the ground and reach the underlying aquifers. The presence of contaminated contact water within the tailings storage facility or in the vicinity of the pits is also a potential source of metal migration to groundwater. In addition, any failure in containment systems - whether structural, operational or due to extreme weather conditions - could facilitate the dispersion of contaminants into the underground environment.

Finally, the management of residual materials, particularly those considered hazardous, would constitute another possible pathway for the introduction of metals into groundwater. Temporary or inadequate storage of metal waste, sludge, filters or other industrial residues on non-waterproofed surfaces would increase the risk of metals leaching into the soil. Accidental spills or leaks from damaged containers could also lead to point or diffuse contamination, particularly if these incidents are not quickly brought under control. The progressive corrosion of certain metal containers in long-term storage could also constitute a slow but continuous source of pollution, difficult to detect without rigorous monitoring.

Operations

During the operational phase, a number of ongoing activities on the mine site could lead to groundwater contamination by metals, particularly in storage, processing and discharge management areas. These sources of contamination should be rigorously monitored to protect the quality of nearby aquifers.

The storage of ore, waste rock and tailings would represent a major pathway for metal contamination. These materials, extracted and handled in large quantities, could contain potentially leachable metals such as arsenic, copper, zinc or nickel. In the presence of rainwater or runoff, waste rock piles or tailings could generate contaminated drainage water, particularly if sulphide minerals are exposed to air. This water, if not effectively captured or treated, could percolate through foundations or containment structures, reaching groundwater. In addition, leaky or poorly drained storage areas would increase the risk of vertical migration of metal contaminants into underlying aquifers.

Ore processing, including crushing, conveying, handling and transportation on site, is also a potential source of contamination. These activities generate dust and sludge that may contain soluble metals, which can accumulate on the ground or in ditches. Metal fallout or ore losses during transport can contribute to diffuse contamination, particularly during heavy rainfall, which facilitates the leaching of particles into groundwater, especially in unpaved or unprotected areas.

The management and treatment of mine site water, including drainage and contact water, is a critical step in preventing the dispersion of contaminants. Water that comes into contact with pits, pits or processing facilities can be loaded with dissolved metals. If this water is not directed to a suitable treatment system, or if leaks occur in retention basins, there is a real risk of contamination of the groundwater. Water management structures should therefore be designed to minimize infiltration and be subject to constant maintenance and monitoring to ensure their long-term integrity.

Progressive reclamation of disturbed areas could also influence groundwater quality, particularly if the capping materials are not sufficiently impermeable or if the chemical stability of the covered tailings is not assured. Inadequate reclamation could allow water to seep through the capping layers and come into contact with mineralized materials, promoting the dissolution of metals and their migration to aquifers.

Finally, the management of residual materials, including hazardous residual materials, will be an important issue during operation. Industrial or chemical wastes containing metals could be generated by maintenance or processing operations. Inappropriate handling, storage and disposal of these wastes could be a direct source of pollution, particularly in the event of leaks, storage on leaking surfaces or poor leachate management. Slow corrosion of containers or lack of effective containment could lead to chronic contamination, often difficult to detect without a targeted monitoring program.

Closure

The closure phase of a mining project remains critical for groundwater quality, particularly with regard to the risk of metal contamination. Although operations cease, tailings, mining infrastructure and disturbed areas will continue to interact with the hydrogeological environment over the long term. Some reclamation measures, if not rigorously planned and implemented, could even generate new pathways for metals to migrate to groundwater.

The progressive flooding of open pits, often used as a rehabilitation strategy, could lead to the remobilization of metals present in exposed walls or in materials left at the bottom of pits. The oxidation of sulphide minerals in contact with water could produce acidic conditions favoring the solubilization of metals, which could then seep into aquifers via hydraulic connections between the pit and neighboring underground formations. If no geotechnical or hydrochemical barriers are in place to limit these exchanges, the water accumulated in the pit could become a diffuse source of contamination for both groundwater and the connected surface environments.

Surface and groundwater management during closure is also a key issue. At this stage, dewatering networks are often modified or simplified, and active treatment systems are sometimes shut down or replaced by passive measures. If flow control or treatment structures are not sufficient to capture runoff or seepage water still laden with metals, the latter may slowly migrate towards the water table. In addition, the progressive saturation of stockpiles, tailings ponds and storage facility would lead to continuous leaching of materials, particularly during periods of heavy rainfall or spring thaw, favoring the leaching of metals and their transfer to the subsoil.

