



CANADA NICKEL
COMPANY



Crawford Nickel Project Impact Statement

Chapter 10 Assessment of Potential Effects on Geology and
Geologic Hazards



Prepared for:
Canada Nickel Company

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Table of Contents

10	Assessment of Potential Effects on Geology and Geologic Hazards	10.1
10.1	Scope of Assessment	10.1
	10.1.1 Regulatory and Policy Setting	10.2
	10.1.2 The Influence of Consultation and Engagement on the Assessment	10.2
	10.1.3 Potential Effects, Pathways and Measurable Parameters	10.4
	10.1.4 Boundaries	10.4
	10.1.5 Residual Effects Characterization	10.5
10.2	Existing Conditions for Geology and Geologic Hazards	10.6
	10.2.1 Methods.....	10.6
	10.2.2 Overview.....	10.7
10.3	Project Interactions with Geology and Geologic Hazards.....	10.10
10.4	Assessment of Residual Effects on Geology and Geologic Hazards	10.14
	10.4.1 Analytical Assessment Techniques.....	10.14
	10.4.2 Change to Terrain Stability.....	10.14
	10.4.3 Summary of Project Residual Effects.....	10.16
10.5	Potential Effects on Federal Lands.....	10.18
10.6	Assumptions.....	10.18
10.7	Prediction Confidence.....	10.18
10.8	Follow-up and Monitoring.....	10.19
10.9	References.....	10.19
10.10	Figures	10.21

List of Tables

Table 10.1	Summary of Key Information, Indigenous Knowledge, and Concerns for the Project Related to Geology and Geologic Hazards	10.3
Table 10.2	Potential Effects, Effect Pathways and Measurable Parameters for Geology and Geologic Hazards	10.4
Table 10.3	Characterization of Residual Effects on Geology and Geologic Hazards.....	10.5
Table 10.4	Project Interactions with Geology and Geologic Hazards	10.10
Table 10.5	Project Residual Effects on Geology and Geologic Hazards.....	10.17

List of Figures

Figure 10.1	Local/Regional Study Area for Geology and Geologic Hazards	10.22
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Abbreviations and Acronyms

CDA	Canadian Dam Association
LSA	Local Study Area
m ³	cubic metres
OGS	Ontario Geological Survey
O. Reg.	Ontario Regulation
PA	Project Area
RSA	Regional Study Area
SI	slope inclinometers
TIS Guidelines	Tailored Impact Statement Guidelines
VC	Valued Component
VWP	vibrating wire piezometers

Glossary of Technical Terms

Fluvial	Materials transported and deposited by streams and rivers; synonymous with alluvial.
Geology	Solid layer of rock underlying the unconsolidated soils and sediments.
Geologic Hazards	Geological conditions that may lead to localized or widespread damage to property and threaten personal safety. Common examples of geohazards can be related to both geotechnical (e.g., landslides and ground movements) and hydrotechnical site conditions (e.g., flooding and shoreline erosion).
Glaciofluvial	Materials deposited by glacial meltwater streams either directly in front of, or in contact with, glacier ice.
Glaciolacustrine	Lacustrine materials deposited in or along the margins of glacial lakes; includes sediments that were released by the melting of floating ice.
Organic (soil)	Soil order classified under the Canadian Soils Classification System (Agriculture and Agri-Food Canada 1998) that is comprised of material of botanical origin varying in different degrees of decomposition within the pedon.
Overburden	Deposition material that is found below topsoil or organic soil and above mine rock that can sometimes be used in reclamation.
Parent materials	Sediments from which soils form that are classified based on their mode of formation.
Project Area	Encompasses the anticipated area of physical disturbance associated with the construction and operations of the Project.
Project Components	The proposed individual facilities and features to be constructed within the Project Area for the Project, from construction to closure.
Subsoil	Weathered material underlying the surface soil.

Crawford Nickel Project Impact Statement
Glossary of Technical Terms – Chapter 10 Assessment of Potential Effects on Geology and Geologic Hazards
September 30, 2024

Surficial Material	Surficial materials are non-lithified, unconsolidated sediments. They are produced by weathering, sediment deposition, biological accumulation, human and volcanic activity.
Topsoil	Leaf litter or organic layer and A and/or AB horizon of mineral soils.
Till	Material deposited directly by glacier ice without modification by any other agent of transportation.

10 Assessment of Potential Effects on Geology and Geologic Hazards

Geology and Geologic Hazards was selected as a Valued Component (VC) because of potential effects the Crawford Nickel Project ('the Project') may have on areas of geological instability, including the potential for increased landslides, slope erosion and potential for ground and rock instability/landslides, and subsidence during the operations, decommissioning and closure phases of the Project.

Geologic hazards (or geohazards) are defined as geological conditions that may lead to localized or widespread damage to property and threaten personal safety. Common examples of geohazards can be related to both geotechnical (e.g., landslides and ground movements) and hydrotechnical site conditions (e.g., shoreline erosion leading to the initiation of a landslide). While 'geology' is defined as the solid layer of rock underlying the unconsolidated soils and sediments, the current chapter includes the assessment of both the unconsolidated sediments forming the overburden, as well as the underlying bedrock strata.

The Tailored Impact Statement Guidelines (TIS Guidelines) identify the need to describe effects of the Project geology and geohazards including areas of geological instability caused by historical mining activities, and the potential for increased landslides, slope erosion and potential for ground and rock instability/landslides, and subsidence during the construction, operations, and decommissioning and closure phases of the Project.

