MACKENZIE VALLEY HIGHWAY PROJECT

DEVELOPER'S ASSESSMENT REPORT

Mandate commitment of the 19th Legislative Assembly

October 2023

VOLUME 3

Subjects of Note

Government of
Northwest Territories

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12.0 ASSESSMENT OF POTENTIAL EFFECTS ON AIR QUALITY

Air Quality has been selected as a Valued Component (VC), as it aligns with the Air Quality Subject of Note (SON) in the Terms of Reference (ToR) for the Developer's Assessment Report (DAR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]). The assessment of potential effects on air quality is valuable for its importance to the health and well-being of people, wildlife, vegetation, and other ecosystems biota. The assessment of potential effects on air quality considers criteria air contaminants (CAC) and greenhouse gases (GHG).

The CAC assessment considers risks from air contaminant emissions to human health and the environment. The assessed CACs are air pollutants that cause smog, acid rain and other health hazards, and can affect visibility by contributing to ice fog. They are typically products of fossil fuel combustion, and are emitted from many sources in industry, mining, transportation, electricity generation and agriculture. Project activities such as equipment operation, camp operations, borrow source and quarry development, and operations including blasting and crushing, dust control, and road traffic are expected to generate CACs.

The GHG assessment considers risks from air pollutant emissions associated with climate change, which has potential long-term ecological and socio-economic effects. As described by the Intergovernmental Panel on Climate Change (IPCC), GHGs are globally emitted from numerous natural sources, and human activities such as the combusting of fossil fuels (IPCC, 2013). Effects from GHG emissions are expected from the same project components as for CAC emissions, as well as the removal of forested areas, whose presence would remove the carbon dioxide (CO_2) from the atmosphere.

The assessment of potential effects on the Air Quality VC concludes that with the application of mitigation measures, residual effects resulting from the Project on air quality will be adverse. Residual effects and cumulative effects from the Project's GHG emissions are expected to exceed reporting thresholds; however, residual effects and cumulative effects from the Project's CAC emissions are not expected to exceed the Northwest Territories (NWT) 2018 to 2020 average facility CAC emissions. Therefore, residual effects and cumulative effects are predicted to be not significant.

12.1 Scope of Assessment

12.1.1 Regulatory and Policy Setting

The following regulations, programs, and protocols are used to quantify the CAC and GHG emission levels and establish thresholds to determine the effect of the air quality emissions on human health and the environment (especially wildlife and vegetation).

12.1.1.1 Change to Criteria Air Contaminants

The Environment and Climate Change Canada (ECCC) National Pollutant Release Inventory (NPRI) tracks the release of substances to the environment, including their disposal or their transfer for recycling (ECCC, 2022a). The program gives methods to quantify the contaminant emissions and lists threshold levels for each contaminant which, if exceeded, may pose a risk to the environment or to health. The Project's CAC emissions were estimated using the NPRI emission factors.

Although CAC concentration limits exist under different programs, such as the Government of the Northwest Territories (GNWT) Department of Environment and Climate Change (ECC) Guideline for Ambient Air Quality Standards in the Northwest Territories (GNWT, 2014), these limits are receptor-based, whereas NPRI is source-based. As NPRI does not specify source-based limits, the following thresholds are used to determine the potential effects from the Project's CAC emissions:

- NPRI reporting thresholds: The level at which the substances begin to pose a risk to the environment or to health. These reporting thresholds are obtained from the ECCC NPRI website (ECCC, 2022c).
- Average NWT facility emissions: The average facility CAC emissions are the average of each individual facility CAC emissions reported for the NWT for the past 3 years, from 2018 to 2020 (ECCC, 2022d). This gives an indication of where the Project's CAC emission levels stand in comparison to the existing CAC-emitting facilities in the NWT and is a better indicator of the potential effects from the CAC emissions. The rationale is that the Project's CAC emission levels are likely acceptable if they are within the range of the facilities' accepted emission levels existing within the NWT.

Table 12.1 lists the NPRI reporting thresholds for each project CAC emission.

Table 12.1 Criteria Air Contaminant Thresholds from NPRI

Substance	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$
Reporting Thresholds (t/year)	20.00	20.00	20.00	0.50	0.30
Average NWT Facility Emissions 2018 to 2020 (t/year)	176.82	258.55	69.23	24.26	8.75

Notes:

CO = carbon monoxide; NO_x = nitrogen oxide; SO_2 = sulphur dioxide; PM_{10} = coarse particulate matter; $PM_{2.5}$ = fine particulate matter

Dust includes the larger particles and smaller particles of PM_{10} and $PM_{2.5}$, as listed in Table 12.1. Since dust emissions other than PM_{10} and $PM_{2.5}$ are hard to quantify, they will be assessed qualitatively instead using general best-practice mitigation measures for highway projects to verify effects are within acceptable levels.

Ice fog affects visibility and will be assessed qualitatively.

12.1.1.2 Change to Greenhouse Gases

The NWT does not have a program that imposes limits on GHG emissions. Instead, the federal program from ECCC called Greenhouse Gas Reporting Program (GHGRP) will be used as guidance (ECCC, 2021a). Under the GHGRP, facilities that emit 10,000 tonnes of CO_2 equivalent (tCO_2e) per year must report their emissions to ECCC. This threshold will be used to assess the significance of the Project's GHG emissions.

The contribution of project GHG emissions will also be compared to the latest available NWT GHG emission total from the National Inventory Report (NIR), published by ECCC (ECCC, 2020), to quantify its contribution relative to the NWT total emissions.

12.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."* Additionally, CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

12.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land Use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to air quality. This feedback has been considered and summarized in Table 12.2 and has been integrated into the assessment of potential effects on air quality that follows.

12.1.3 Potential Effects, Pathways, and Measurable Parameters

The potential effects, pathways, and measurable parameters for CACs and GHGs are described.

12.1.3.1 Change to Criteria Air Contaminants

The CACs are divided into the gaseous CACs and particulate CACs, all of which are quantified in tonnes per year. The gaseous CACs associated with the Project are nitrogen dioxide (NO_2), carbon monoxide (CO), and sulphur dioxide (SO_2). As described in Environment and Climate Change Canada's (ECCC) Greenhouse Gas Emissions Reporting Program (ECCC, 2022a), the gaseous CACs are described, along with their associated sources from the Project:

- Sulphur dioxide is formed from the sulphur contained in raw materials such as coal, oil, and metal-containing ores. The SO_2 gas, on its own or in its transformed state, can cause adverse effects on respiratory systems of humans and animals, and damage to vegetation. Sulphur dioxide emissions are expected mainly from blasting activities during the project construction phase.
- Carbon monoxide gas is colourless, odourless, tasteless, and poisonous. It is a product of incomplete combustion of hydrocarbon-based fuels and is emitted directly from automobile tailpipes. Other lesser but significant sources are the wood industry, residential wood heating, and forest fires. The CO gas can have a serious effect on human health. It enters the bloodstream through the lungs and affects the respiratory system. Carbon monoxide emissions are expected mainly from blasting activities during the project construction phase, and from road traffic during the operations and maintenance phase.
- Nitrogen dioxide gas is formed primarily from the liberation of nitrogen contained in fuel and in combustion air during combustion processes. It dissolves in water vapour in the air to form acids and interacts with other gases and particles in the air to form particles known as nitrates and other products that may be harmful to people and their environment. The NO_2 gas, on its own or in its transformed state, can cause adverse effects on respiratory systems of humans and animals, and damage to vegetation. Nitrogen dioxide emissions are expected mainly from heavy truck equipment during the project construction phase and heavy truck traffic during the operations and maintenance phase.

Table 12.2 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
CAC Effects Major habitat changes that have occurred in the Dehcho Region have been due to oil and gas development, introduction of bison, and forest fires, which may cause a disturbance in air quality from the smoke.	Dehcho First Nations, 2011	The GNWT has identified mitigation measures to reduce or eliminate the effects on air quality. Cumulative effects are addressed in Section 12.5.1. The presence of forest fires and dust as existing conditions is addressed in the Technical Data Report (TDR) for Air Quality, Greenhouse Gas and Climate Baseline (see Appendix 12A; K'alo-Stantec, 2022b) and summarized in Section 12.2.2 of this report. Dust and emissions resulting from project activities are addressed in Section 12.4.2. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For mitigation measures to reduce or eliminate effects on air quality, see Table 12.7 See also: Section 12.2.2 (Overview) Section 12.4.2 (Change to Criteria Air Contaminants) Section 12.5.1 (Residual Effects Likely to Interact Cumulatively) Appendix 12A; K'alo-Stantec, 2022b
CAC Effects The community of Wrigley[1], expressed concerns about dust resulting from the project activities and pollution from the road operation.	Dessau, 2012 (Public Registry [PR]#13)		
CAC Effects Engagement participants expressed concerns about dust, including how far it will spread and whether there will be chemicals and carcinogens in the dust; they recommended appropriate dust suppressants and other control measures near water, including major creeks.	November to December 2022 Engagement		

[1] Wrigley (Pehdzéh Kį N'deh), hereafter referred to as Wrigley

Comment	Source	GNWT Response	Where Addressed
GHG Effects The Dehcho Region is reported to be getting warmer and wetter overall, with more rainfall in August and September and even into October.	Dehcho First Nations, 2011	The GNWT has identified mitigation measures to reduce or eliminate the effects on air quality. The historical and predicted change in climate is addressed in the TDR for Air Quality, Greenhouse Gas and Climate Baseline (see Appendix 12A; K'alo-Stantec, 2022b). The effect of climate on fish and wildlife is addressed in the TDR for Fish and Fish Habitat (see Appendix 17A; K'alo-Stantec, 2022c) and the TDR for Wildlife and Wildlife Habitat (see Appendix 19A; K'alo-Stantec, 2022d3), respectively. Food security is considered in Chapter 9 (Socio-Economic Impact Assessment). GHG emissions resulting from the project activities are addressed in Section 12.4.3. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	For mitigation measures to reduce or eliminate effects on air quality, see Table 12.7. See also: Section 12.4.3 (Change to Greenhouse Gas) Appendix 12A; K'alo-Stantec, 2022b Appendix 17A; K'alo-Stantec, 2022c Chapter 9 (Socio-economic Impact Assessment)
GHG Effects Community engagement participants from the Sahtu Region expressed concerns about warmer temperatures, thawing permafrost, erosion, slumping, and other environmental changes which negatively affect fish, wildlife, and food security.	November to December 2022 Engagement		

Particulate matter (PM) consists of airborne particles in solid or liquid form. Numerous studies have linked fine PM to aggravated cardiac and respiratory diseases, and to various forms of heart disease. PM can also have adverse effects on vegetation and structures and contributes to visibility deterioration and regional haze. The size of PM particles largely determines the extent of environmental and health damage. For this reason, ECCC identifies different sizes of PM. The PM CACs relevant to the Project are dust (total particulate matter or TPM), coarse particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$). Each are described (ECCC, 2022b).

- Dust: Composed of solid particles that are present in the atmosphere and includes the larger particles (Total Suspended Particulate [TSP] or TPM) and smaller particles of PM_{10} and $PM_{2.5}$. The larger particles (TSP or TPM), with an upper size limit of approximately 100 micrometres (μm) in aerodynamic equivalent diameter, do not have the ability to penetrate to the lungs to potentially cause adverse health effects because they are captured in the oral and nasal passages. The TSP and TPM are most closely associated with concerns related to aesthetics and can be a source of nuisance (BC ENV, 2020). Note that since dust emissions other than PM_{10} and $PM_{2.5}$ are hard to quantify, they will be assessed qualitatively. Thus, dust in this report refers to the TSP and TPM only. Dust emissions from the Project are expected mainly from mobile equipment activities and blasting activities. Dust emissions are not expected to be a concern during winter because the frozen ground and snow cover during winter act as natural dust suppression.
- PM_{10}: Airborne particulate matter with a mass median diameter less than 10 μm. It is associated with dust and can be a nuisance. PM_{10} emissions are expected mainly from blasting activities during the project construction phase and road traffic during the operations and maintenance phase.
- $PM_{2.5}$: Airborne particulate matter with a mass median diameter less than 2.5 μm. It is known to have harmful effects on human health and the environment and contribute to visibility impairment and regional haze. $PM_{2.5}$ emissions are expected mainly from truck traffic during the project construction phase and operations and maintenance phase.

The CACs excluded from the assessment are listed along with the reason for their exclusion:

- Volatile Organic Compounds (VOCs): Chemical compounds whose composition makes it possible for them to evaporate under normal atmospheric conditions. They are produced by fossil fuel use and production, and the use of indoor products like solvents. Although they are part of the CAC list in the NPRI as detailed in Section 12.1.1.1, they are not part of the Northwest Territories (NWT) ambient air quality standards (GNWT, 2014) and the Project is not expected to generate substantial amounts of VOCs.

Like dust, fog may affect visibility. Ice fog forms in calm conditions when there is excess moisture in the air and conditions are cold enough for moisture to freeze; this is aggravated by local emission sources such as idling vehicles (IOL et al., 2004). Potential sources that increase fog are construction vehicles and road traffic.

Table 12.3 summarizes the effect parameters for the change to CACs.

Table 12.3 Potential Effects, Effects Pathways and Measurable Parameters for Air Quality and Greenhouse Gases

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change to CACs	Atmospheric release of air emissions from project equipment and activities during construction and operations and maintenance	• Emissions of gaseous CACs (NO_2, CO, and SO_2) in tonnes per year • Emissions of particulate CAC (PM_{10} and $PM_{2.5}$) in tonnes per year • Emissions of dust as a qualitative assessment • Emissions of ice fog as a qualitative assessment
Change to GHGs	Release of GHG emissions to the atmosphere from project equipment and activities during construction and operations and maintenance	• GHG emissions (CO_2, CH_4, and N_2O) in tCO_2e per year

12.1.3.2 Change to Greenhouse Gases

The GHGs associated with the Project are CO_2, methane (CH_4), and nitrous oxide (N_2O), all of which are quantified in tCO_2e per year. Each GHG is described below and further in (IPCC, 2013):

- Carbon dioxide is a naturally occurring gas and a by-product of burning fossil fuels from fossil carbon deposits (such as oil, gas, and coal), of burning biomass, of land use changes, and of industrial processes (e.g., cement production).
- Methane is the major component of natural gas and associated with all hydrocarbon fuels, animal husbandry, and agriculture.
- Nitrous oxide is naturally produced from a wide variety of biological sources in soil and water, particularly microbial action in wet tropical forests. There are many anthropogenic sources of N_2O, however the most abundant source is agriculture (e.g., soil and animal manure management). Other common sources of N_2O include sewage treatment, combustion of fossil fuel, and chemical and industrial processes.