Residual materials, including hazardous residual materials, would remain a long-term vector of contamination if containment measures are not sustainable or if their integrity is compromised over time. Storage facilities will need to be designed to minimize infiltration and exchange groundwater, as stored industrial and metal waste could continue to release metals for decades. Deteriorated containers, cover defects or the presence of misidentified materials could all become sources of point or diffuse pollution, difficult to detect in the absence of prolonged post-closure monitoring.

Closure of a mine site marks the beginning of a new phase in long-term environmental management. Groundwater quality can be compromised if metal mobilization and migration mechanisms are not anticipated and controlled. The success of this phase would depend on rigorous flooding planning, judicious integration of passive treatment measures, effective containment of residual materials, and robust environmental monitoring enabling measures to be adjusted in the light of observed results.

14.4.1.2 Mitigation and Enhancement Measures

To limit these impacts and promote groundwater quality, several mitigation and enhancement measures will be implemented:

- Conduct a study of existing iron-rich seepage from the tailings facility to design provisions to mitigate or control potential future impacts associated with future tailings storage at the facility;

- Plan the sequencing of mining operations to balance the extraction of high- and low-sulfide materials, based on detailed geochemical mapping of the deposit;
- Rapid stabilization of exposed soils: temporary cover (geotextile fabric, mulch, hydroseeding) to limit erosion and runoff;
- Erosion and sediment control: installation of perimeter ditches, settling basins and sediment barriers to intercept fine particles potentially rich in metals;
- Minimization of exposed areas: phasing of stripping work to limit the amount of substrate exposed at any one time;
- Covering plan for tailings pits and tailings storage areas: use of low-permeability materials and vegetation to limit infiltration;
- Maintenance or replacement of treatment systems: transition to passive treatments where possible, while maintaining treatment efficiency.

14.4.1.3 Project Residual Impact

Despite the implementation of stringent mitigation measures to prevent the mobilization and migration of metals to groundwater, residual impacts could persist throughout the project life cycle.

During the construction and operation phases, active pumping of the pits will result in a local drawdown of the piezometric level, creating a hydraulic gradient directed towards the excavated areas. This phenomenon will act as a hydraulic control mechanism, limiting the dispersion of contaminants by potentially directing metal-laden groundwater towards the pits themselves, where it can be captured, monitored and, if necessary, treated. This dynamic will help limit the risk of off-site migration during active operations.

However, when the site closes, with the cessation of pumping and the gradual rise in groundwater levels (hydrogeological equilibration), a redistribution of underground flows may occur, modifying potential contaminant migration paths. This change in hydrogeological regime would represent a critical timing for the control of residual contamination by dissolved metals in groundwater.

To minimize long-term impacts, a post-closure environmental follow-up program will be implemented to monitor changes in groundwater quality and detect any signals of metal release. Depending on the results observed, adaptive management tools may be deployed. Thus, although the risk of contamination cannot be completely eliminated, it can be contained and controlled through a combination of hydraulic controls, continuous monitoring and targeted corrective measures, ensuring the long-term protection of groundwater.

14.4.2 Hydrocarbon Contamination

14.4.2.1 Project Pathways

Construction

The construction phase of the Troilus mine involves a number of activities likely to generate hydrocarbon contamination. The constant use of heavy machinery for land clearing, earthworks and infrastructure construction is a major source of risk. Accidental leaks or spills of fuel, engine oil or hydraulic fluid could occur from poorly maintained or intensively used machinery. In addition, temporary storage of fuels and lubricants on site, particularly in developing or undeveloped areas, could lead to spills if adequate containment measures (waterproof liners, retention tanks) are not in place.

In addition, fuel transfer operations using tanker trucks or mobile pumps in the field would present an increased risk of point-source contamination in the event of human error or technical failure. These hydrocarbons could then infiltrate the soil, run off into nearby ditches or bodies of water, and potentially migrate into shallow aquifers, especially in the absence of impermeable surfaces.

Operation

During the operating phase, the sustained presence of motorized equipment, fuel tanks and maintenance activities intensifies the risk of hydrocarbon contamination. Transport, ore processing and handling operations involve the continuous use of fuels, oils and lubricants. Normal wear and tear of equipment, mechanical incidents and maintenance operations can lead to chronic leaks. Refuelling and maintenance areas for mining vehicles are particularly sensitive, especially if the management of oily residues, contaminated filters or sludge is not rigorous.