The Project may affect geology and geohazards because of potential changes to terrain stability through the aggravation of existing geohazards, or the occurrence of new ones.

Geology and Geologic Hazards are linked to other VCs, including:

- Soil (Chapter 11), whereby changes in terrain stability may affect soil quality and/or quantity (and vice versa).
- Groundwater (Chapter 14), whereby changes in terrain stability may affect groundwater quality and/or quantity.
- Surface Water (Chapter 15), whereby changes in terrain stability may affect surface water quality and/or quantity.
- Vegetation, Riparian and Wetland Environments (Chapter 16), whereby changes in terrain stability may affect soils and vegetation communities.

10.1 Scope of Assessment

An assessment of the impacts of the Project was conducted to determine potential residual changes to geology and geohazards.

10.1.1 Regulatory and Policy Setting

10.1.1.1 Federal Requirements

The Project is being assessed in accordance with the *Impact Assessment Act*, 2019, which requires that it include a description of the baseline for the environmental, health, social and economic conditions related to the Project. The requirements to consider potential Project effects on geology and geologic hazards are described in Section 8.2 of the TIS Guidelines for the Project.

10.1.1.2 Provincial Requirements

The Ontario *Mining Act* (R.S.O. 1990, c. M.14 Part VII: Rehabilitation and Remediation of Lands), Ontario Regulation (O. Reg.) 35/24 (Rehabilitation of Lands) and the Mine Rehabilitation code of Ontario provide guidelines related to geological hazards and terrain stability. This includes the following:

- Part 2 Open Pits relates to limiting potential hazards (i.e., including potential pit instability), maintain public safety and restore the site to an appropriate land use.
- Part 8 Physical Stability Monitoring of the Code relates to the current Impact Statement chapter, where the objective of the guidelines is to “ensure the safety of the site by requiring that all lands, water management structures and other mine-related structures are left in a stable condition”.
- Part 9 Revegetation of the Code also contains guidelines that related to terrain stability.

Refer to the *Mining Act* and O. Reg. 35/24 for the details regarding each of the above-sited parts of the Act.

10.1.2 The Influence of Consultation and Engagement on the Assessment

Canada Nickel Company (Canada Nickel) has engaged with potentially affected Indigenous nations, regulators, landowners, and other stakeholders. Table 10.1 provides a summary of the topics, key information including Indigenous knowledge, and concerns that Canada Nickel identified as part of their engagement efforts that relate to geology and geologic hazards, as well as a summary of the influence that the outcomes of this engagement had on the assessment.

This information was considered when evaluating whether Canada Nickel's planned mitigation will effectively manage the identified potential interactions, or whether additional or refined mitigation is warranted.

Table 10.1 Summary of Key Information, Indigenous Knowledge, and Concerns for the Project Related to Geology and Geologic Hazards

Topic	Key Information, Indigenous Knowledge, and Concerns	Influence on the Assessment	Where Information is Addressed in the Impact Statement
Geology and Geologic Hazards in the Project Area	<ul style="list-style-type: none"> • Apitipi Anicinapek Nation, Flying Post First Nation, Matachewan First Nation, Mattagami First Nation, and Taykwa Tagamou Nation recommend potential re-use of excavated waste rock to improve nearby ATV trails. • Taykwa Tagamou Nation recommends Canada Nickel conduct further geochemical analysis to assess the potential for metal leaching under acidic and non-acidic conditions, for tailing, waste rock, and other rock materials that will be stockpiled and left on site. Taykwa Tagamou Nation also recommends Canada Nickel prepare contingency plans that demonstrate how stockpile or tailings runoff can be managed in a manner that allows for runoff waste to be safely discharged to the environment following Project closure. • Members of the public and/or other stakeholders requested additional information regarding: <ul style="list-style-type: none"> - surficial geology, including mineralogy, the presence of chrysotile in rock, and applicable mitigation measures - geotechnical studies completed to date - brucite and carbonation process - range of recoveries anticipated for Canada Nickel 	<ul style="list-style-type: none"> • Informed engagement plans. • Contributed to the development of mitigation and management measures, supported scope of issues assessed, and the development of a Conceptual Acid Rock and Metal Leaching Management Plan (Appendix L of the Impact Statement). • Informed the assessment of effects on Indigenous interests in Chapters 25 to 28 of the Impact Statement (Assessment of Potential Effects on Indigenous Interests). • Canada Nickel’s responses to mitigation recommendations made by the Indigenous nations are provided in Chapters 25 to 28 of the Impact Statement (Assessment of Potential Effects on Indigenous Interests). 	<ul style="list-style-type: none"> • Chapter 10 (Assessment of Potential Effects on Geology and Geologic Hazards), Sections 10.2, 10.4.2 • Chapter 11 (Assessment of Potential Effects on Soil and Sediment), Sections 11.4 and 11.9 • Chapters 25 to 28 (Assessment of Potential Effects on Indigenous Interests) • Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement) • Geotechnical Investigation Factual Report (Appendix B.12 of the Impact Statement) • Conceptual Acid Rock and Metal Leaching Management Plan (Appendix L of the Impact Statement)

Where made available by Indigenous nations through engagement, information gathering, and voluntary information sharing, Indigenous knowledge has been considered and incorporated into the Impact Statement, as applicable. Refer to the Description of Engagement with Indigenous Peoples (Chapter 7 of the Impact Statement) for detailed methods regarding the incorporation of Indigenous knowledge to the Impact Statement.