Greenhouse gas emissions are expected mainly from heavy truck equipment during the project construction phase, and road traffic during the project operations and maintenance phase. The removal of forested area will also result in the effect of reduction of CO_2.

The GHGs excluded from the assessment are listed along with the reason for their exclusion:

- Sulphur hexafluoride (SF_6): This gas can be found in insulating gas used in electrical switch breakers. If the Project does use a SF_6 breaker, they are closed cycle and do not escape into the atmosphere. Therefore, the SF_6 gas is not expected to be released by the Project.

- Nitrogen trifluoride (NF_3): This gas is used in industrial processes related to semiconductors and liquid-crystal display panels. It also occurs in certain types of solar panels and chemical lasers. The NF_3 gas is not expected to be used or released by the Project.
- Hydrofluorocarbon (HFC) and Perfluorocarbon (PFC): These groups of gases are typically used as refrigerants in various applications. If the Project does use these gases, the systems would be designed so that there are no releases of these gases to the atmosphere. Therefore, HFCs and PFCs were not included in this assessment.

Table 12.3 summarizes the effect parameters for the change to GHGs.

12.1.4 Boundaries

The spatial and temporal boundaries for the CAC effect and the GHG effect are presented.

12.1.4.1 Spatial Boundaries

The spatial boundaries are described for the CAC effect and the GHG effect.

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sources with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. For the CAC effect the LAA is approximately a 1-kilometre (km) buffer around the PDA. This distance, estimated from professional experience, represents the distance at which the CACs emitted from construction and transportation sources disperse or settle. This is explained by the fact that construction and transportation sources are mostly mobile, intermittent, and the emissions intensity is relatively low compared to large stationary sources such as municipal or industrial diesel power plants. According to the United States Environmental Protection Agency (US EPA), dust particles are likely to settle within a few hundred feet (tens of metres) from the road (US EPA, 1995). For the GHG effect, since the effect affects the world climate independent of distance, the LAA does not apply.
- **Regional Assessment Area (RAA)**: The area that provides context for determining the significance of project effects and potential cumulative effects. The Project is located within the Dehcho Region (Dehcho) and Tulita District of the Sahtu Region. For the CAC effect, the RAA for the assessment of CAC effects was set as approximately a 15 km buffer around the PDA. This distance, estimated from professional experience, represents the distance at which the CACs emitted from large stationary sources may disperse or settle to baseline values. Physical activities located beyond the 15 km buffer are not expected to interact with project residual CAC effects due to air dispersion over distance. As cumulative effect of GHG emissions affects the world climate independent of distance, the RAA does not apply for the GHG effect.

Figure 12.1 shows a map of the Project's air quality LAA and RAA. The yellow squares in Figure 12.1 are the facilities within the air quality LAA and RAA that reported emission to the ECCC NPRI system during 2018 to 2020. These facilities are further discussed in Section 12.2.2.

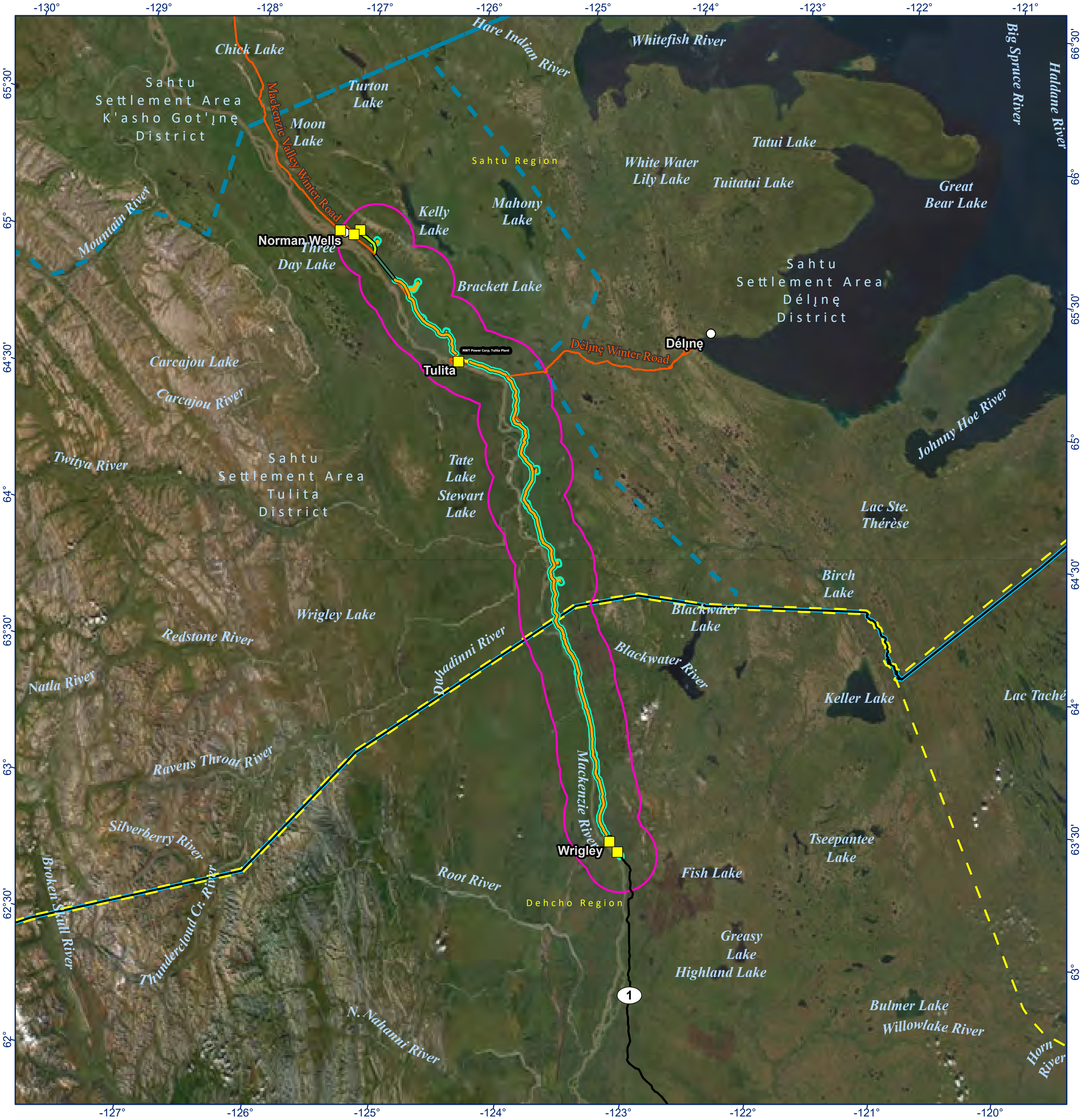
12.1.4.2 Temporal Boundaries

Since the assessment is based on yearly emissions and the project phases occur in separate years, the project activities have been separated into mobilization and demobilization activities of the construction phase, road construction activities of the construction phase, and the operations and maintenance phase.

- Construction phase:
  - The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita[2] south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells[3] sometime between 2041 and 2046.
  - Within the construction phase, mobilization and demobilization activities occur during the summer and/or winter season. The mobilization occurs prior to each of the three construction segments and the demobilization occurs at the end of each segment. The mobilization and demobilization activities are expected to have similar effects. Each segment is expected to take three to four years to construct, with approximately 300 workdays per year.
- Operations and maintenance phase: The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

[2] Tulita (Tulít'a), hereafter referred to as Tulita
[3] Norman Wells (Tłegǫ́hłı̨), hereafter referred to as Norman Wells



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Existing Facility (within Regional Assessment Area)
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 25 50 Kilometres

(At original document size of 8.5x11)
1:2,500,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AJ on 8/2/2023
TR by CES on 8/2/2023

Client/Project
144903025-0113 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
12.1

Title
Air Quality Assessment Areas

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021

12.1.5 Residual Effects Characterization

Air quality effects are assessed using the following characterizations: direction, magnitude, geographic extent, timing, duration, frequency, and reversibility. Each characterization is described, along with their respective possible outcome, in Table 12.4 and Table 12.5 for CAC and GHG, respectively.

The main characterization to determine significance is the magnitude of CAC and GHG emissions. Significance is further described in Section 12.1.6.

Table 12.4 Characterization of Residual Effects on Criteria Air Contaminants

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a residual effect that moves measurable parameters of ambient air in a negative direction relative to baseline **Neutral –** no net change in measurable parameters for the air quality relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely** – the residual effect is almost certainly not to occur **Possible** – the residual effect could occur **Certain –** the residual effect will certainly occur
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No Measurable Change –** no measurable change in any of the CAC can be noted **Low –** measurable change in at least one CAC that is less than the NPRI reporting thresholds[1] and the 2018 to 2020 average facility emissions for the NWT[2] **Moderate –** measurable change in at least one CAC that exceeds the NPRI reporting thresholds but that is less than the NPRI 2018 to 2020 average facility emissions for the NWT **High –** measurable change in at least one CAC that exceeds both the NPRI reporting thresholds and the NPRI 2018 to 2020 average facility emissions for the NWT
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA **Not Applicable -** the geographic extents do not apply to the residual effects

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**– residual effect is unlikely to be influenced by seasonal aspects or time of day **Sensitive** – residual effect may be influenced by seasonal aspects or time of day
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	**Short-term –** the residual effect lasts 5 years or less, which approximately corresponds to the construction period for each highway segment **Long-term –** the residual effect lasts more than 5 years
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event –** residual effect occurs once **Multiple irregular event –** residual effect occurs at no set schedule **Multiple regular event –** residual effect occurs at regular intervals **Continuous –** residual effect 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

Notes:

[1] The NPRI reporting thresholds are the level at which the substances begin to pose a risk to the environment or to health. See Section 12.1.1.1 for details.

[2] The average facility emissions for each CAC is obtained from the average of each individual facility reported for the NWT for the past 3 years, from 2018 to 2020. See Section 12.1.1.1 for details.

Table 12.5 Characterization of Residual Effects on Greenhouse Gases

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a net increase in measurable parameters for the GHG emissions relative to baseline **Neutral –** no net change in measurable parameters for the GHG emissions relative to baseline
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No Measurable Change –** no measurable change in GHG over the baseline **Low –** the Project's annual emissions are below 10,000 tCO_2e annually[1] **High –** the Project's annual emissions are above 10,000 tCO_2e annually
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA
Timing	Considers when the residual effect is expected to occur, where relevant to the VC.	**Not Applicable** – residual effect is unlikely to be influenced by seasonal aspects or time of day **Applicable** – residual effect may be influenced by seasonal aspects or time of day
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	**Short-term –** the residual effect lasts 5 years or less, which approximately corresponds to the construction period for each highway segment **Long-term –** the residual effect lasts more than 5 years
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event** – residual effect occurs once **Multiple irregular event –** residual effect occurs at no set schedule **Multiple regular event –** residual effect occurs at regular intervals **Continuous –** residual effect 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

Note:

[1] The 10,000 tCO_2e is the reporting threshold for the federal GHGRP under Section 46 of the *Canadian Environmental Protection Act* (CEPA).

12.1.6 Significance Definition

12.1.6.1 Change to Criteria Air Contaminants

The NPRI program, under which air emissions are source-based and not receptor-based, does not have specific thresholds or standards that could be used to determine significance when assessing the residual effects of the Project's CAC emissions. The report threshold is a good indicator of the magnitude of the potential effect, although it is not sufficient on its own to define a significant adverse effect, because the pathways and receptors also have to be considered.

Even though the pathways and receptors are not included, the Project's CAC emission levels are likely not significant if they are less than the 2018 to 2020 average of the facilities' accepted emission levels existing within the NWT.

Therefore, a significant adverse residual effect for CAC is one where the Project's CAC emissions are predicted to exceed the NWT 2018 to 2020 average facility CAC emissions, as described in Section 12.1.1.1.

12.1.6.2 Change to Greenhouse Gases

Territorial and federal policies and regulations do not identify specific thresholds or standards that could be used to determine significance when assessing the residual effects of the Project's GHG emissions. However, the federal GHGRP (ECCC, 2021a) has a minimum reporting threshold of 10,000 tCO_2e for annual emissions reporting. Therefore, a significant adverse residual effect for GHG is one where the Project's GHG emissions are predicted to exceed 10,000 tCO_2e per year.

12.2 Existing Conditions for Air Quality

The following sections summarize the baseline conditions for CAC emissions and GHG emissions as based on the TDR for Air Quality, Greenhouse Gas and Climate Baseline (Appendix 12A; K'alo-Stantec, 2022b).

12.2.1 Methods

The assessment considered the Traditional Knowledge, TLRU information, and community engagement feedback available from Indigenous Governments, Indigenous Organizations, and other affected parties. This included both project-specific TLRU studies and studies completed for previous projects. Following a review of each information source, air quality information was identified in the following reports and sources:

- Pehdzéh Kį N'deh Area (IMG-Golder Corporation, 2006)
- Dehcho Region (Dehcho First Nations, 2011; Dessau, 2012 [PR#13])
- Sahtu Region (McDonald, 2010; 5658 NWT Ltd. and GNWT, 2011 [PR#16]; Golder, 2015)
- Project-specific engagement program (2021-2023)

Other TLRU information did not report air quality related information.

The latest (2019 to 2021) existing conditions have been retrieved from publicly available data and reports from the following territorial and federal sources:

- ECCC National Air Pollution Surveillance (NAPS) Program: To obtain the CAC concentrations measured at stations near the project location, Norman Wells (Tłegǫ́hłı̨), hereafter referred to as Norman Wells, and Fort Smith
- The GNWT-ECC and Canadian Council of Ministers of the Environment (CCME): To obtain the CAC concentration thresholds
- ECCC NPRI: To obtain the CAC emissions from NWT industrial sources
- ECCC NIR: To obtain the GHG emission levels from NWT industries

12.2.2 Overview

Based on feedback received through the community engagement program, TLRU studies, and Traditional Knowledge, these general concerns were expressed:

- Community engagement participants from the Sahtu Region expressed concerns about warmer temperatures, thawing permafrost, erosion, slumping, and other environmental changes which negatively affect fish, wildlife, and food security.
- Recent changes in climate include warmer temperatures, rain and freezing rain increase, and stronger winds. The Dehcho Region is reported to be getting warmer and wetter overall, with more rainfall in August and September and even into October (Dehcho First Nations, 2011).
- Increasing extremes may negatively affect the caribou.
- The community of Wrigley expressed concerns about dust resulting from the project activities and pollution from the road operation (Dessau, 2012 [PR#13]).