Accidental spills can occur during filling or emptying, and their impact is magnified if surfaces are not watertight or drainage is inadequate. Long-term storage tanks are also a source of risk, particularly in the event of containment defects, corrosion or poor maintenance. Overall, hydrocarbons can seep into the ground, percolate slowly to groundwater or contaminate runoff, particularly in unpaved or poorly protected areas.

Closure

Even after mining operations have ceased, the closure phase entails residual risks of hydrocarbon contamination. Volumes of hydrocarbons may still be present in equipment, pipes, tanks or storage areas. If dismantling is not complete or thorough, these sources could continue to release contaminants into the ground. Aging of the remaining infrastructure, such as buried tanks or pipes, could lead to slow, often undetected leaks.

Furthermore, inadequate disposal of contaminated materials - such as soiled soil, absorbents or used oil containers - could lead to long-term diffuse pollution. This contamination is of particular concern when groundwater levels gradually rise (post-closure hydrogeological rebalancing), which could mobilize buried hydrocarbons and encourage their migration. Periods of heavy rain or thaw would also increase the risk of leaching these pollutants into the water table. So, even though mining activities are over, passive release mechanisms could persist if adequate containment and remediation measures are not put in place.

14.4.2.2 Mitigation and Enhancement Measures

- Sealed and confined areas will be set up to prevent any accidental discharge into the environment from sealed refueling and maintenance areas.
- Hydrocarbons will be stored in secure containers, on impermeable surfaces with adequate retention capacity.
- Strict procedures will govern fuel transfers, including supervision, equipment inspection and operator training.
- An emergency plan will be put in place, with response equipment available at all times and regular simulations to ensure responsiveness.
- The site will be restored after work, with decontamination if necessary and environmental monitoring to verify the effectiveness of the measures.

14.4.2.3 Project Residual Impact

Despite the mitigation measures implemented at all stages of the Troilus mining project, certain residual risks of hydrocarbon contamination of groundwater would remain. These impacts are considered low in magnitude, as potential sources (e.g., accidental spills, occasional leaks from machinery or containers, maintenance residues) will be limited and controlled by effective preventive measures.

These impacts will be present during all phases of the project, i.e. construction, operation and closure, and will be localized to the PDA, without extending into the Local Study Area or Regional Study Area. Their frequency is described as irregular, corresponding to one-off or accidental events (e.g. refuelling incident, slow leak not immediately detected).

Given the presence of containment and clean-up measures in the event of an incident, any contamination would be reversible, thanks in particular to targeted rehabilitation and post-closure environmental monitoring. However, the potential duration of persistence in the environment is estimated at medium term, especially if late detection or delayed intervention occurs.

Sensitivity timing is considered moderate, particularly during periods of heavy precipitation, spring melt or intense machinery activity. In the long term, monitoring mechanisms and emergency response plans will help contain and correct potential impacts, thus limiting the extent of impact on underground aquifers.

14.4.3 Nutrient or Nitrate Enrichment

14.4.3.1 Project Pathways

Construction

During the construction phase, several activities could contribute to nutrient or nitrate enrichment in groundwater. Site infrastructure development (earthworks, road construction, temporary camps, etc.) could generate discharges from sanitary facilities (domestic wastewater containing ammoniacal nitrogen and nitrates), particularly in the event of failure or poor management of temporary sanitation systems. Poorly treated or confined effluent could seep into the ground and reach shallow aquifers.

In addition, inadequate storage of organic residual matter or food waste in living or work areas could lead to the release of nutrients through leaching, particularly during precipitation. Soil exposure and reworking could also alter natural drainage conditions, increasing the risk of nitrogen compounds migrating to groundwater.

Mining

During operation, the use of nitrates in explosives (notably ammonium nitrate) would be a major pathway. Undetonated explosive residues and losses during borehole preparation or loading could lead to nitrate percolation into soils and, ultimately, groundwater, particularly in areas where open-pit or underground drilling and blasting will take place. This source is diffuse but continuous.

In addition, leaching from mine piles and tailings could also contribute to nutrient inputs if nitrogenous materials are present in reworked or stockpiled materials. In processing areas, process water management systems or contaminated drainage could contain nitrogen loads if contact waters are not adequately treated. Finally, on-site personnel sanitary wastewater management systems must be rigorously maintained, as any leaks or overflows could cause nitrogenous infiltration into aquifers.

Closure

At closure, nitrate and nutrient risks could persist, although they would tend to diminish with the cessation of active operations. However, slow infiltration of residual nitrates from stockpiles or blasting areas could continue for several years. Nitrates accumulated in soils or saturated zones could be mobilized during hydrological cycles (e.g. thawing, heavy rainfall), causing them to migrate to groundwater.