10.1.3 Potential Effects, Pathways and Measurable Parameters

The Project may affect geology and geohazards because of potential changes to terrain stability through the aggravation of existing geohazards, or the occurrence of new ones. The key potential effect addressed in the assessment on geology and geohazards is the ‘change in terrain stability’ due to Project construction and operations activities. Measurable parameters facilitate qualitative or quantitative measurement of Project effects and provide a means to evaluate the change to a VC. The potential effects, effect pathways and measurable parameters for the geology and geohazards assessment are provided in Table 10.2.

Table 10.2 Potential Effects, Effect Pathways and Measurable Parameters for Geology and Geologic Hazards

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change to terrain stability	<p>Aggravation of existing geohazards, or occurrence of new ones (e.g., landslides, slope erosion and potential for ground and rock instability/landslides).</p> <p>Effect pathways include excavations, land clearing (vegetation removal, topsoil and/or organics stripping), and water management.</p>	<p>Quantitative: Surface topography using digital surface models (e.g., subsidence monitoring).</p> <p>Qualitative: The increase occurrence of erosion and mass movements (e.g., visual reconnaissance and terrain mapping exercise).</p>

10.1.4 Boundaries

10.1.4.1 Spatial Boundaries

The **Project Area (PA)** encompasses the Project footprint and is the anticipated area of physical disturbance associated with the construction, operations and decommissioning and closure of the Project. The PA includes the 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 existing 500 kilovolt (kV) transmission line. The extent of the PA for the Project is shown on Figure 10.1.

The **Local Study Area (LSA)** encompasses the area in which Project-related effects (direct or indirect) on geology and geologic hazards can be predicted or measured with a level of confidence appropriate for the assessment. The LSA includes the PA as well as a 500 metre (m) buffer applied to the PA. This LSA is considered large enough to provide a confident assessment of the effects on geology and geologic hazards from the Project and potential cumulative effects from the Project and previous, existing and reasonably foreseeable developments. The extent of the LSA for geology and geologic hazards is shown on Figure 10.1.

Given the localized nature of potential Project-related effects to geology and geological hazards, the **Regional Study Area (RSA)** is the same as the LSA and is shown on Figure 10.1.

10.1.4.2 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 5): 60 kilotonnes 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+)

10.1.5 Residual Effects Characterization

The characterizations used to assess residual effects on geology and geologic hazards are provided in Table 10.3.

Table 10.3 Characterization of Residual Effects on Geology and Geologic Hazards

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect.	<p>Positive – a residual effect that moves measurable parameters in a direction beneficial to geology and geologic hazards relative to baseline.</p> <p>Adverse – a residual effect that moves measurable parameters in a direction detrimental to geology and geologic hazards relative to baseline.</p> <p>Neutral – no net change in measurable parameters for the geology and geologic hazards relative to baseline.</p>
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions.	<p>Negligible – no measurable change in the effect can be noted.</p> <p>Low – effect slightly exceeds baseline conditions but has no impact on slope stability or geologic hazard potential.</p> <p>Moderate – effect exceeds baseline conditions and creates terrain conditions with limited geologic hazard potential.</p> <p>High – effect exceeds baseline conditions and results in the presence of unstable terrain susceptible to geological hazards.</p>
Geographic Extent	The geographic area in which a residual effect occurs.	<p>PA – residual effects are restricted to the PA.</p> <p>LSA/RSA – residual effects extend into the LSA/RS.</p>

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Timing	Considers when the residual effect is expected to occur, where relevant to the VC.	No sensitivity – timing does not affect VC. Moderate sensitivity – timing may affect VC during lower sensitivity period, but the effects are manageable with proper planning and mitigation measures. High sensitivity – residual effects occur during high sensitivity period.
Duration	The time required until the measurable parameter or the VC returns to its existing condition, or the residual effect can no longer be measured or otherwise perceived.	Short-term – residual effect restricted to no more than the duration of the construction phase (<3 years). Medium-term – residual effect extends through the operations phase (3-41 years). Long-term – residual effect extends beyond the operations phase (>41 years).
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase.	Single event Multiple irregular event – occurs at no set schedule. Multiple regular event – occurs at regular intervals. Continuous – occurs continuously.
Reversibility	Pertains to whether a measurable parameter or the VC can return to its existing condition after the project activity ceases.	Reversible – the residual effect is likely to be reversed after activity completion and reclamation. Irreversible – the residual effect is unlikely to be reversed.

10.2 Existing Conditions for Geology and Geologic Hazards

10.2.1 Methods

The existing (baseline) geology and geologic hazard conditions in the PA and LSA/RSA were characterized by completing the following tasks, as outlined in the Soils and Terrain Baseline Report (Appendix B.1), which are listed in operational order:

1. Compilation and review of available background information, including:
 - a. Site-specific datasets and reports provided by Canada Nickel, including Light Detection and Ranging (LiDAR) data used for terrain mapping as part of the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement).
 - b. Project-specific reporting completed by third-party consultants, including Borrow Source Test Pit Field Program (Golder Associates Ltd. 2022) in Tailings Management Facility Feasibility Design (WSP 2023), the 2023/2024 Geotechnical Field Investigations by SRK Consulting Ltd. (Appendix B.12.1 and B.12.2 of the Impact Statement).
 - c. Recent satellite imagery (Google™ Earth Pro and ESRI® ArcGIS online imagery), dated from 2019-2022.
 - d. Provincial surficial geology mapping, bedrock geology mapping, soils mapping, and well records (water).