Based on the latest data from the air quality monitoring programs, the baseline case includes the following conditions in the Regional Study Area (RSA), as reported in Appendix 12A (K'alo-Stantec, 2022b):

- CAC concentrations in the RSA: All measured air contaminants, except the PM_{10} concentrations, are well below the applicable territorial and federal thresholds. The PM sources near the Norman Wells station include forest fire smoke as well as dust/sand from gravel and sand roads, which are exposed after being snow-covered during the winter months. There may also be sources of CAC emissions local to Norman Wells that were recorded during 2019.

- Existing CAC emissions from the NWT industries and municipal activities: There are no major industrial sources of air contaminants in the RSA, as confirmed by the latest available online NPRI inventory. There are, however, smaller industrial and municipal facilities in the RSA that release CAC emissions. As shown in Figure 12.1 (yellow squares), the nearest reporting municipal facilities to the project location are the Northwest Territories Power Corporation generating stations in Norman Wells, Tulita, and Wrigley. The nearest reporting industrial facilities are Enbridge Pipeline stations (near Norman Wells and Wrigley) and Imperial Oil Resources facility (near Norman Wells). Besides these industrial and municipal sources, other emission sources in the RSA include aviation, community activities (such as traffic and space heating), and natural sources such as regional wildfires that occur mainly during the summer months.
- Existing visibility conditions in the RSA: Atmospheric visibility can be affected by precipitation, fog, haze, or other suspended particles in the air such as snow, dust, or smoke from wildfires. High visibility (more than 9 km) occurs approximately 90% of year, predominantly during the summer months; and low visibility (less than 1 km) occurs approximately 1% of the year, mainly during the fall months.
- Existing GHG emissions in NWT: Emissions in NWT account for a small portion (about 0.2%) of the federal total. Changes in yearly emissions are mostly due to factors such as increasing or decreasing use of off-road diesel engines for large construction projects or the utilization of aviation fuel for mining exploration and fighting wildfires. Despite the NWT’s low total GHG emissions, the emissions on a per capita basis are well above the national average. This is mainly due to a low population, long distances between communities, energy-intensive resource industry, and heating required during the long, cold winters.

12.3 Project Interactions with Air Quality

The assumed schedule of activities in the construction phase (which includes the mobilization activities, road construction activities, and demobilization activities) and operations and maintenance phase used in the assessment is summarized in Table 12.6. Emissions associated with multiple project activities include CAC and GHG emissions.

Generally, gaseous CAC emissions and $PM_{2.5}$ emissions are associated with combustion sources. In the Project, these include activities from construction equipment, maintenance vehicles, transportation equipment, road traffic vehicles, and camp facilities.

Table 12.6 Project-Environment Interactions with Air Quality

Physical Activities	Timing	Environmental Effects	
		Change to CAC	Change to GHG
Construction Phase			
Mobilization and demobilization activity			
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	✓	✓
Construction activities			
Establishment and operation of camps	Year-round	✓	✓
Site preparation of ROW, access, and workspaces	Winter	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓
Material haul	Year-round	✓	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓
Culvert installations	Summer or winter	✓	✓
Road base placement, compaction, and surfacing	Summer	✓	✓
Water withdrawal to support construction activities	Year-round	✓	✓
Closure and reclamation of Mackenzie Valley Winter Road (MVWR) and temporary borrow sources/ quarries, camps, and workspaces	Summer	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–
Operations and Maintenance Phase			
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓
Material haul and stockpiling	Summer	✓	✓
Operation of, and activities at, maintenance yards	Year-round	✓	✓
Water withdrawal for dust control	Summer	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–
Presence and use of the highway	Year-round	✓	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓
Vegetation control	Summer	✓	✓
Bridge and culvert maintenance	As needed	✓	✓

Notes:

✓ = Potential interaction

– = No interaction

1 Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, “Employment and contracted good and services” have been introduced as an additional component under each project phase.

Particulate CAC emissions such as dust, PM_{10}, and $PM_{2.5}$ to a lesser extent, are associated with mechanical disturbance of rock and dirt surfaces, where the latter are commonly referred to as fugitive dust sources because they are not discharged to the environment in a combined flow stream through a stack or vent. In the Project, this includes sources from activities performed on the highway, on the access roads, and at the quarry/borrow source.

Project GHG emissions are associated with combustion sources, chemical processes, and indirectly by the removal of carbon sinks, which include the same activities listed for the gaseous CAC and $PM_{2.5}$ emissions, plus the removal of carbon sinks associated with clearing of forest for the highway and access roads ROWs and borrow sources and quarries.

12.4 Assessment of Residual Effects on Air Quality

Based on project interactions with the environment identified in Table 12.3, the Project may affect air quality. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on air quality are summarized in Table 12.7. The mitigation measures are further described in the Section 12.4.2.2.

Table 12.7 Potential Effects and Mitigation Measures for Air Quality

Effect Name	Effect Pathway	Mitigation Measures
Change to CACs	• Release of CAC emissions to the atmosphere from project equipment and activities during the construction phase	• A dust control program will be implemented during construction, operations and maintenance. Where applicable, dust suppression will follow the GNWT Guideline for Dust Suppression. • Details of management and operation of incinerators will be included in the Waste Management Plan (WMP); see Volume 5. • Incinerators, if intended to be used by the contractor, will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury. • Vehicles and equipment will be maintained regularly. • Equipment idling will be discouraged or limited. • Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces. • Cold starts of equipment will be limited to the extent possible. • Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.

Effect Name	Effect Pathway	Mitigation Measures
Change to CACs (cont'd)		• Road surfaces will be repaired and maintained to reduce rolling resistance of vehicles. • The contractor will be encouraged to use passenger vehicles (e.g., passenger van or bus) to move crews. • Blast mats will be used when blasting near receptors sensitive to noise.
	• Release of CAC emissions to the atmosphere from project equipment and activities during the operations and maintenance phase	• A dust control program using water will be implemented during construction and operations and maintenance. • Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies. • Where applicable, dust suppression will follow the GNWT Guideline for Dust Suppression. Vehicles and equipment will be maintained regularly. • Equipment idling will be discouraged or limited. • Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces. • Cold starts of equipment will be limited to the extent possible.
Change to GHGs	• Release of GHG emissions to the atmosphere from project equipment and activities during the construction phase	The mitigation measures are the same as the ones listed for the incinerator and construction equipment, with the following additional measures: • The contractor will be encouraged to use modern construction equipment that has lower GHG emissions. • The area of direct ground disturbance will be limited by following the pre-existing MVWR road alignment to the extent possible. • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). • Closure and reclamation will promote natural re-establishment of vegetation. • Temporary access roads, quarries and workspaces not needed after construction will be closed and reclaimed.

Effect Name	Effect Pathway	Mitigation Measures
Change to GHGs	• Release of GHG emissions to the atmosphere from project equipment and activities during the operations and maintenance phase	The mitigation measures are the same as the ones listed for the incinerator, with the following additional measures: • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical. • Closure and reclamation will promote natural re-establishment of vegetation. • Temporary access roads, quarries and workspaces not needed after construction will be closed and reclaimed.

12.4.1 Analytical Assessment Techniques

The CAC emissions were assessed quantitatively with the exception of dust emissions, which were assessed qualitatively. The GHG emissions were assessed quantitatively.

The CAC emission factors were obtained from the following programs and previous projects:

- ECCC NPRI Calculation Guidance (ECCC, 2022e)
- US EPA AP-42: Compilation of Air Emissions Factors (US EPA, 2022)
- Australian Government – Department of Agriculture, Water and the Environment: National Pollutant Inventory (NPI) – Emission estimation technique (EET) manuals (NPI, 2022)

Factors relevant to GHG emissions were obtained from the following programs and publicly available reports:

- ECCC National Inventory Report 1990-2019: Greenhouse Gas Sources and Sinks in Canada (ECCC, 2019)
- National Research Council of Canada (NRC) Research Press – Carbon in Canada's boreal forest — A synthesis (Kurtz et al., 2013)
- Rescan Environmental Services report: Application for an Environmental Assessment Certificate / Environmental Impact Statement for the KSM Gold/Copper Project (Rescan, 2013); to estimate the blasting emission factor
- Dyno Nobel- Blasting and Explosives - Quick Reference Guide 2010 (Dyno Nobel, 2010); to estimate the blasting powder factor

There are no specific NWT CAC emission factors; therefore, emission factors from guidance from ECCC, US EPA, and the Australian Government were used.

The methods followed to calculate the GHG emissions were the accounting and reporting principles of the GHG Protocol developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WRI, 2015). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions.

Since the assessment is based on yearly emissions and the project phases occur in separate years, the project activities have been separated in phases as described in Section 12.1.4.2.

The air quality emissions were quantified for each project activity for each phase and summed up for the period of one calendar year. The total yearly emissions for each phase were compared against the thresholds described in Section 12.1.1.

Mitigation measures are designed to reduce the emission levels below the thresholds, as practically and economically feasible.

12.4.2 Change to Criteria Air Contaminants

The potential effects of the Project on CAC emissions are discussed.

12.4.2.1 Effects Pathways

The CAC emissions from the various project activities are released to the atmosphere and increase the concentrations in ambient air. The atmospheric conditions at the time of the release of the CAC emissions determine how they are dispersed in the ambient air. The Project's CAC emissions were calculated for the following activities during the various project phases. The information comes from Chapter 5. The assumptions come from construction literature (FHWA, 2006), a Climate Lens Assessment report done for the Project (Appendix 24A; K'alo-Stantec, 2021), and professional experience.

Construction phase

- Construction mobilization and demobilization:
  - Trucks: up to 500 trucks during one year
  - Barges: up to 10 barges during one year
- Road construction equipment:
  - Excavators: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Bulldozers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Graders: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Mulchers: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Tree harvesters: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Water trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Vacuum trucks: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Fuel trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Mobile drills: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Loaders: up to 4 units on a single day, assumed to operate 40% of the daytime
  - Compaction equipment: up to 2 units on a single day, assumed to operate 20% of the daytime

- Transportation equipment:
  - Haul trucks: up to 10 trucks on a single day, travelling from the quarry/borrow source to the road construction site
  - Transport shuttles for workers: assuming 5 shuttles to transport 70 workers from the campsite to the road construction site each day
  - Resupply trucks: up to 100 trucks annually
  - Resupply barges: up to 10 barges annually
- Construction campsite equipment:
  - Vacuum truck: up to 1 truck on a single day
  - Generator: assumed to operate 50% of the daytime
  - Incinerators: up to 2 campsite incinerators, assumed to operate 2 hours per day
- Quarry/borrow source activities at 15 quarries and borrow sources:
  - Crushers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Sorting and stockpiling: up to 10 rock trucks on a single day, assumed to operate 50% of the daytime
  - Blasting activities: ammonium nitrate fuel oil (ANFO) for blasting explosive; assumed to occur at most once per day per quarry/borrow source

Operations and maintenance phase

- Quarry/borrow source activities at 9 permanent quarries and borrow sources:
  - Crushers: assumed up to 1 unit on a single day, operating 50% of the daytime
  - Sorting and stockpiling: assumed up to 5 rock trucks on a single day, operating 50% of the daytime
  - Blasting activities: ANFO for blasting explosive; assumed to occur at most once every 10 days
- Highway traffic:
  - 50 vehicles per day, assuming 15% of vehicles are heavy trucks
- Snow clearing, grading and dust control:
  - Plow truck
  - Grader
  - Water truck
- Right of way vegetation control:
  - Mulcher: assumed to operate 12 hours a day, every day during September and October
- Culvert and bridge maintenance:
  - Light duty truck

The potentially CAC-emitting activities that have been excluded are listed, followed by the justification for their exclusion.

- Maintenance campsite equipment: No major air-emitting activities are expected in the maintenance campsites

12.4.2.2 Mitigation

The mitigation measures listed in Table 12.7 should be implemented to reduce the potential effects from the release of the CAC emissions. Key mitigation measures include:

- A dust control program using water will be implemented during construction and operations and maintenance.
- Where applicable, dust suppression will follow the GNWT Guideline for Dust Suppression (GNWT, 2013).
- Incinerators, if intended to be used by the contractor, will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury (ECCC, 2017).
- Vehicles and equipment will be maintained regularly.
- Equipment idling will be discouraged or limited.
- Vehicle speeds will be limited to 50 km/h on unfinished project road surfaces.
- Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.
- The contractor will be encouraged to use passenger vehicles (e.g., passenger van or bus) to move crews.
- Blast mats will be used when blasting near receptors sensitive to noise.

12.4.2.3 Residual Effects

Table 12.8 summarizes the results for the CAC emissions along with their respective threshold criteria, after the application of the mitigation measures described in Section 12.4.2.2. The calculations followed the methodologies from the programs listed in Section 12.4.1. Each CAC emission value is compared individually to its respective threshold.

As described in Section 12.1.4.2, the construction phase is subdivided into the mobilization and demobilization activities, and the road construction activities. Even though the operations and maintenance phase of a highway segment will begin right after the end of the construction phase for that segment, little to no traffic volume is expected before all highway segments are completed. As such, for the main assessment, the construction phase excludes the contribution of the operations and maintenance activities for the completed segments; and the operations and maintenance activities of the completed segments are included with the construction phase activities as a separate row below as a conservative estimate for informational purposes only.