What's more, if water or domestic effluent treatment systems are deactivated prematurely or fail, nutrients still present in basins or pipes could be released into the environment. Redevelopment of disturbed areas must therefore include measures to limit the percolation of nutrients through capping materials and reconstituted soils.

14.4.3.2 Mitigation and Enhancement Measures

- Domestic wastewater will be adequately treated in compliant facilities to avoid any contamination of soil or water.

- Organic matter (e.g. food waste) will be stored in closed containers and disposed of regularly to prevent nuisance and wildlife attraction.
- The use of explosives will be strictly controlled, and any residue generated will be recovered, stored or disposed of in accordance with standards to avoid contamination.

14.4.3.3 Project Residual Impact

During the construction phase, nutrient and nitrate enrichment is mainly associated with effluent from temporary sanitary facilities and the management of organic matter. Risks are low, given the short duration of this phase and management measures such as wastewater treatment and appropriate management of organic waste. Impacts on groundwater quality will be limited and remain reversible in the short term if adequate control measures are applied.

During the operating phase, nitrate enrichment could result from effluents generated by industrial activities and the use of explosives. However, management measures such as effluent treatment systems and retention ponds will significantly reduce the risk of nutrient leaching into soils and aquifers. The magnitude of the impact will remain low and is reversible in the short term, thanks to appropriate discharge management.

During closure, the risk of nutrient or nitrate enrichment is relatively low. The main potential sources of contamination include tailings remaining on site and organic matter left behind after operations have ceased. However, effective management of the rehabilitation of impacted areas and dewatering systems could limit any risk of leaching into aquifers. The impact will remain low and reversible if appropriate measures are put in place to manage surface water and tailing storage areas.

14.4.4 Summary of Project Residual Impacts

Table 14.10 summarizes the residual impacts on groundwater quality.

Table 14.10 Anticipated residual impacts of the project on groundwater quality

Residual impact	Residual impact Characterization							
	Project phase	Direction	Magnitude	Geographic extent	Timing	Duration	Frequency	Reversibility
Metal contamination	C	A	L	PDA	MS	LT	C	R
	O	A	L	PDA	MS	LT	C	R
	D	P	L	PDA	MS	LT	C	R
Hydrocarbon contamination	C	Neutral	L	PDA	MS	MT	IR	R
	O	Neutral	L	PDA	MS	MT	IR	R
	D	Neutral	L	PDA	MS	MT	IR	R
Nutrient or nitrate enrichment	C	A	L	PDA	MS	ST	C	R

Residual impact	Residual impact Characterization							
	Project phase	Direction	Magnitude	Geographic extent	Timing	Duration	Frequency	Reversibility
	O	A	L	PDA	MS	ST	C	R
	D	A	L	PDA	MS	ST	C	R

Project phase :
C: Construction
O: Operation
D: Decommissioning and Closure

Direction :
P: Positive
A: Adverse

Magnitude :
NMC: No Measurable Change
L: Low
M: Moderate
H: High

Geographic extent :
PDA: Project Development Area
LSA: Local Study Area
RSA: Regional Study Area

Timing :
NS: No sensitivity
MS: Moderate sensitivity
SE: High sensitivity

Duration :
ST : Short term
MT: Medium-term
LT : Long term

N/A Not applicable

Frequency :
S : Single event
IR : Irregular event
R: Regular event
C : Continuous

Reversibility :
R : Reversible

I: Irreversible

14.4.4.1 Summary of Adverse Residual Impacts

The three types of contamination (metals, hydrocarbons and nutrient enrichment) present adverse risks mainly during the construction and operation phases. However, with rigorous management measures, these impacts can be minimized and are generally reversible in the short term. The closure phase requires long-term monitoring to minimize any persistent residual contamination, particularly as regards metals and hydrocarbons.

14.5 Prediction Confidence

The assessment of impacts on groundwater quality was carried out qualitatively, based on available data from sampling campaigns and existing knowledge of the site's geochemical and hydrogeological context. No numerical modelling was carried out to predict the spatio-temporal evolution of contaminant concentrations. Confidence in predictions is limited by the ad hoc nature of the data, the potential variability of contamination sources (tailings, stockpiles, infrastructure) and the absence of transport simulation. Certain conservative assumptions have been made, notably with regard to contaminant containment, natural attenuation capacities and the effectiveness of management infrastructures. Consequently, results must be interpreted with caution, taking into account uncertainties related to spatialization, geochemical reactivity and long-term water quality trends.

14.6 References

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