- e. Other relevant, publicly available reports and scientific literature.
2. Preliminary mapping and classification - Completion of preliminary (pre-field assessment) mapping and terrain classification in ESRI® ArcGIS using client-supplied LiDAR and terrain mapping and classification standards for the Province of British Columbia (due to a lack of any provincial terrain standards for the Province of Ontario). The scale of mapping was completed at ~1:2,500 to 1:7,500 and presented as a map at a scale of 1:10,000 in Appendix B.1 of the Impact Statement.

The specific mapping methodologies utilized by Stantec are outlined in Appendix B.1 of the Impact Statement.

3. Field survey program - Field investigation to verify the mapping and determine whether geologic hazards (geohazards) that are present in the PA or LSA, with particular attention given to watercourses with moderate to steeply incised slopes.
 - a. A field program was completed in October of 2023, and included assessment of both the terrain (including but not limited to characteristics such as surficial materials, drainage, topography in addition to geohazards) and soils. Due to the large size of the LSA/RSA (16,453 hectares [ha]), both field traverses and soil pits were strategically planned in areas where geohazards would be most likely and where planned infrastructure is sited, respectively.
 - b. Information documented during the field program included slopes, surficial materials, drainage conditions, depth to bedrock, land use, and complete soil profile details for 106 hand dug or augured inspection sites.
 - c. The field program was also supported by utilizing pre-existing data from 107 boreholes, test pits, and monitoring wells completed for geotechnical and groundwater studies.
4. Final soils and terrain mapping - Revision (where necessary) and finalization of terrain (and soils) mapping and subsequent assignment of the following ratings to the Soil Map Units (SMUs):
 - a. Water erosion risk
 - b. Soil compaction risk
 - c. Soil reclamation suitability

The SMU ratings are discussed in Chapter 11 of the Impact Statement (Assessment of Potential Effects on Soil and Sediment).

10.2.2 Overview

The PA and LSA/RSA have been partly disturbed through a combination of historical timber harvesting operations, highway construction (Highway 655, with an average width of ~45 m), and transmission line construction (with an average right of way width of 65 m). Intact mature and successional forest (both coniferous and boreal), as well as wetlands, lakes, small watercourses, and larger tributaries are present throughout the PA and LSA/RSA. Several roads (both primary and secondary resource roads) have also been established throughout the LSA/RSA. An example of a primary road is the Lower Sturgeon Dam

Road situated on the west side of the LSA/RSA near the proposed West Stockpile. The most (currently) disturbed area is situated in the southern end of the LSA/RSA, as it overlaps with part of Glencore Inc.'s operating Kidd Creek Mine.

From the terrain mapping completed as part of the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement), it was confirmed that the most frequent surficial materials expected in both the PA and LSA consist of (in order of importance) glaciolacustrine (LG), followed by organics (O) then till (M).

Within the PA, local ground surface elevations typically range between a high of 286 m above sea level to the south, to a low of 266 m above sea level to the northwest. Local average relief is generally under 15 m. Site slopes average 2 percent (%) (1.2 degrees [°]), with little evidence of underlying bedrock expression due to deep surficial materials; only 1 ha of exposed bedrock was mapped ~285 m west of Highway 655 (existing alignment) in the southern portion of the LSA/RSA. Another area of shallow surficial materials (near surface bedrock) is situated in the southern portion of the LSA/RSA, east of the existing Highway 655.

The two most notable landforms in the LSA/RSA are the esker complex containing kettle lakes along the west of the current highway position (and planned Tailings Management Facility [TMF]) and the deeply incised Jocko Creek, which intersects the PA/LSA/RSA southwest of the TMF and north of Kidd Creek. The Jocko Creek floodplain is situated up to 8 m below the surrounding terrain due to creek incision through a fine-grained glaciolacustrine-dominated landscape.

The geotechnical characteristics of the PA and LSA/RSA are best documented in the Geotechnical Report completed by WSP (formerly Golder) (Golder Associates Ltd. 2022) and SRK Consulting Inc. (Appendix B.12.1 and B.12.2 of the Impact Statement) for Canada Nickel. The Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement) utilized the borehole, test pit, and monitoring well results from these programs (106 total) to refine both the terrain and soils mapping; generally, only information from the top 3 to 4 m is used. Additional subsurface information and stability criteria developed for the Open Pit slope are contained within the Project Feasibility Report (Ausenco Engineering Canada ULC 2023).

The bedrock geology of the PA and outlying LSA/RSA has been summarized from 2011 mapping by the Ontario Geological Survey (OGS) (Ontario Geological Survey 2011). It is noted here that this mapping is at a 1:250,000 scale therefore, local differences (from the mapping) are certainly possible and expected. Broadly, all bedrock is a succession of supracrustal rock units dated from 3.2 to 2.5 billion years. From north to south in the LSA, the main geological units are:

- Felsic to intermediate metavolcanic formations (dacitic and andesitic flows, tuffs and breccias)
- Mafic to intermediate metavolcanic flows (basalt, andesite, tuff and breccias)
- Metasedimentary rocks (wacke, siltstone, argillite)

Within all these units, there are intrusive contact rocks, mafic to ultramafic rock, and granitoid intrusions. In the north and middle metavolcanic formations, iron formations have a northwest-southeast orientation.