Table 12.8 Criteria Air Contaminant Emission Calculation Results (Annual)

Project Phase or Activity	CAC Emissions (t/year)				
	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$
Construction Phase					
Mobilization and Demobilization Activities	1.42	4.81	0.02	0.37	**0.35**
Road Construction Activities	**22.39**	**27.95**	0.45	**4.81**	**1.68**
Road Construction Activities + Operations and Maintenance Activities for two completed segments [1]	**28.08**	**34.52**	0.48	**5.78**	**2.42**
Operations and Maintenance Phase					
Operations and Maintenance Activities	8.93	10.31	0.05	**1.51**	**1.15**
CAC Thresholds from NPRI					
NPRI Reporting Thresholds [2]	20.00	20.00	20.00	0.50	0.30
2018 to 2020 Average NWT Facility Emissions [3]	176.82	258.55	69.23	24.26	8.75

Notes:

Bold values indicate that the emission level exceeds the reporting threshold.

[1] The operations and maintenance activities of the completed segments are included with the construction phase activities as a conservative estimate for informational purposes only.

[2] The level at which the substances begin to pose a risk to the environment or to health.

[3] The average of each individual facility CAC emissions reported for the NWT for the past 3 years.

Mobilization and demobilization activities: The Project's CAC emissions are less than their NPRI reporting thresholds, except for $PM_{2.5}$. The dominant sources of $PM_{2.5}$ are the mobilization of trucks.

Road construction activities: The Project's CAC emissions are greater than their NPRI reporting thresholds, except for SO_2. The dominant source of CO is the blasting activity. The dominant sources of nitrogen oxide (NO_x) are the rock trucks, haul trucks, loaders, and the blasting explosives. The dominant source of PM_{10} is the blasting activity. The dominant sources of $PM_{2.5}$ are the rock trucks and haul trucks.

Operations and maintenance phase: The Project's CAC emissions are less than their NPRI reporting thresholds, except for PM_{10} and $PM_{2.5}$. The dominant sources of PM_{10} and $PM_{2.5}$ are the traffic vehicles (e.g., tailpipe emissions).

The Project's CAC emissions are less than the 2018 to 2020 average NWT facility emissions for both the construction phase and the operations and maintenance phase.

Dust emissions are not expected to affect human health or visibility after the application of the dust control program, as described in Section 12.4.2.2. Furthermore, they are not expected to affect terrestrial and aquatic environments. The dust mitigation methods for this Project are best management practices that have been implemented with successful outcomes for similar types of projects in different jurisdictions. The potential effects from the dust emissions are generally observed near the dust sources. There is a sufficient distance separating the dust sources from the nearby residential receptors that there is a low potential for adverse residual effects from the dust emissions.

12.4.2.3.1 Ice Fog

Though not a contaminant, potential increase in the extent or frequency of ice fog may occur during the construction phase when construction vehicles are operating in a specific location for a period of time, such as at the quarry/borrow source or the portion of the segment of the highway being constructed. By operating in one location, a build-up of emissions from construction vehicles may contribute to ice fog conditions; however, these effects are anticipated to be transient in nature, and its duration on the public would be the short time it takes for the MVWR traffic to pass by the activity. During the operations and maintenance phase, the number of vehicles anticipated to use the constructed highway is 50 vehicles per day. Vehicles will be traveling (not idling) on the highway, which would not lead to a build-up of emissions in one location.

12.4.3 Change to Greenhouse Gas

The potential effects of the Project on GHG emissions are discussed.

12.4.3.1 Effects Pathways

The GHG effect pathways will be all those described in Section 12.4.2.1 for the CAC effect, with the following additional pathways:

- Loss of carbon sink associated with boreal forest clearing areas from the highway right-of-way, temporary and permanent quarry/borrow source, and their access roads
- Construction campsite incinerator (if used) during the construction phase: up to 2 campsite incinerators, assumed to operate 2 hours per day

12.4.3.2 Mitigation

The mitigation measures to consider for GHG effects are the same as the ones listed in Section 12.4.2.2 for the CAC effects, with the following additional measures:

- The contractor will be encouraged to use modern construction equipment that has lower GHG emissions.

- The area of direct ground disturbance will be limited by following the pre-existing MVWR alignment to the extent possible.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Closure and reclamation will promote natural re-establishment of vegetation.
- Temporary access roads, quarries, and workspaces not needed after construction will be closed and reclaimed.

12.4.3.3 Residual Effects

Table 12.9 summarizes the GHG emission results for each project phase, along with their respective contribution relative to the NWT total emissions for 2020.

Table 12.9 GHG Emission Calculation Results

Project Phase	GHG Emissions (tCO_2e/year)	Contribution to the NWT Total Emissions [1]
Construction Phase		
Mobilization and Demobilization Activities	1,845	0.13%
Road Construction Activities	6,436	0.46%
Road Construction Activities + Operations and Maintenance Activities for two completed segments [2]	8,240	0.59%
Operations and Maintenance Phase		
Operations and Maintenance Activities	3,633	0.26%

Notes:

1 Based on 2020 data (ECCC, 2020), the NWT total emissions for 2020 were 1,400,000 tCO_2e.

2 The operations and maintenance activities of the completed segments are included with the construction phase activities as a conservative estimate for informational purposes only.

As described in Section 12.1.4.2, the construction phase is subdivided into the mobilization and demobilization task, and the road construction task. Even though the operations and maintenance phase of a highway segment will begin right after the end of the construction phase for that segment, little to no traffic volume is expected before all highway segments are completed. As such, for the main assessment, the construction phase excludes the contribution of the operations and maintenance activities for the completed segments. The operations and maintenance activities of the completed segments are included with the construction phase activities as a separate row below as a conservative estimate for informational purposes only.

The Project's annual emissions for all phases are below 10,000 tCO_2e annually, which is the reporting threshold for the federal GHGRP. For the mobilization and demobilization activities, the dominant source is the mobilization trucks. For the road construction activities, the dominant source is the rock trucks. For the operations and maintenance phase, the dominant sources are the traffic vehicles (e.g., tailpipe emissions).

The NWT total emissions for 2020 were 1,400,000 tCO_2e (ECCC, 2020). The Project's annual GHG emissions for each of the project phases and activities range between 0.13% and 0.46% of the NWT total GHG emissions for 2020.

12.4.4 Summary of Residual Effects

12.4.4.1 Change to Criteria Air Contaminants

Table 12.10 summarizes the residual effects for the CAC effect, based on the characterizations as described in Section 12.1.5.

- Direction: The direction of change in CAC emissions during both project phases is rated adverse (A) because the phases result in a predicted increase of ambient concentrations compared to baseline conditions.
- Likelihood: The likelihood for change in CAC during all the project phases is rated certain (CE) because the activities from all the project phases emit CACs.
- Magnitude: The magnitude for change in air quality during both project phases is rated moderate (M) because for each phase, at least one of the CACs is greater than the NPRI reporting threshold, but no CAC is over the 2018 to 2020 average NWT facility emissions.
- Geographic Extent: The geographic extent for change in CAC emissions is expected to be limited to the LAA for each phase of the Project because the LAA was set at the maximum geographic extent to which the air emissions, mostly fugitive dust, from the project highway traffic is expected to disperse until the concentrations are undiscernible from the background PM concentrations.
- Timing: Seasonality is applicable (A) to the CAC emissions because during summer there are higher PM emissions, especially from the fugitive dust sources such as unpaved roads, compared to winter when the ground is frozen and sometimes covered in snow.
- Duration: The duration for change in CAC emissions during the construction phase is short-term (ST) because the construction activities do not extend past the construction period for each highway segment which is predicted to be 5 years or less. The duration for change in CAC emissions during the operations and maintenance phase is long-term (LT) because the operation activities extend through the duration of the operations and maintenance phase which is longer than 5 years.

- Frequency: The frequency for change in CAC emissions during the construction phase is rated regular event (R) because the CAC emissions from the construction activities are scheduled at times during the daytime and are not assumed to occur during the nighttime. The frequency for change in CAC emissions during the operations and maintenance phase is rated continuous (C) because the road will be open on a continuous basis for travel by vehicles.
- Reversibility: The reversibility for change in air quality during the construction phase is rated reversible (R) because the predicted increase in ambient CAC concentrations and dust due to the project activity would return to baseline conditions after the end of the activity. The reversibility for change in air quality during the operations and maintenance phase is rated Irreversible (I) because even though the predicted increase in ambient CAC concentrations and dust due to the phase activities would return to baseline condition after the end of the activity, the phase is indeterminate.

Table 12.10 Residual Effects on CAC Emissions

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in CAC - Construction Phase	A	CE	M	LAA	A	ST	R	R
Change in CAC - Operations and Maintenance Phase	A	CE	M	LAA	A	LT	C	I

KEY

* See Table 12.4 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NA: Not Applicable
A: Applicable

N/A: Not applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

12.4.4.2 Change to Greenhouse Gases

Table 12.11 summarizes the residual effects for the GHG effect, based on the characterizations as described in Section 12.1.4.2.

- Direction: The direction for change in GHG during both Project phases is rated adverse (A) because the phases result in a predicted increase of GHG emissions compared to baseline conditions.
- Likelihood: The likelihood for change in GHG during all the project phases is rated certain (CE) because the activities from all the project phases emit GHGs.
- Magnitude: The magnitude for change in GHG during both project phases is rated low (L) because the emission levels are below the threshold of 10,000 tCO_2e annually.
- Geographic Extent: The geographic extent for change in GHG during operation is not applicable (NA) because the effect is determined at the territorial, national, and global scales.
- Timing: Seasonality is not applicable (NA) to change in GHG because emissions are released across all seasons.
- Duration: The duration for change in GHG is long-term (LT) because effects related to the release of GHG emissions will contribute to climate change for the long-term.
- Frequency: The frequency for change in GHG during the construction phase is rated regular event (R) because the GHG emissions from the construction activities are scheduled at times during the daytime and do not occur during the nighttime. The frequency for change in GHG during the operations and maintenance phase is rated continuous (C) because the road will be open on a continuous basis for travel by vehicles.
- Reversibility: The reversibility for change in GHGs during the construction phase is rated reversible (R) because the predicted increase in yearly emissions due to the project activity would return to baseline conditions after the end of the activity. The reversibility for change in GHGs during the operations and maintenance phase is rated Irreversible (I) because the duration of the phase is indeterminate.

Table 12.11 Residual Effects on GHG Emissions

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in GHG - Construction Phase	A	CE	L	NA	NA	LT	R	R
Change in GHG - Operations and Maintenance Phase	A	CE	L	NA	NA	LT	C	I

KEY

*See Table 12.4 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area
NA: Not Applicable

Timing
NA: Not Applicable
A: Applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

N/A: Not applicable

12.4.4.3 Sahtu Land Use Plan

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement consideration of engagement input and incorporation of Traditional Knowledge.

Mitigation measures for reducing effects of the Project on air quality respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ą̨lǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats, and take into account traditional and community use of these areas.

12.5 Assessment of Cumulative Effects on Air Quality

12.5.1 Residual Effects Likely to Interact Cumulatively

The project and physical activities inclusion list, in Chapter 4, identifies other projects and physical activities that have the potential to act cumulatively with residual effects of the Project on air quality.

For the GHG effect, as GHG emissions have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and any specific activities in the RAA is not expected other than immeasurably within the global climate change phenomena.

For the CAC effect, projects and physical activities have the potential to act cumulatively with the Project if all the following conditions apply:

- The activity period overlaps with the project activity period, because CAC effects have a short duration before settling to the ground or dispersing in the atmosphere and returning to the baseline ambient concentration levels.
- The activity is within the RAA, that is, 15 km from the PDA, which represents the distance at which the CACs emitted from large stationary sources may disperse or settle and return to baseline values.
- The activity, to be considered CAC-emitting, includes combustion emission sources and mechanical disturbance of rock and dirt surfaces.

Where residual effects from the Project act cumulatively with residual effects from other projects and physical activities, as listed in Table 12.12, a cumulative effects assessment is undertaken to determine their significance. For each air quality effect identified in Table 12.12 that is marked as not likely to interact cumulatively with residual effects of other projects and physical activities (no check mark) a justification is given, and a cumulative effects assessment is not warranted.

Table 12.12 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects	
	Change in CAC	Change in GHG
Past and Present Physical Activities and Resource Use (Base Case)		
Geotechnical	-	-
Oil, Gas & Seismic*	-	-
Infrastructure		
MVWR, including bridges and bridge-sized culverts	✓	-
Mackenzie Highway #1 Operation and Maintenance	✓	-
Délı̨nę Winter Road	✓	-
Prohibition Creek Access Road	✓	-
Norman Wells Pipeline	✓	-
Quarries and Borrow Sources	-	-
Mining & Exploration	-	-
Municipal Operations, including water, waste, power, and community development		
Wrigley Municipal Activities	✓	-
Tulita Municipal Activities	✓	-
Norman Wells Municipal Activities	✓	-
Project-Related Physical Activities (Project Case)		
Mackenzie Valley Highway Project	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)		
Quarries		
Dhu-1 Quarry	✓	-
Infrastructure		
Great Bear River Bridge	✓	-
Oil and Gas		
Enbridge Maintenance Camp	✓	-

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

For the CAC effect, the following Infrastructure activities are expected to interact cumulatively with the project activities. The assessment of cumulative effects is provided in the next section.

- Highway #1: The highway is open to all-season traffic. It overlaps with the RAA near Wrigley.
- The MVWR: Is open to traffic every winter and runs along the same corridor as the project highway corridor.
- The Délı̨nę Winter Road is open to traffic every winter and overlaps a portion of the RAA south of Tulita.
- Prohibition Creek Access Road (PCAR): This road connects to the northernmost segment of the Project and is partly in the RAA. The maintenance and use of the PCAR will overlap temporally with the construction of the Tulita to Norman Wells segment.
- Dhu-1 Quarry: The development of this quarry in the RAA could overlap temporally with the construction of the Tulita to Norman Wells segment.
- Proposed Great Bear River Bridge: The construction of a permanent bridge spanning the Great Bear River north of Tulita is planned between 2024 and 2027. This activity is within the project RAA, approximately 2 km south of the Project Tulita North highway segment, and may overlap temporally during the project construction phase.
- Enbridge Pipelines stations: permanent surface pipeline terminal stations located within the RAA in Norman Wells and Wrigley.

The following infrastructure activities located within the RAA currently exist or may occur during the project period; the magnitude of the cumulative effect on air quality from the interaction of these activities with the project activities is expected to be low or unmeasurable, as explained below:

- Highway #1 south of the project PDA ends at the community of Wrigley, where the PDA begins, and has traffic activities year-round. The area of overlap of the two activities, between Wrigley and the Project's southernmost quarry/borrow source, is a highway portion of approximately 10 km in length. The Highway No.1 has approximately 60 to 70 vehicles per day, as obtained from the nearest traffic count location at Mackenzie River Ferry (GNWT, 2020) located approximately 130 km south of Wrigley. If the CAC emissions from the Highway No.1 activities were estimated to be equal to the emissions from the Project traffic activities, this would be equivalent to adding 10 km to the existing 281 km of Project traffic activity, or less than 4% of the Project traffic emissions, which is low or unmeasurable. Thus the contribution of the Highway No.1 activities to cumulative effects is expected to be low or unmeasurable.

- The Délı̨nę Winter Road is built every winter and allows traffic between Tulita and Délı̨nę, located approximately 105 km east of Tulita. This road is connected to the MVWR in the PDA which will become the Project, approximately 20 km southeast of Tulita. A small overlap area of activities of 2 km is expected every winter at the connection of the two roads, and the construction duration in the overlapping area is expected to be short. The Délı̨nę Winter Road has approximately 40 vehicles per day (GNWT, 2020) which is less than the expected traffic from the project operations. If the CAC emissions from the Délı̨nę Winter Road activities were conservatively estimated to be equal to the emissions from the Project activities, this would be equivalent to adding 2 km to the existing 281 km of Project activity, or less than 1% of the Project emissions, which is low or unmeasurable. Thus the contribution of the Délı̨nę Winter Road activities to cumulative effects is expected to be low or unmeasurable.

Three municipal activities located within the RAA currently exist; one oil and gas activity is reasonably foreseeable. The cumulative effect on air quality from the interaction of these activities with the project activities is not expected to be measurable, as explained:

- Power Generation by the Northwest Territories Power Corporation at Wrigley, Tulita, and Norman Wells: Although there would be a temporal overlap and a possible spatial overlap due to the CAC emission plumes from these municipal power generation activities and the project activities, since the project sources are intermittent and transient, the cumulative effect is not expected to be measurable on an annual basis. The same is expected for the fog emissions.
- A camp site in support of Enbridge Line 21 is expected to be built at an unknown date in the future and will be located approximately 9 km away from the Project's temporary quarry/borrow source called Edie Lake near Norman Wells. The camp will have a 300-kW generator as part of its CAC emitting equipment (Mackenzie Valley Land and Water Board, 2023). The Edie Lake quarry/borrow source is temporary and will be active for only 3 years between 2027 and 2029; after which, the camp will no longer be within the project RAA. Based on professional experience, the magnitude of CAC effect 9 km away from a generator is not expected to be measurable on an annual basis. Thus, the magnitude of the cumulative effect from the interaction of the camp activities and the project activities on air quality is not expected to be measurable on an annual basis.

The following Oil, Gas & Seismic, Infrastructure, and Municipal activities that were identified in Section 12.2.2 from the TDR for Air Quality, Greenhouse Gas and Climate Baseline (Appendix 12A; K'alo-Stantec, 2022b) are not expected to interact cumulatively with the project activities, as listed along with an explanation:

- Oil, Gas & Seismic activities:
  - Imperial Oil Resources Ltd. activities (near Norman Wells): All Imperial Oil activities ended in 2020, and as the initial project construction phase is planned for 2026, there is no temporal overlap.

No other surrounding projects or activities are expected to interact cumulatively with the Project, as explained:

- No Mining & Exploration activities, Remediation activities, or Staging Area activities are planned to occur during the time of the Project (i.e., no activity period overlap).
- No Geotechnical or Quarrying activities are planned to occur during the time of the project activities for the segments at the same location.

12.5.2 Mackenzie Valley Winter Road, Great Bear River Bridge, and Norman Wells Pipeline Criteria Air Contaminants Effect

12.5.2.1 Cumulative Effects Pathways

For the CAC effect, three Infrastructure activities are expected to interact cumulatively with the project activities: the MVWR, the proposed Great Bear River Bridge, and the Norman Wells Pipeline.

The MVWR is built every winter and runs along the same corridor as the project highway corridor. It provides winter access to Sahtu communities north of Wrigley, including Tulita, Norman Wells, Fort Good Hope (K'asho Got'ine), Délı̨nę and Colville Lake. The Project will share the ROW of the MVWR in places, and construction of the Project will be ongoing when the MVWR is open to public traffic. Based on the DAR Detailed Project Description (see Chapter 5), public access along the MVWR will be maintained during project construction, including portions of the MVWR that need to be operated until the full highway is connected from end to end.

Change in CACs is expected from the annual road construction and traffic activities during the winter season. The following information on the infrastructure comes from the DAR Detailed Project Description (see Chapter 5) and Climate Lens Assessment report (K'alo-Stantec, 2021):

- The road is open to traffic annually from December 25 to April 1 on average
- The average annual daily traffic volume is estimated to be 50 vehicles per day, assuming 15% of vehicles are heavy trucks
- The construction equipment includes one grader, one plow truck, and one water truck

The construction of the Great Bear River Bridge, a permanent bridge spanning the Great Bear River in Tulita, is planned between 2024 and 2027. This activity is within the project RAA, between the Tulita to Prohibition Creek highway segment, and Tulita to Dehcho/Sahtu border segment. The projects may overlap temporally during the project construction phase, if the segment of the highway from Tulita to the Dehcho/Sahtu border is constructed first.

Changes in CACs are expected from the construction activities during its four-year construction period. Similar to the project construction activities, the Great Bear River Bridge construction activity CAC emissions are not expected to disperse past 1 km, and thus the spatial overlap is small. As the construction activities for the Great Bear River Bridge are similar to those of the project (including road construction) CAC emissions are conservatively estimated to be equivalent to the project annual construction activities emissions.

The Norman Wells Pipeline includes stations near Norman Wells and Wrigley. According to the NPRI website, the Norman Wells and the Wrigley pipeline stations reported CAC emissions from 2018 to 2020 (ECCC, 2022c). Other CAC effects expected from the Norman Wells pipeline maintenance activities include maintenance of cleared fireguard areas, roads, camp sites and seasonal trails. Since these activities and their resulting CAC emissions are intermittent, transient, and generally low intensity, the cumulative effect from these activities is not expected to be measurable on an annual basis.

12.5.2.2 Mitigation for Cumulative Effects

The mitigation measures used to mitigate the effects on air quality for the annual building of the MVWR, the construction of the Great Bear River Bridge, and the Norman Wells Pipeline stations are assumed to be the same as those planned for the project construction phase listed in Table 12.7, as applicable.

12.5.2.3 Cumulative Effects

Table 12.13 summarizes the results of the cumulative CAC effect of the Project, MVWR, the Great Bear River Bridge, and the Norman Wells Pipeline. Each CAC emission value is compared individually to its respective threshold.

The Project will replace the MVWR and will incorporate the Great Bear River Bridge during the operations and maintenance phase once all segments are completed, and thus the MVWR and Great Bear River Bridge activities will interact cumulatively with the project activities only during the construction phase. Furthermore, Great Bear River Bridge activities will only interact cumulatively with the project activities if construction of both projects within the RAA occurs at the same time.

The Norman Wells Pipeline stations are expected to operate permanently, and as such, their activities will interact cumulatively with the Project activities during both the construction phase and the operations and maintenance phase of the Project.

Note that, since the MVWR runs along the same corridor as the project highway corridor, the three other infrastructure activities that interact with the project activities as described in Section 12.5.1 will also interact with the MVWR. However, as explained in Section 12.5.1, the emissions from these activities are expected to be low or unmeasurable; and thus their contribution to cumulative effects is expected to be low or unmeasurable and are not included in this cumulative effects assessment.

As described in Section 12.1.4.2, the construction phase is subdivided into the mobilization and demobilization activities, and the road construction activities. Even though the operations and maintenance phase of a highway segment will begin right after the end of the construction phase for that segment, little to no traffic volume is expected before all highway segments are completed. As such, for the main assessment, the construction phase excludes the contribution of the operations and maintenance activities for the completed segments; and the operations and maintenance activities of the completed segments are included with the construction phase activities as a separate row below as a conservative estimate for informational purposes only.

Table 12.13 Cumulative CAC Emission Calculation Results (Annual)

Activity	CAC Emissions (t/year)				
	CO	**NO_x**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
MVWR Activities	2.28	2.86	0.00	0.37	**0.35**
Great Bear River Bridge Activities	**22.39**	**27.95**	0.45	**4.81**	**1.68**
Norman Wells Pipeline Activities	-	**28.61**	-	**0.59**	**0.59**
Cumulative Effects During Construction Phase Activities [1]					
Mobilization and Demobilization Activities	**26.09**	**64.23**	0.48	**6.14**	**2.97**
Road Construction Activities	**47.06**	**87.37**	0.91	**10.59**	**4.31**
Road Construction Activities + Operations and Maintenance Activities for two completed segments [2]	**52.75**	**93.94**	0.94	**11.55**	**5.04**
Cumulative Effects during Operations and Maintenance Phase Activities [1]					
Operations and Maintenance Phase Activities	8.93	**38.92**	0.05	**2.10**	**1.74**
CAC Thresholds from NPRI					
NPRI Reporting Thresholds [3]	20.00	20.00	20.00	0.50	0.30
2018 to 2020 Average NWT Facility Emissions [4]	176.82	258.55	69.23	24.26	8.75

Notes:

Bold values indicate that the emission level exceeds the reporting threshold.

[1] The project activity CAC emissions are found in Table 12.8.

[2] The operations and maintenance activities of the completed segments are included with the construction phase activities as a conservative estimate for informational purposes only.

[3] The level at which the substances begin to pose a risk to the environment or to health.

[4] The average of each individual facility CAC emissions reported for the NWT for the past 3 years.

Cumulative effects during the mobilization and demobilization activities of the construction phase: The cumulative CAC emissions are greater than their NPRI reporting thresholds, except for SO_2.

Cumulative effects during the road construction activities of the construction phase: The cumulative CAC emissions are greater than their NPRI reporting thresholds, except for SO_2.

Cumulative effects during the operations and maintenance phase: The cumulative CAC emissions are greater than their NPRI reporting thresholds, except for CO and SO_2.

The cumulative CAC emissions are less than the 2018 to 2020 average NWT facility emissions for both the construction phase, and the operations and maintenance phase of the Project.

Dust emissions, as described in Section 12.4.2.3, are not expected to affect human health or visibility after the application of the dust control program as described in Section 12.4.2.2. Furthermore, dust emissions from the MVWR activities are not expected to be measurable during the winter when the ground is frozen and sometimes covered in snow.

Ice fog, as described in Section 12.4.2.3, is not expected to have a measurable effect on the public.

As GHG emissions only have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and the MVWR and Great Bear River Bridge activities is not expected other than immeasurably within the global climate change phenomena.

12.5.3 Summary of Cumulative Effects

Table 12.14 summarizes the cumulative CAC effect from the MVWR, the Great Bear River Bridge, the Norman Wells Pipeline, and the project activities, based on the characterizations as described in Section 12.1.5.

- Direction: The direction of change in cumulative CAC emissions is rated adverse (A) during both the construction phase and the operations and maintenance phase of the Project because the cumulative effect results in a predicted increase of CAC concentrations compared to baseline conditions.
- Likelihood: The likelihood for change in cumulative CAC is rated certain (CE) during both the construction phase and the operations and maintenance phase because the activities from the MVWR, the Great Bear River Bridge, the Norman Wells Pipeline and the Project emit CACs.
- Magnitude: The magnitude for change in cumulative CAC is rated moderate (M) during both the construction phase and the operations and maintenance phase of the Project because at least one of the CACs is greater than the NPRI reporting threshold, but no CAC is over the 2018 to 2020 average NWT facility emissions.
- Geographic Extent: The geographic extent for change in cumulative CAC emissions is expected to be the RAA during both the construction phase and the operations and maintenance phase of the Project, because the RAA was set at a 15 km buffer around the PDA, which is the maximum geographic extent to which the air emissions from the project activities is expected to disperse until the concentrations are undiscernible from the background PM concentrations, and the MVWR, the Great Bear River Bridge and the Norman Wells Pipeline are located within 15 km of the project highway corridor.
- Timing: Seasonality is applicable (A) to the CAC emissions during both the construction phase and the operations and maintenance phase of the Project because during summer there are higher PM emissions, especially from the fugitive dust sources such as unpaved roads, compared to winter when the ground is frozen and sometimes covered in snow.
- Duration: The duration for change in cumulative CAC emissions during the construction phase of the Project is short-term (ST) because the project construction activities do not extend past the construction period for each highway segment which is predicted to be 5 years or less. The duration for change in cumulative CAC emissions during the operations and maintenance phase of the Project is long-term (LT) because the both the Norman Wells Pipeline activities and the Project operations and maintenance phase activities are expected to last more than 5 years.

- Frequency: The frequency for change in cumulative CAC emissions of the Project is rated regular event (R) during both the construction phase and the operations and maintenance phase of the Project because even though the MVWR and the Norman Wells Pipeline stations operations are expected to be continuous, the construction activities from the Great Bear River Bridge and the Project are assumed to be scheduled at times during the daytime and not during the nighttime.
- Reversibility: The reversibility for change in air quality during the construction phase of the Project is rated reversible (R) because the predicted cumulative increase in CAC concentrations due to the MVWR activity, the Great Bear River Bridge activity, and the project construction activity would return to baseline conditions after the end of the activity. The reversibility for change in air quality during the operations and maintenance phase of the Project is rated irreversible (I) because the predicted cumulative increase in CAC concentrations due to the Norman Wells Pipeline activity and the project operations and maintenance activity are permanent.

Table 12.14 Residual Effects on CAC Emissions

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in CAC - Construction Phase	A	CE	M	RAA	A	ST	R	R
Change in CAC - Operations and Maintenance Phase	A	CE	M	RAA	A	LT	R	I

KEY

* See Table 12.4 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NA: Not Applicable
A: Applicable

N/A: Not applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

As GHG emissions only have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and the MVWR activity is not expected other than immeasurably within the global climate change phenomena.

12.6 Determination of Significance

12.6.1 Significance of Residual Effects

The criteria that determine the effect significance are described in Section 12.1.6. Project activities have been grouped into the construction phase (which includes the mobilization activities, road construction activities, and demobilization activities) and operations and maintenance phase.