Exposed bedrock was observed on the west side of Highway 655, due west of Boundary Lake in the southern portion of the LSA/RSA. Otherwise, unconsolidated sediments tend to be deep (up to 80 m), covering the bedrock over the majority of the LSA/RSA.

The OGS mapped three sub-parallel faults over the PA, starting northwest and converging southeast on the east side of the LSA/RSA. Every major structure area is crossed by these three faults, including the Open Pit, Stockpiles, and the TMF. 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 (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.

From the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement), it is noted that no earthquake with a magnitude greater than three has occurred within the LSA in the last 40 years since records have been kept by the OGS.

No historical or recent landslides were identified in the LSA/RSA as part of the baseline assessment; the main reason for this is the overall subdued topography. The future occurrence of small landslides is opined to still remain a possibility, and if they occur, are most likely along the moderately steep to steep slopes along the watercourses delineated throughout the LSA/RSA (in particular Jocko Creek).

Natural riverine processes such as bank erosion, flooding, and gullying, are not considered to be landslides; further downcutting into the soft glaciolacustrine is expected to occur over time, which will result in deeper and potentially steeper watercourse banks. Existing erosion along the banks of Jocko Creek is likely from review of the bare-earth hillshade (derived from LiDAR), particularly at the meander bends where the river erodes into the toe of moderately-steep (up to 50%) valley slopes.

As outlined above, the OGS does not indicate active versus inactive faults in the LSA/RSA; it is noted that in the last 40 years, no magnitude 3.0 or greater earthquake has been recorded by the OGS, which may indicate the identified faults in the LSA/RSA are currently inactive. As noted in the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement), the Project is located in a stable continental region within the North American Plate and, as a consequence, has a relatively low level of seismic activity (Earthquake Canada, 2024). Earthquakes recorded for the 2010-2019 period show only 1 or 2 magnitude events for the Timmins area, all are assumed related to blasting events associated to nearby mining activities (e.g., Kidd Creek Mine, southwest from the Project LSA/RSA).

At a regional scale, there is a still active isostatic rebound (rise) in the range of 6.4 ± 2.6 mm per year registered at nearby Timmins, Ontario (Peltier, Argus and Drummond 2015).

Subsidence, or gradual settling or sudden sinking of the earth's surface due to anthropogenic processes such as excavation, groundwater withdrawal, organic soil disturbance (wetland draining), underground mining, sinkholes (e.g., karst), and permafrost degradation, was not observed to be occurring within the limits of the PA and LSA/RSA from the review of background data and terrain mapping exercises.

No historical mining activities are evident in the LSA/RSA. As such, there are no associated instabilities with historical mining. The Kidd Mine, which is located approximately 0.7 km from the southwestern limit of the LSA/RSA is the closest existing mining activity to the project. Mining-related hazards such as subsidence, however, have occurred in the broader region, the most notable instances being related to the severe subsidence (sinkholes) that occurred at a number of locations on the former Hollinger and McIntyre mine sites located in Timmins.

Additional baseline details and mapping are contained in the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement) and should be referred to for more detail of the above summarized baseline conditions.

10.3 Project Interactions with Geology and Geologic Hazards

Table 10.4 identifies, for each potential effect, the physical activities that might interact with the VC and result in the identified effect. These interactions are indicated by a check mark (✓) and are discussed in detail in Section 10.4, in the context of effects pathways, standard and Project-specific mitigation/enhancement, and residual effects.

Table 10.4 Project Interactions with Geology and Geologic Hazards

Physical Activities	Effects
	Change to terrain stability
Construction	
Mobilization of construction equipment and materials on site.	–
Vegetation clearing, including the removal and disposal of trees, brush, shrubs, and other foliage.	✓
Stripping, including the removal of topsoil and other organic materials, as well as storing of some materials for use in reclamation.	✓
Grading of overburden to be used as fill.	✓
Handing and use of explosives, including blasting.	✓
Excavating and pre-stripping of mine rock from the Open Pit and surrounding area.	✓
Development of the Impoundment Facility for storage of rock, clay, sand, and till.	✓
Preparation of construction surfaces, including hauling reclaimed graded material and crushed mine rock to construction locations.	–
Construction of water management systems to collect, manage, treat and discharge contact water from mine components to the receiving waterbodies via collection ponds, ditches, and water treatment plants.	✓
Construction of minor water diversions around perimeter of the mine site to collect and divert flows.	✓
Dewatering of natural water bodies within the Project Area.	✓
Waste management, including collection and temporary storage.	–
Construction of mine infrastructure, including crusher facilities, process plant and Tailings Management Facility, as well as the potable water well, and	✓

Physical Activities	Effects
	Change to terrain stability
ancillary infrastructure (e.g., offices, workshop, fuel farm, magazine storage and explosives pad).	
Construction of internal haul roads and internal access roads, including water crossings.	✓
Construction of power supply and distribution systems.	–
Construction of temporary Highway 655 by-pass and overpass.	✓
Construction of the rail spur.	✓
Vehicle operation within the Project Area.	–
Employment and expenditures ¹ .	–
Operation (Mining and Processing)	
Construction of Project infrastructure, including the expansion of ore processing components.	✓
Relocation and decommissioning of Highway 655 and associated infrastructure.	✓
Relocation of 500 kV transmission line.	–
Construction of the North Driftwood Diversion Channel.	✓
Handling and use of explosives including blasting.	✓
Ore extraction in the Main Zone and East Zone of the Open Pit, including drilling, loading and hauling of mine rock from the pits.	✓
Maintenance and management of mine rock stockpiles, overburden, and Tailings Management Facility.	✓
Ore processing, including conveyor, crushing and processing activities with and between the Stockpiles, crusher facilities and Process Plant.	–
Operation of water management systems, including the collection, management, treatment and discharge of contact water from mine components to the receiving waterbodies via collection ponds, ditches and water treatment plants.	–
Transportation of Ore via the rail spur line.	–
Waste management, including collection and temporary storage.	–
Vehicle operation within the Project Area.	–
Progressive reclamation of disturbed areas.	✓
Employment and expenditures ¹ .	–
Decommissioning and Closure	
Pit flooding through the creation of channels from the collection ponds towards the Open Pit.	✓
Water management, including groundwater and surface water.	–
Decommissioning, dismantling and/or disposal of buildings and mine infrastructure.	–
Removal of power lines and electrical equipment.	–
Decommissioning of potable water and sewage systems.	–
Vehicle operation within the Project Area.	–

Physical Activities	Effects
	Change to terrain stability
Reclamation, including the placement of overburden, seeding and re-grading.	✓
Monitoring and maintenance.	–
Employment and expenditures ¹ .	–
Notes: ✓ = Potential interaction – = No interaction 1. Project employment and expenditures are generated by most Project activities and are the main drivers of many potential socio-economic effects. Rather than acknowledging this by placing a checkmark against each of these activities, 'employment and expenditures' is listed as a separate item under each phase of the Project.	

There are several Project non-interactions in each of the Project phases specifically for geology and geologic hazards, with effects to terrain stability (as outlined above in Table 10.4).

Construction Phase

For the construction phase, the mobilization of vehicles and other equipment, as well as the movement of materials via vehicles and equipment is not expected to impact terrain stability. There will be soil impacts (e.g., soil quality) associated with material mobilization but these are discussed in Chapter 11 of the Impact Statement (Assessment of Potential Effects on Soil and Sediment). The operation of vehicles in all phases (construction, operations, and decommission and closure) will not interact with geology or geologic hazards, as their operation will not change the in-situ materials, the topography, nor the stability of the roadways and parking areas where they are operated.

During the construction phase, the grading of (*in situ*) overburden to be used as fill will not interact with terrain stability. As discussed in the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement), the vast majority of the LSA features gentle topography with slopes under 2%. The exceptions are gullied areas around Jocko Creek, North Driftwood River, and the esker complex identified to the west of the TMF (which rises ~15 m above the broad glaciolacustrine plain). The grading of fill into areas of deep organics (that cannot be reasonably excavated and replaced) and waterbodies depends on whether the associated areas are drained and therefore, this interaction is considered as part of the dewatering activities (which may result in subsidence and therefore not identified as a non-interaction).

The preparation of construction surfaces (including hauling of reclaimed graded material and crushed mine rock) during the construction phase will similarly not interact with terrain stability due to the overall subdued topography over the majority of the LSA/RSA. Construction surfaces are assumed to be laydown areas, stockpile locations, and boundaries of planned components such as buildings, pit, and access roads.

Waste management during the construction phase will not interact with terrain stability; the hauling of waste can be facilitated by utilizing existing roads to a designated off-site facility.

Note that during the preliminary construction phase, the clearing and disposal of vegetation and the stripping of topsoil over the broadly gentle landslide (overall slopes are under 2% or 1.2°, as outlined in the Soils and Terrain Baseline Report [Appendix B.1] of the Impact Statement) will not result in changes to terrain stability, however, the exception to this is vegetation and organic topsoil stripped/removed from the headwalls and side slopes of gullies in the vicinity of Jocko Creek and to a lesser extent, the North Driftwood River, which could result in small, localized failures and/or slope erosion. Therefore, this activity is identified as a potential interaction.

Operations Phase

As for construction, the operation of vehicles in the LSA/RSA is not expected to result in an interaction with terrain stability.

The transport of ore via railway during operations does not interact with terrain stability. The railway, once constructed, will remain a permanent Project component that is situated over broadly gentle terrain. Any subsequent construction or maintenance (e.g. track re-alignment, replacement of crossings) to the railway in the vicinity of the Jocko Creek and North Driftwood River crossings may have an interaction with terrain stability however, this does not fall under the physical activity of transport itself.

The operation of ore processing equipment between stockpiles and associated facilities and plants will not have an interaction with terrain stability. These conveyors and facilities, once constructed, will have no impact to the topographically subdued ground surface.

The management of waste (non-water) will continue to not interact with terrain stability during the operations phase, for the same reasons as discussed above.

Note that the handling of explosives does not interact with terrain stability however, the use of explosives does, and this remains listed as an interaction. This technically falls under the physical activity of blasting.

Decommissioning and Closure Phase

During decommissioning and closure of the Project, the dismantling and disposal of buildings and other mine infrastructure such as ore processing equipment will not have an interaction with terrain stability. This does not include the closure of the Open Pit (which will be flooded, and identified as an interaction), nor the TMF, which will be monitored and maintained (and considered an interaction due to the potential for instability within the TMF).