The change in CAC are not significant. As detailed in Section 12.4.2.3, the predicted annual CAC emissions are below the 2018 to 2020 average NWT facility emissions for each of the CACs assessed and for all phases of the Project.

The change in GHG is not significant. As detailed in Section 12.4.3.3, the annual GHG emissions are below the federal GHGRP annual reporting threshold of 10,000 tCO_2e, for all phases of the Project.

12.6.2 Significance of Cumulative Effects

The cumulative CAC effects are not significant. As described in Section 12.5, the MVWR, the Great Bear River Bridge, and the Norman Wells Pipeline are the only activities whose effect magnitude from the cumulative interaction with the Project is expected to be medium to high. As described in Section 12.5.2.3, the cumulative annual CAC emissions from the MVWR activity, the Great Bear River Bridge activity, the Norman Wells Pipeline activity, and the project activities are below the 2018 to 2020 average NWT facility emissions for each of the CACs assessed.

As GHG emissions only have a global effect and not any effect localized to the RAA, cumulative interaction between the project activities and any specific activities in the RAA is not expected.

12.6.3 Project Contribution to Cumulative Effects

Since the Project's CAC effects on their own are not significant, as explained in Section 12.6.1, and the cumulative CAC emissions of the Project's activities and the other existing activities are below the 2018 to 2020 Average NWT Facility Emissions threshold, as described in Section 12.5.2.3, the Project's contribution to cumulative CAC effect is not significant. Since the project CAC effects are expected to settle or disperse within a 1 km distance, as described in Section 12.1.4.1, the overall regional effects are not expected to be measurable.

Since there are no measurable cumulative effects as a result of the residual effects of the Project in combination with the effects of other emission sources for GHG, the determination of significance from the Project's contribution to cumulative GHG effect does not apply.

12.7 Prediction Confidence

The prediction confidence for residual effects and cumulative effects for air quality is moderate and is based on the accuracy of the project design information, emission source data, and accuracy of the emission factors.

Calculations can be revised, if necessary, when final design information on equipment and activities is available. Conservative assumptions were used, as described in the next section.

Emission factors are based on the latest available data from the various air emissions monitoring programs, which update the values from time to time. Calculations can be revised, if necessary, before the start of the project construction phase if the programs revise their emission factors.

12.7.1 Assumptions

The following assumptions have been made to estimate the air quality effects:

Blasting activities

- The blasting depth does not exceed 21 m. This pertains to the calculation formula used.
- Based on a previous road construction project, it is expected that if and when blasting is required, it will only occur once daily per quarry/borrow source (Stantec, 2016).
- Based on the estimated amount of rock material needed yearly during the operations and maintenance phase (30,000 to 50,000 m^3) and the estimated amount needed during the whole construction period (14.7 million m^3) reported in the DAR Detailed Project Description (see Chapter 5), the blasting frequency for the operations and maintenance phase is conservatively estimated to be 10% of the frequency for the construction phase.
- Based on uniform use, approximately 50,000 cubic metres (m^3) of blasted rock is assumed to be required for every 13 km of the Project. The weight of the rock is assumed to average 2.3 tonnes per cubic metre (t/m^3), based on professional experience.

Construction equipment

- The daily frequency of activities was obtained from construction literature for similar equipment (FHWA, 2006).
- The annual work hours of each construction equipment unit is estimated based on the maximum number of units in a day.
- Transport shuttles for workers have an estimated capacity of 14 passengers per vehicle, based on research on typical transport shuttles in Canada (Alberta Transportation, 2016).
- Based on the quarry and campsite locations relative to the proposed highway location, the average daily round trip for workers transport shuttles is estimated to be 40 km.

- Off-road and on-road equipment is assumed to be powered with diesel fuel, as described in the Climate Lens Assessment done for the Project (K'alo-Stantec, 2021).
- Fuel consumption rates (litres/hour) are based on the GNWT experience with construction projects, and various information sources including NRCan (2019 and 2020) and Generator Source (2020).

Operations and maintenance

- Average annual daily highway traffic volume is 50 vehicles per day, assuming 15% of vehicles are heavy trucks, based on the DAR Detailed Project Description (see Chapter 5).
- The maintenance equipment operation time was obtained from the Climate Lens Assessment done for the Project (K'alo-Stantec, 2021) and pro-rated per km for use in the calculations.
- Based on the estimated amount of rock material needed yearly during the operations and maintenance phase (30,000 to 50,000 m^3) and the estimated amount needed during the whole construction period (14.7 million m^3) reported in the DAR Detailed Project Description (see Chapter 5), the activity frequency at the quarry/borrow sources during the operations and maintenance phase is conservatively estimated to be 10% of the frequency at the quarry/borrow sources during the construction phase.
- Where data was unavailable for an activity such as equipment load factor or fuel consumption, the reasonable worst-case values were selected.

Loss of Carbon Sink

- The construction and presence of the highway could result in changes to permafrost, resulting in the release of CH_4. Due to limited data on the correlation between road construction and a measurable release of GHG emissions from permafrost decay in the NWT, the release of CH_4 from permafrost decay was not factored into the analysis. See the Climate Lens Assessment report (K'alo-Stantec, 2021) for more information about permafrost thaw.

MVWR

- The traffic volume is estimated to be 50 vehicles per day, assuming 15% of vehicles are heavy trucks, as described in the Climate Lens Assessment done for the Project (K'alo-Stantec, 2021).

Great Bear River Bridge

- The activity CAC emissions are assumed to be equivalent to the project annual construction activities emissions. Since the Great Bear River Bridge construction footprint area is smaller than the Project PDA, this assumption is conservative.

12.7.2 Gaps and Uncertainties

Gaps that may affect the air quality effects are listed:

- Detailed data on blasting activities is unavailable currently. Conservative assumptions were made based on a previous road construction project (Stantec, 2016). Blasting activities is a dominant source of CAC emissions for the construction phase.

Uncertainties in the calculations are listed:

- Emission factors get updated by the air quality programs from time to time. Calculations can be revised, if necessary, before the start of the project construction phase if the programs revise the emission factors.

12.8 Follow-up and Monitoring

As part of an adaptive management plan for follow-up and monitoring, mitigation measures will be regularly reviewed and updated by the GNWT to verify and enhance their effectiveness. In the event that an unexpected deterioration of the environment is observed as part of follow-up and/or monitoring, intervention mechanisms will apply the adaptive management process.

Regular monitoring of climate data, such as snowfall accumulation and rainfall, will be undertaken as part of terrain, soils and permafrost monitoring to better correlate the changes in the highway with climate-related parameters.

Monitoring will also be initiated on a case-by-case basis should any complaints related to air quality occur from Indigenous Governments, Indigenous Organizations or other affected parties as a result of project activities.

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13.0 ASSESSMENT OF POTENTIAL EFFECTS ON NOISE

Noise has been selected as a valued component (VC) because changes in noise levels have potential effects on communities, which may lead to adverse effects such as annoyance and interference with speech comprehension. It may also result in changes to wildlife and wildlife habitat.

The Mackenzie Valley Highway Project (the "Project") has the potential to change noise levels in the environment from activities during the construction phase and the operations and maintenance phase. Noise emissions from road projects are generally associated with the mechanical movement of construction equipment and vehicle traffic.

The effects of noise on wildlife are assessed in Chapter 10 (caribou and moose), and Chapter 19 (wildlife and wildlife habitat). The assessment of potential effects of the Project on noise focuses on the effects on communities and other human receptor locations. Receptor locations are locations where human noise sensitive receptors are present, based on the Health Canada Noise Guidance 2017 recommendations (Health Canada, 2017). In this assessment, it includes permanent and seasonal residences.

The assessment of potential effects on noise concludes that with the application of mitigation measures, residual effects resulting from the Project on noise will be adverse. Residual effects and cumulative effects will be of magnitude, duration, frequency and timing such that they will be below criteria required to be considered significant as defined in Section 13.1.6. Predicted residual effects and cumulative effects of the Project on noise are predicted to be not significant.

13.1 Scope of Assessment

13.1.1 Regulatory and Policy Setting

The Government of the Northwest Territories (GNWT) has developed guidelines that, along with legislation, regulations, and policies, help manage the environment in the Northwest Territories (NWT). However, there is no dedicated territorial regulation or guideline that regulates the acoustic environment. In the absence of territorial noise regulations, the following regulations are used as guidelines.

13.1.1.1 Health Canada Noise Guidance

Health Canada - Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (Health Canada, 2017): The Health Canada Noise Guidance concerns the assessment of health risks associated with noise and types of sound predicted in federal environmental assessments of proposed major resource and infrastructure projects. The thresholds for the parameters relevant to the Project are listed below. See Section 13.1.3 for a description of those parameters.

- Long-Term Community Annoyance: If change in percent highly annoyed (%HA) between baseline and application case exceeds 6.5%, then the project-related noise effect is considered "severe" and noise mitigation measures should be considered.
- Short-Term Community Annoyance: If a noise level exceeds the Mitigation Noise Level (MNL) of 47 A-weighted decibels (dBA) day-night sound level (L_{dn}), then adverse noise effects are likely and noise mitigations are warranted.
- Low-Frequency Noise: If a noise level exceeds 70 Z-weighted or unweighted decibels (dBZ) equivalent sound level (L_{eq}) (which translates to daytime sound level [L_d] in the Project) for the energy summation of the 16 Hertz (Hz), 31.5 Hz, and 63 Hz bands, then the activities would be expected to cause additional annoyance by creating a "rattle" noise in the environment.
- Speech Comprehension: If noise level exceeds 55 dBA L_{eq} (which translates to L_d in the Project), then the activities would be expected to interfere with speech comprehension outdoors.

13.1.1.2 Alberta Transportation

Alberta Transportation - Noise Attenuation Guidelines for Provincial Highways Under Provincial Jurisdiction Within Cities and Urban Areas (Alberta Transportation, 2002): Determines when noise mitigation measures such as noise barriers or berms are warranted near residences due to highway traffic noise levels. If the noise effect from highway traffic exceeds the threshold of 65 dBA 24-hour equivalent sound level ($L_{eq\text{-}24hr}$), then noise control such as noise barriers or berms would be warranted to attenuate the traffic noise.

13.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."* Additionally, CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ą̨lǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

13.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to noise. This feedback has been considered and summarized in Table 13.1 and has been integrated into the assessment of potential effects of noise on wildlife and wildlife resources that follows.

Table 13.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Norman Wells Renewable Resources Council (NWRRC) TLRU study participants reported that muskox generally avoid noise and activity, however, they are not as sensitive as caribou to sensory disturbance.	NWRRC, 2023	The GNWT has identified mitigation measures to reduce noise levels resulting from project activities. The effects of the Project on caribou, moose and other wildlife from changes in noise are assessed in Chapters 10, 19, and 20. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction	For mitigation measures to reduce or eliminate effects on noise levels, see Table 13.5. The effects of the Project on wildlife from changes in noise are assessed in Section 10.5.2 (caribou and moose change in habitat); Section 19.4.2 (wildlife change in habitat).
Indigenous Governments, Indigenous Organizations, and other affected parties (Sahtu Dene and Métis, Pehdzéh Kį N’deh community members and Dehcho First Nations, NWRRC and Tulita Renewable Resources Council [TRRC] study participants) have also advised that boreal caribou avoid the winter roads due to sensory disturbance (i.e., noise, pollution), and concerns have been raised about the effects of future road construction and operations and the potential to affect the availability and accessibility of caribou for cultural use within proximity of the highway.	Auld and Kershaw, 2005; Dehcho First Nations, 2011; IMG-Golder Corporation, 2006; TRRC, 2022		
Participants of the NWRRC study explained that the intensity of noise can affect the level of response in wildlife, particularly moose. While most wildlife would be disturbed by most noise, NWRRC study participants reported that moose are relatively unbothered by noise unless it is loud or more disturbing, citing ground disturbance as a problem.	NWRRC, 2023		

Comment	Source	GNWT Response	Where Addressed
Participants of the NWRRC study reported that previous road construction and operation have affected migratory patterns and calving locations of wildlife around the Mackenzie Valley Winter Road (MVWR).	NWRRC, 2023		
Participants of the NWRRC study expressed concern that potential project effects to wildlife, including increased traffic and noise along the MVWR may compound existing effects on wildlife identified by NWRRC, including effects related to noise and vehicle traffic.	NWRRC, 2023		
Sahtu Region reported that boreal caribou are particularly sensitive to sensory disturbance; noise disturbance was identified as a major factor that affects boreal woodland caribou.	McDonald et. al., 2010		
Community engagement participants expressed concern about noise and vibration, including from blasting and traffic.	November to December 2022 Engagement		

13.1.3 Potential Effects, Pathways, and Measurable Parameters

Based on Health Canada noise guidance and Alberta Transportation noise guideline, the following noise effects are assessed quantitatively:

- Long-term community annoyance: Some of the project noise-emitting activities are long-term, (i.e., last more than one year), such as traffic on the completed highway.
- Short-term community annoyance: Even though the construction phase is expected to last several years, the construction activities at particular locations are expected to be short-term (i.e., last less than one year).
- Low-frequency noise: Annoyance related to noise is greater when low-frequency noise is present (International Organization for Standardization [ISO] 1996-1:2003). Some of the Project activities, such as heavy truck operations, have the potential to emit low-frequency (below 100 to 200 Hz) noise.
- Interference with Speech Comprehension: Project noise levels may occasionally affect speech comprehension.
- Traffic Noise: Once the highway is open for operation, the main source of noise will be from the daily traffic.

Listed below are other types of effects that are excluded from this assessment, along with a justification for their exclusion:

- Sleep disturbance: Nighttime sleep disturbance assessment does not apply for the construction and maintenance activities as the work is planned to be conducted on a day shift only. Nighttime traffic during operation is not expected to reach noise levels close to the sleep disturbance threshold.
- Noise-Induced Hearing Loss: Project noise levels are not expected to be close to the hearing loss threshold.
- Effect on Wildlife: This is assessed as part of the assessment of potential effects on caribou and moose (Chapter 10), and wildlife and wildlife habitat (Chapter 19).