The removal of power lines, electrical equipment, and potable water and sewage systems will not result in an interaction to terrain stability. This assumes that these components will be sited in areas of gentle topography and away from the gullied side slopes of both Jocko Creek and North Driftwood River. Power lines, unlike highway and railway crossings, can be sited at a sufficient distance to avoid any construction impacts (including but not limited to ground vegetation clearing, topsoil stripping, creation of large cuts and fills, and foundations) to the identified gully slopes in the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement) and associated mapping.

The operation of vehicles during the decommissioning and closure phase on established roadways will not interact with terrain stability.

10.4 Assessment of Residual Effects on Geology and Geologic Hazards

10.4.1 Analytical Assessment Techniques

The analysis of the Project interactions was completed by reviewing baseline information, as well as detailed terrain mapping and datasets for the PA and LSA/RSA in conjunction with the locations of the proposed Project components.

Using available orthoimagery and LiDAR data, the LSA/RSA was divided into geomorphological units characterized by distinct surficial geology, landforms, and geomorphological processes (see terrain mapping conducted as part of the Soils and Terrain Baseline Report [Appendix B.1] of the Impact Statement). The LiDAR was used to compile a 1 m digital elevation model (DEM), from which a grey-scaled bare-earth hillshade raster image was produced. The use of bare-earth images provides the advantage of displaying the ground surface without the vegetation cover, therefore allowing for visualization of topographic features otherwise hidden by the canopy layer.

10.4.2 Change to Terrain Stability

10.4.2.1 Project Pathways

The mechanisms, or pathways by which the effects may occur include:

- Vegetation removal and soil stripping (land clearing) from areas of moderately steep slopes (>35% or 3H:1V) and gullied terrain around Jocko Creek and North Driftwood River to facilitate the construction of Project components, including the relocation of the highway, transmission line, and railway. This pathway would occur during both the construction and operations phases of the Project, due to the relocation being scheduled during the early part of the operations phase.
- Excavations to prepare, construct, maintain, and reclaim project components, particularly those that create steep and/or undermined slopes (i.e., the Open Pit, diversion channels) and those in the vicinity of the moderately-steep slopes and gullied terrain of Jocko Creek and North Driftwood River. This pathway would occur during all Project phases.
- Weathering and potential instability of newly exposed rock masses as part of the excavation of the Open Pit.
- Surface water runoff during all phases of the Project in areas of exposed fine-grained soils (e.g., excavation or material storage areas) and in proximity to moderately-steep, gullied terrain identified in the Soils and Terrain Baseline Report of the Impact Statement (Appendix B.1). Specifically, any mismanagement of water can aggravate existing gully erosion and result in new instabilities along stream banks, particularly if vegetation and soil has been removed for

construction. Examples include uncontrolled drainage or discharge and undersized diversion channels and ponds, which can be exacerbated by adverse weather conditions.

10.4.2.2 Mitigation and Enhancement Measures

Potential changes to terrain stability within the PA and LSA/RSA can be avoided or reduced by deploying mitigation and enhancement measures, particularly around the Open Pit, TMF, the identified gullied terrain around Jocko Creek and North Driftwood River as well as in the vicinity of all artificial water management components such as ponds and diversion channels.

The following measures have been incorporated into the design of the Project and/or are proposed to avoid or reduce Project-related effects on geology and geological hazards:

- Canada Nickel will apply best management practices to promote terrain stability via recontouring, terracing or benching and maintaining slope gradients for all excavated areas and stockpiled materials through the duration of the Project for construction activities.
- Canada Nickel will prepare and implement an Erosion and Sediment Control Plan prior to construction to reduce the potential for erosion and sedimentation into the surrounding environment.
- Canada Nickel will prepare and implement a Soil Management and Rehabilitation Plan that will outline mitigations to revegetate soils to stabilize surface materials from erosion.
- Canada Nickel will implement a Site-Wide Water Management Plan (Appendix J of the Impact Statement) for all phases of the Project, including a dewatering strategy to mitigate the risk of slope instability within the pit slopes.
- At closure, Canada Nickel will conduct a slope stability assessment to demonstrate the long-term physical stability of the Open Pit and the Impoundment Facility. For the TMF embankments, Canada Nickel will demonstrate that the requirements set out by the Global Industry Standard on Tailings Management or and Canadian Dam Association (CDA) guidelines for long-term care are met.

10.4.2.3 Project Residual Effects

Potential changes in terrain stability most commonly relates to physical activities that involve ground disturbance. Typical activities often include clearing, topsoil stripping, grading and excavating. While near surface ground disturbance activities such as vegetation clearing, topsoil stripping may cause localized instabilities, they are not expected to result in an increase of residual terrain instability as potential hazard scenarios will be mitigated through the implementation of the above-listed mitigations and enhancement measures.

It is expected that residual effects of the Project on terrain stability will be associated with activities resulting in significant alteration of baseline slope gradients and material characteristics. Such activities are primarily expected to occur at the Open Pit and Impoundment Facility, where moderately steep to steep slopes will be created from excavation activities.

During construction, topsoil and overburden will be removed to reach the main nickel orebody. Excavating normally consolidated, soft, saturated clays, and sand and till layers, with a combined thickness ranging from 10 m to 90 m, with an average thickness of about 40 m across the PA, will present technical challenges. The inherent weakness of the saturated clay soils could potentially affect the structural integrity of the overburden slopes within the pit. Potential high degrees of saturation within the clay and sand layers are expected to add complexity to the stability of the pit overburden slopes. These conditions could lead to localized instability along the Open Pit slopes (e.g., soil and rock landslides). Localized instabilities are also possible along the pit slopes, for example where rock mass quality and joint conditions may influence the potential unravelling and failures of rock mass.