Table 13.2 summarizes the effects included in the assessment. The project life cycle is divided into two phases: the construction phase, and the operations and maintenance phase. The construction phase has been further divided into tasks: a construction mobilization task and a road construction task are part of the construction phase and are assessed separately for this VC because they occur during separate time periods. Note that the construction demobilization task planned at the end of each road segment is expected to have similar effects as the construction mobilization task, and thus is not assessed separately.

Table 13.2 Potential Effects, Effects Pathways, and Measurable Parameters for Noise

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in noise level	Noise effects during the mobilization activity of the construction phase, due to the transportation of equipment	• Short-Term Construction day-night sound level (L_{dn}), measured in dBA • Daytime sound level (L_d), measured in dBZ, for low frequency noise analysis • Interference with Speech Comprehension noise effect daytime sound level (L_d), measured in dBA
	Noise effects during the road construction activity of the construction phase, due to the mobile equipment along different highway segments and stationary noise sources at the quarries and borrow sources (e.g., blasting, excavating, crushing)	• Short-Term Construction day-night sound level (L_{dn}), measured in dBA • Daytime sound level (L_d), measured in dBZ, for low frequency noise analysis • Interference with Speech Comprehension noise effect daytime sound level (L_d), measured in dBA
	Noise effects during the operations and maintenance phase, due to the traffic vehicles and maintenance activities on the completed highway, and stationary noise sources at the quarries and borrow sources	• Long-Term High Annoyance, measured in change in percent highly annoyed (%HA) between baseline and Application case, for longer term community annoyance • Daytime sound level (L_d), measured in dBZ, for low frequency noise analysis • 24-hour equivalent sound level ($L_{eq-24hr}$), measured in dBA, for traffic noise analysis

13.1.4 Boundaries

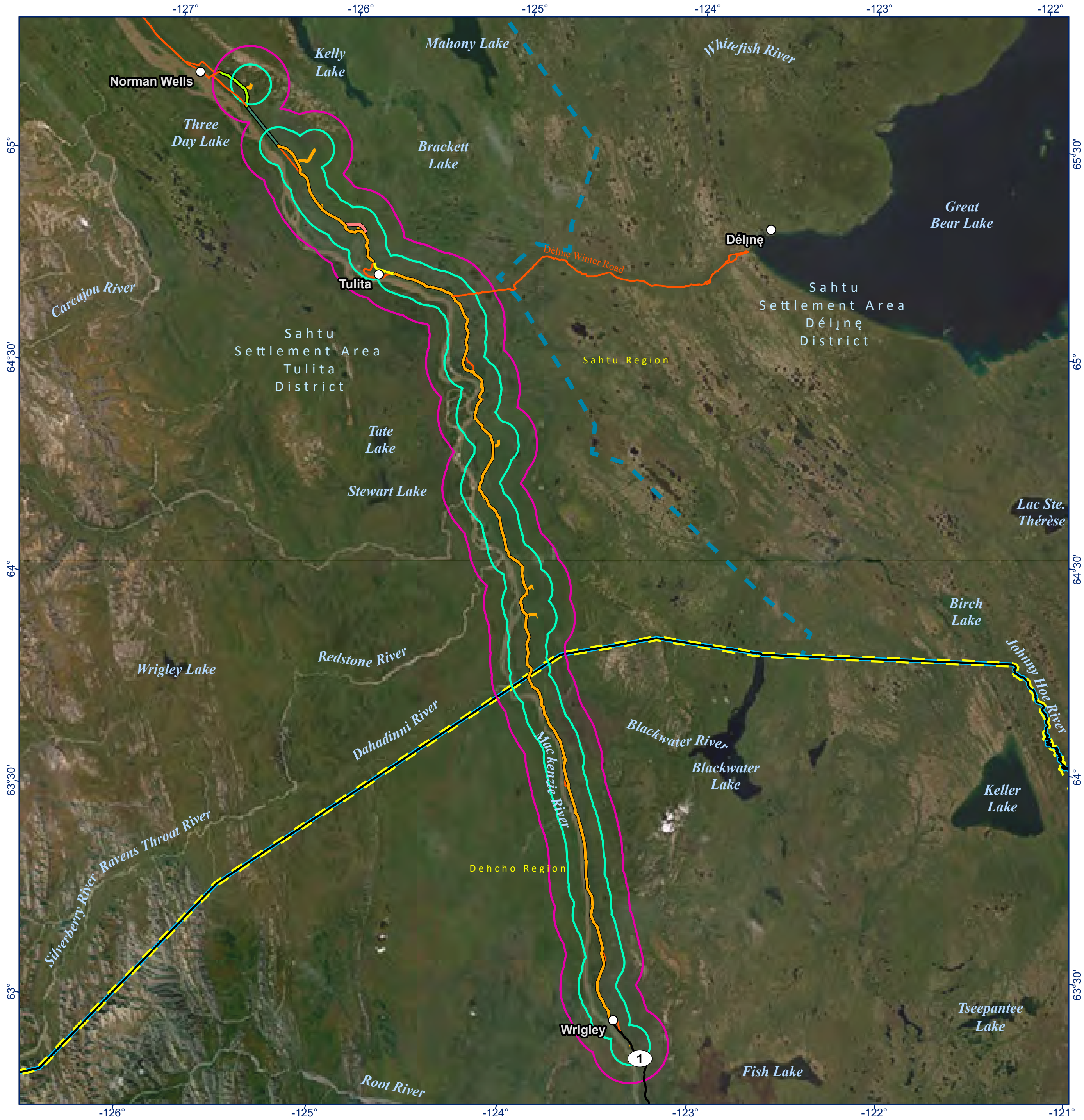
13.1.4.1 Spatial Boundaries

This section provides the rationale and a description of the three study areas:

- **Project Development Area (PDA):** The area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. This assessment considers receptors located within the LAA, which is defined as an approximately 5 kilometre (km) buffer around the PDA. Further than 5 km, the project noise effects are expected to attenuate well below the baseline sound level due to natural atmospheric attenuation and ground absorption over distance.
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of Project effects and potential cumulative effects. The RAA for the assessment of effects on acoustic environment was set as an approximately 10 km (double of LAA) buffer around the PDA. The RAA is to account for other existing and future physical activities that may act cumulatively with the Project. Physical activities located beyond the 10 km buffer are not expected to interact with Project residual acoustic effects due to natural atmospheric attenuation and ground absorption.

Figure 13.1 shows a map of the Project's location, LAA, and RAA. Figure 13.2 to Figure 13.4 show the presence of receptors in the communities of Wrigley, Tulita, and Norman Wells, respectively.

Receptor areas are the boundaries within which human receptors are present. As shown in Figure 13.2 to Figure 13.4, the receptor areas in the community of Wrigley are located within the LAA and are the closest areas to the PDA due to their proximity to the road alignment route and borrow source 10.043 (approximately 350 m away), and therefore the residences within these areas are expected to be the most affected by the project's noise effects. The receptor area in the community of Tulita is also located within the LAA, but it is not as close to the PDA (approximately 2.5 km away) as the receptor areas in the community of Wrigley, and thus, the Tulita residences are not expected to be as affected by the Project's noise effects as the Wrigley residences. The receptor areas in the community of Norman Wells are outside of the LAA (approximately 5.7 km from the PDA), which means these receptors are not expected to be substantially affected by the Project's noise effects.



- Local Assessment Area
- Regional Assessment Area
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Proposed Bear Rock Alignment Option
- Proposed Borrow Source / Quarry Site and Access
- Community
- Winter Road
- Northwest Territories Highway
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres

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1:600,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 7/28/2023
TR by AJ on 7/28/2023

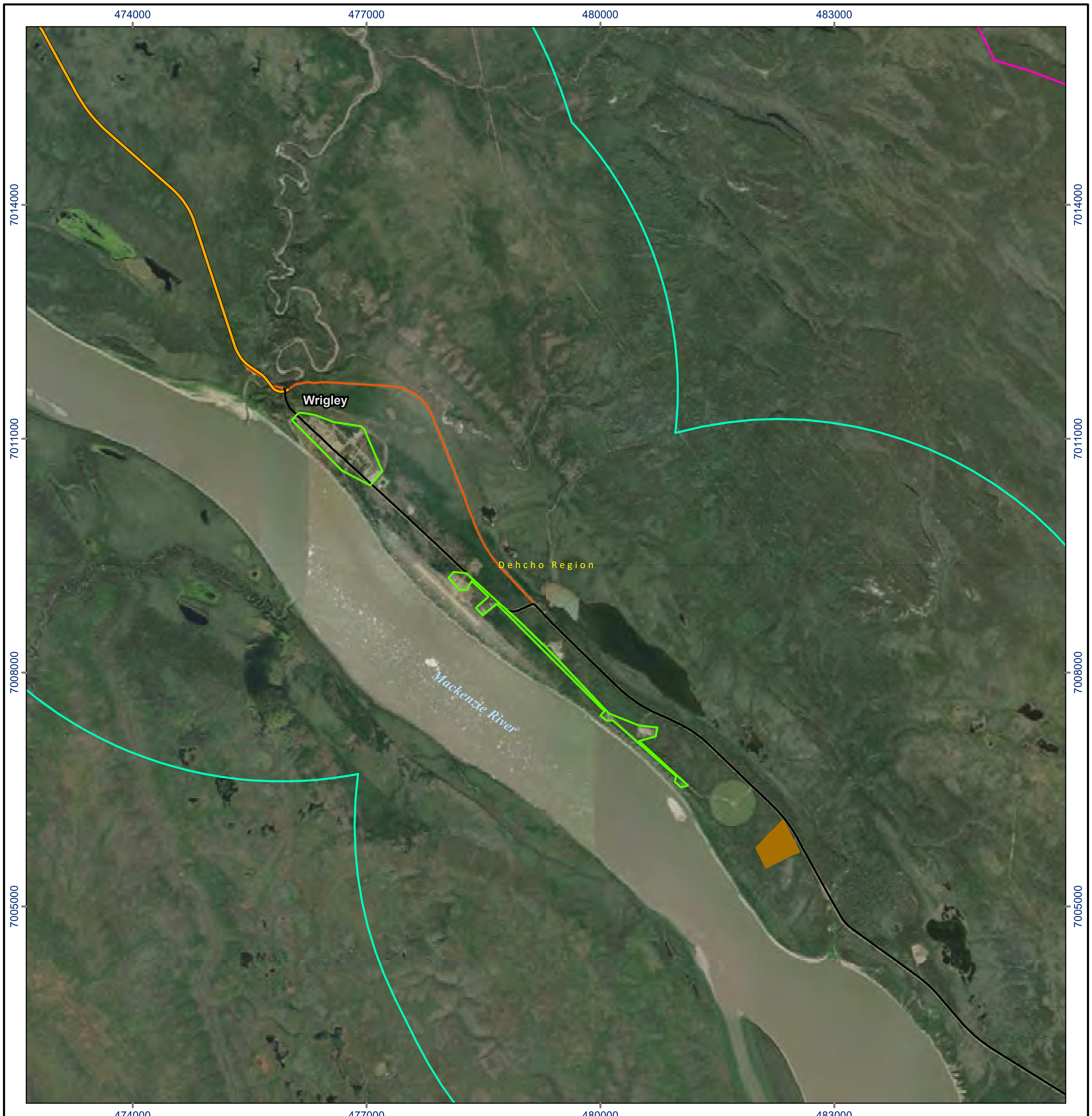
Client/Project
144903025-0089 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.1

Title
Project Location, Local Assessment Area and Regional Assessment Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, Northwest Territories Cumulative Impact Monitoring Program (CIMP), GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, d. Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS



- Wrigley Receptor Area
- Proposed Mackenzie Valley Highway Project Route
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Winter Road
- Northwest Territories Highway

0 1 2 Kilometres
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N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

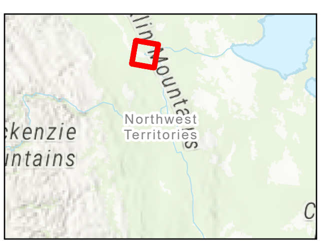
Client/Project
144903025-0090 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.2

Title
Receptor Area in the Community of Wrigley

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Hillshade: Esri, USGS
Imagery date: 2021



- Tulita Receptor Area
- Proposed Mackenzie Valley Highway Project Route
- Proposed Great Bear River Bridge
- Proposed Bear Rock Alignment Option
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Winter Road
- Northwest Territories Highway

0 1.5 3 Kilometres

(At original document size of 8.5x11)
1:150,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
144903025-0091 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.3

Title
Receptor Area in the Community of Tulita

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Northwest Territories, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

- Norman Wells Receptor Area
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Winter Road
- Northwest Territories Highway

0 2.5 5 Kilometres

(At original document size of 8.5x11)
1:250,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
144903025-0092 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.4

Title
Receptor Area in the Community of Norman Wells

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

13.1.4.2 Temporal Boundaries

The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.

The project temporal boundaries include the construction phase and operations and maintenance phase. The construction phase has been further divided into the construction mobilization and activity, and road construction activities, because these activities generally occur at different times and their noise effects differ.

- Construction phase:
  - Construction mobilization and demobilization activity: The mobilization occurs prior to each of the three construction segments; and the demobilization occurs at the end of each segment. Each mobilization activity is expected to last approximately eight months, and may be in summer or winter. Equipment will be mobilized to and from sites within the PDA via barges and the MVWR as applicable.
  - Road construction activities: These include activities associated with road construction, such as site preparation, camp operations, quarry and borrow source development, embankment construction and culvert installations.
- Operations and maintenance phase: Operations and maintenance will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the Project is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

13.1.5 Residual Effects Characterization

Noise effects are assessed using the following characterizations: direction, magnitude, geographic extent, timing, duration, frequency, and reversibility. Table 13.3 provides the definition of residual effects characterizations.

The main characterization to determine significance is the magnitude of noise effect. Significance is further described in Section 13.1.6.