Once the impoundment facility is created, the soil and overburden stockpiles have the potential to present a landslide hazard. Soil and overburden stockpiles created during construction will continue to be maintained during operations to prevent erosion and slide hazard. Design-related mitigation will be applied to maintain stockpiles to prevent or limit slope erosion and to reduce the susceptibility to mass movements, the occurrence of localized instability is still possible.

10.4.3 Summary of Project Residual Effects

Table 10.5 summarizes Project residual effects on geology and geologic hazards.

Table 10.5 Project Residual Effects on Geology and Geologic Hazards

Residual Effect	Residual Effects Characterization							
	Project Phase	Direction	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in terrain stability	C, O	A	L	PA	NS	ST	IR	R
KEY								
See Table 10.3 for detailed definitions								
Project Phase			Geographic Extent:			Frequency:		
C: Construction			PA: Project Area			S: Single event		
O: Operations			LSA: Local Study Area			IR: Multiple Irregular event		
D: Decommissioning and closure			RSA: Regional Study Area			R: Multiple Regular event		
						C: Continuous		
Direction:			Timing			Reversibility:		
P: Positive			NS: No sensitivity			R: Reversible		
A: Adverse			MS: Moderate sensitivity			I: Irreversible		
N: Neutral			HS: High sensitivity					
Magnitude:			Duration:			N/A: Not applicable		
N: Negligible			ST: Short-term					
L: Low			MT: Medium-term					
M: Moderate			LT: Long-term					
H: High								

10.4.3.1 Summary of Adverse Residual Effects

As detailed in Table 10.4, changes in terrain stability may be associated with each Project phase. Adverse residual effects, on the other hand, are principally associated with the construction and operations as the alteration of natural terrain conditions during these Project phases could exacerbate baseline terrain stability, resulting in higher risks of occurrence of a geological hazard.

Within the context of the factors utilized to characterize adverse residual effects, and in consideration of proposed mitigations, the following is noted with respect to geology and geological hazards. The residual effect can be considered to be adverse (changes in terrain stability may occur), however are expected to be of low magnitude, and of negligible geographic extent (i.e., limited to localized instabilities within the PA). The effects are expected to be of short-term duration, of multiple irregular events, and reversible.

10.4.3.2 Summary of Positive Residual Effects

There are no positive effects of the project on geology and geologic hazards.

10.5 Potential Effects on Federal Lands

There are no federal lands within the LSA or RSA. The closest Federal lands are the Taykwa Tagamou Nation Reserve lands located approximately 37 km away (straight line) from the PA (14 km southeast of Cochrane). No additional mitigation measures beyond those identified are specifically required for federal lands.

10.6 Assumptions

Changes to geology and geologic hazards at each Project phase are predicted using the following assumptions:

- Topographic changes (with the exception of the Open Pit and TMF) will be limited relative to baseline conditions given the already subdued topography and slopes (under 2%) on average within the LSA.
- That 500 kV transmission line towers, highway components (relocated Highway 655), and the new railway components will be sited and designed in a way that limits disturbances (cuts, placement of fills, vegetation clearing) in the vicinity of the planned Jocko Creek crossing in the southern portion of the PA and the North Driftwood River in the northern portion of the PA. As outlined in the Soils and Terrain Baseline Report (Appendix B.1 of the Impact Statement), Jocko Creek in particular features deeply incised, moderate to moderately steep slopes and fine-grained glaciolacustrine sediments exposed along the banks.
- The final slopes of the Project facilities will be designed and engineered to be within ranges for geotechnical stability (e.g., 3:1 with bench heights not exceeding 20 m at the Sand and Till Impoundment). This is highly dependent on the Project component type, the surrounding geotechnical properties of the surficial materials and bedrock over which the facility is placed, and external sources of potential instability.
- Limitations of the field program include assessment of geohazards associated with yet to be constructed infrastructure such as tailings facilities (dam, dike, levee, or any other water retaining or diversion structure). Furthermore, the collection of field data regarding bedrock was limited by the lack of near-surface bedrock in the PA and LSA. There is therefore a reliance on the OGS bedrock mapping and associated reporting regarding occurrences of asbestos and faulting.

10.7 Prediction Confidence

The prediction confidence in assessing potential effects on terrain stability is high based on professional judgement, the overall quality of the data compiled as part of the baseline program, the experience learned from similar projects, as well as the expected effectiveness of proposed mitigation measures. Given the lack of existing geologic hazards in the area and limited potential for aggravation of hazards as a result of the Project, combined with the certainty regarding the engineered design of the Open Pit, TMF and other slopes on site, confidence in the predicted effects and effectiveness of proposed mitigation measures is high.

10.8 Follow-up and Monitoring

Canada Nickel will implement follow-up and monitoring programs to verify the accuracy of effects and to evaluate the effectiveness of mitigation measures, the results of which will be used to identify and implement adaptive management measures, as appropriate. As it relates to terrain stability, follow-up and monitoring measures will be implemented to monitor the dams around the TMF. Chapter 34 of the Impact Statement includes additional details on follow-up and monitoring programs proposed by Canada Nickel.

10.9 References

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Crawford Nickel Project Impact Statement
Chapter 10 Assessment of Potential Effects on Geology and Geologic Hazards
September 30, 2024

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10.10 Figures