Table 13.3 Characterization of Residual Effects on Noise

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a residual effect that moves measurable parameters of noise in a negative direction relative to baseline **Neutral –** no net change in measurable parameters for noise relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** the residual effect is almost certainly not to occur **Possible –** the residual effect could occur **Certain –** the residual effect will certainly occur
Magnitude	The amount of change in noise level relative to existing conditions	**Low -** Project noise effect is 10 decibels (dB)[1] below the baseline sound level or lower, as applicable **Moderate -** Project noise effect is below the noise thresholds[2] **High -** Project noise effect exceeds the noise thresholds[2]
Geographic Extent	The geographic area in which noise effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA
Timing	Considers when the noise effect is expected to occur.	**Not Sensitive -** Effect occurs outside of the period of receptor occupancy or timing does not change the effect **Moderate Sensitivity -** Effect occurs during the daytime period when people are generally less sensitive to noise **High Sensitivity -** Effect occurs during the nighttime period, when people are generally more sensitive to noise than during the daytime period
Duration	The time required until noise effect returns to its existing condition, or the noise effect can no longer be measured	**Short-term -** the residual effect lasts less than 1 year **Long-term -** the residual effect lasts more than 1 year
Frequency	Identifies how often the noise 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

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Reversibility	Pertains to whether the noise effect 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

Notes:

1 A 10 dB margin is a typical safety margin because in logarithmic arithmetic, adding a noise source that is 10 dB below the existing levels results in less than a 1 dB cumulative increase. Note that baseline levels do not apply to all parameters.

2 See Section 13.1.1 for a description of the Health Canada Noise Guidance thresholds for Long-Term, Short-Term Construction Noise Exposure, Long-Term Annoyance, Low-Frequency Noise, Speech Comprehension, and Alberta Transportation Traffic Noise Level.

13.1.6 Significance Definition

A project's noise effect is considered significant if all of the following criteria are met for a majority of the noise sensitive receptors:

- High-magnitude
- Duration of more than two months: the Health Canada noise guidance recommends higher noise thresholds for short-term community annoyance if the activity duration is less than two months (Health Canada, 2017)
- Moderate or high sensitivity timing
- Continuous, multiple irregular, or multiple regular event frequency

13.2 Existing Conditions for Noise

13.2.1 Methods

The assessment considered the Traditional Knowledge, TLRU information, and community engagement feedback available from Indigenous Governments, Indigenous Organizations, and other affected parties. This included both project-specific TLRU studies and studies completed for previous projects. Following a review of each information source, information related to noise was identified in the following reports and sources:

- Auld, J. and R. Kershaw. 2005. The Sahtú Atlas
- Dehcho First Nations. 2011. Traditional Knowledge Assessment of Boreal Caribou (Mbedzih) in the Dehcho Region
- IMG-Golder Corporation. 2006. Draft Report on Renewable Resource Assessment of the Pehdzéh Kį N'deh Area of Interest

- McDonald et al. 2010. Boreal Caribou Traditional Knowledge Collection Study: The Sahtu Settlement Area
- NWRRC TLRU Study (NWRRC, 2023)
- Project-specific engagement program (2021-2023)
- TRRC TLRU Study (TRRC, 2022)

The following guidance documents and baseline noise study were used to obtain information on estimation of baseline levels based on project activity duration, characteristics of activity, and characteristics of the receptors.

- Alberta Energy Regulator (AER), 2007: Noise Control
- Alberta Utilities Commission (AUC), 2021: Noise Control
- British Columbia Oil and Gas Commission (BC OGC), 2021: British Columbia Noise Control Best Practices Guideline
- Health Canada - Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise (Health Canada, 2017)
- Imperial Oil Resources Ventures Limited (IOL), 2004. Mackenzie Gas Project Environmental Impact Statement Volume 3: Biophysical Baseline Part A Environmental Setting, Air Quality and Noise
- Enbridge Pipelines (NW) Inc., 2018. Environmental Noise Impact Assessment For The Line 21 Segment Replacement Project

13.2.2 Overview

Based on feedback received through the public engagement program, TLRU studies, and publicly available literature, concerns were expressed regarding the effect of noise on wildlife. These potential effects are assessed in Chapter 10 (for caribou and moose), and Chapter 19 (for wildlife).

The Acoustic Environment Baseline Technical Data Report (Appendix 13A; K'alo-Stantec, 2022b) provides findings from the review of noise guidance documents and baseline noise study. The baseline sound levels for the Project are assumed to be 38 dBA L_{dn}, based on the 34 dBA daytime sound level (L_d) and 31 dBA nighttime sound level (L_n). These assumed levels are based on the average measurement results from the Mackenzie Gas Project and Norman Wells Pipeline project. The project baseline noise levels are assumed the same for the PDA along the proposed highway route and near the proposed quarry/borrow sources.

13.3 Project Interactions with Noise

The assumed schedule of activities in the construction phase (which includes the mobilization activities and road construction activities) and operations and maintenance phase used in the assessment is summarized in Table 13.4. Noise emissions are associated with multiple project activities.

Table 13.4 Project-Environment Interactions with Noise

Physical Activities	Timing	Environmental Effect
		Change in Noise Level
Construction Phase		
Mobilization of equipment, materials and fuel, resupply, and demobilization	Summer and winter	✓
Establishment and operation of camps	Year-round	✓
Site preparation of ROW, access, and workspaces	Winter	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓
Material haul	Year-round	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓
Culvert installations	Summer or winter	✓
Road base placement, compaction, and surfacing	Summer	✓
Water withdrawal to support construction activities	Year-round	✓
Closure and reclamation of Mackenzie Valley Winter Road (MVWR) and temporary borrow sources quarries, camps, and workspaces	Summer	✓
Employment and contracted goods and services[1]	Year-round	–
Operations and Maintenance Phase		
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓
Material haul and stockpiling	Summer	✓
Operation of, and activities at, maintenance yards	Year-round	✓
Water withdrawal for dust control	Summer	✓
Employment and contracted goods and services[1]	Year-round	–
Presence and use of the highway	Year-round	✓
Highway and access road maintenance, including snow clearing, repair, grading, dust control	Year-round	✓
Vegetation control	Summer	✓
Bridge and culvert maintenance	As needed	✓

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, “Employment and contracted goods and services” have been introduced as an additional component under each project phase.

Generally, noise emissions are associated with the activities from stationery and mobile equipment. In the Project, this includes activities from construction equipment, maintenance vehicles, off-road transportation equipment, borrow sources operation, campsite equipment, and road traffic vehicles.

13.4 Assessment of Residual Effects on Noise

Based on project interactions with the environment identified in Table 13.2, the Project may affect the noise levels. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on noise levels are summarized in Table 13.5. The mitigation measures are further described in the Section 13.4.2.2.

Table 13.5 Potential Effects and Mitigation Measures for Noise

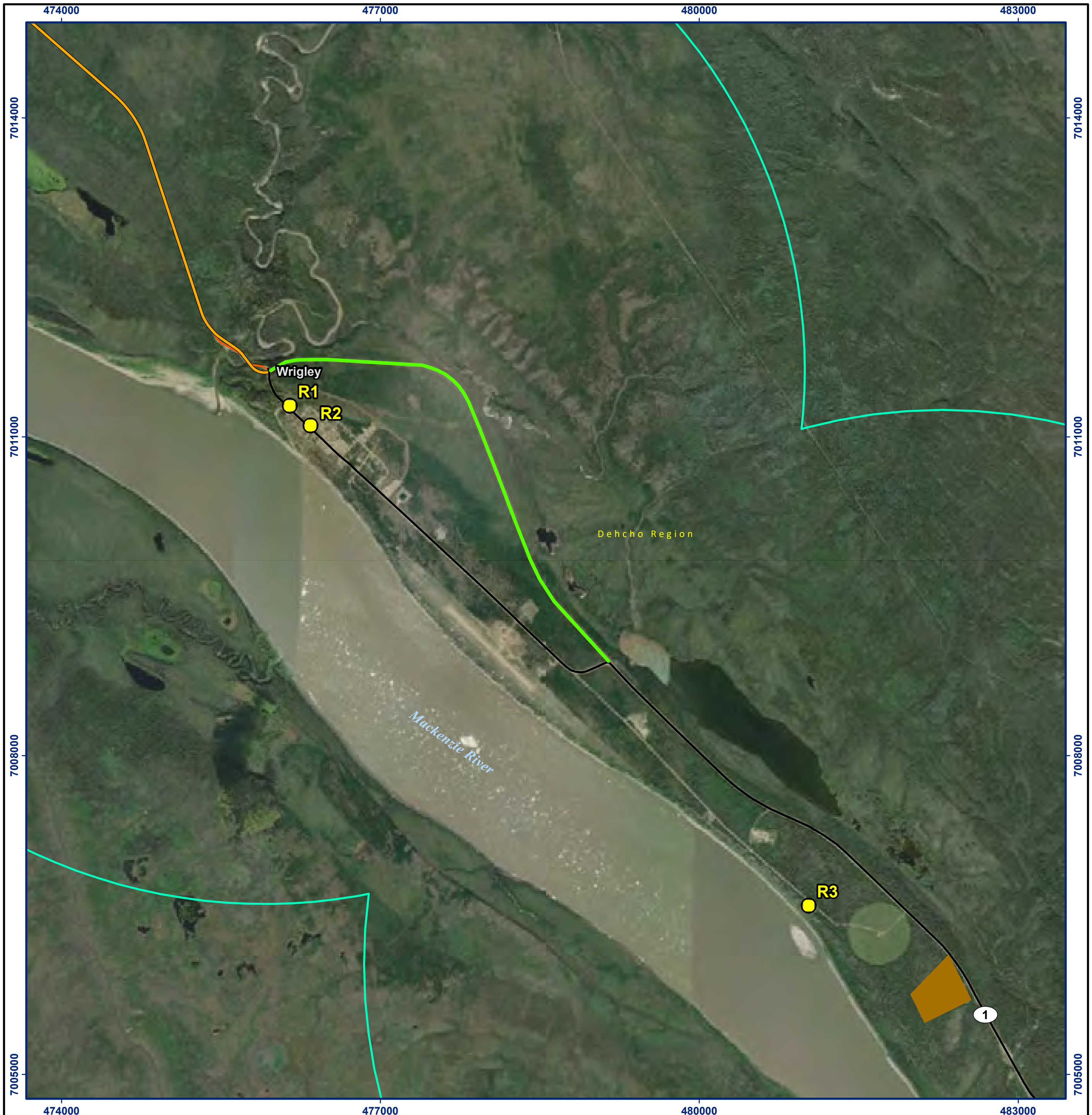
Effect Name	Effect Pathway	Mitigation Measures
Change in noise levels	Noise effects during the construction phase due to the mobile equipment along different highway segments and stationary noise sources at the borrow sources	• The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction. • Blasting activities: – Blasting activities will be limited to daytime hours to the extent practical. – Methods to reduce the powder factor will be considered (e.g., through a combination of increased hole spacing, decreased column height of explosives, increased depth of stemming material in the blasthole, variable diameter blastholes) to reduce blasting effects. – The use of modified blasting techniques will be considered to reduce blasting effects, including use of electronic detonation instead of explosive detonation cord; use of air decking, which involves the use of an inverted cone in the blasthole to constrain energy within the rock mass; timing sequence to develop an echelon effect; and coordinating blast patterns towards a partially open face. – Blast mats will be used when blasting near receptors sensitive to blasting effects, including residences within 5 km. • Use of residential roads: – Use of residential roads by construction equipment will be limited, where possible. – Project vehicles will avoid the use of residential roads, where possible. • Communities will be informed of time periods and characteristics of noise that may exceed the recommended noise threshold. • Vehicles and equipment will be equipped with manufacturer-recommended noise muffling equipment. • Construction equipment will be regularly maintained. • The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns.
	Noise effects during the operations and maintenance phase, due to the traffic vehicles and maintenance vehicles on the completed highway, and stationary noise sources at the borrow sources	

Effect Name	Effect Pathway	Mitigation Measures
Change in noise levels (cont'd)		• Transportation of construction materials and equipment via barge will be used to reduce the number of trucks for construction resupply along the Mackenzie Highway (Highway No. 1). Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.

13.4.1 Analytical Assessment Techniques

The following list presents the methodology used to predict and assess the project noise levels:

- The noise emission from each noise source is quantified using samples found in acoustical literature (Department for Environmental Food and Rural Affairs [DEFRA], 2005, 2008; Federal Highway Administration [FHWA], 2006; Federal Transit Administration [FTA], 2018) and previous studies done on similar equipment.
- Receptors of concern include human occupancies such as permanent residences, campgrounds, cabins and work camps used for the Project. Known receptors in the LAA were identified from area maps and satellite images and engagement input. Based on the best available information at the time, the main receptors within the study area are located in the communities of Wrigley, Tulita, and Norman Wells, where there are permanently occupied residences. Work camps have been excluded because these are expected to be occupied during the nighttime only when no project noise activities take place. Receptors for wildlife are assessed in the Wildlife and Wildlife Habitat VC (see Chapter 19). Figure 13.2 to Figure 13.4 show maps of the areas with the presence of receptors in the communities of Wrigley, Tulita, and Norman Wells, respectively. As described in Section 13.1.4.1, the residences in the receptor areas in the communities of Tulita and Norman Wells are expected to be less affected by the Project's noise effects than the residences in the community of Wrigley, due to their distances to the PDA. Figure 13.5 shows the location of the most affected receptors in the LAA, which are also all located in the community of Wrigley. These receptors represent the residences that are closest to the project activities as described below:
  - R1 represents the receptor that is closest to the road construction site
  - R2 represents the receptor that is closest to the path of the mobilization equipment
  - R3 represents the receptor that is closest to the borrow sources
- Each effect parameter is quantitatively assessed using the noise modelling software CadnaA (DataKustik, 2021). The model predicts the sound levels (e.g., L_d, L_n, L_{dn}) received at the receptors by considering parameters such as noise source acoustic factors and location, receptor location, and ground acoustic factors.
- The resulting sound levels are compared to their respective noise level threshold as described in Section 13.1.1 to determine its magnitude.
- Mitigation measures are designed to reduce the noise effect levels to below the thresholds, as feasible.



Most Impacted Receptor
Wrigley Winter Bypass Road
Proposed Mackenzie Valley Highway Project Route
Proposed Borrow Source
Local Assessment Area
Winter Road
Northwest Territories Highway

0 0.5 1 Kilometres
(At original document size of 8.5x11)
1:55,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/1/2023
TR by AJ on 8/1/2023

Client/Project
144903025-0093 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
13.5

Title
Most Impacted Receptors in the Community of Wrigley

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. 2015-2016
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

13.4.2 Noise Effect

13.4.2.1 Effects Pathways

Increase in noise level is a potential effect associated with each of the project phases, notably via the following major noise effect pathways. The information comes from Chapter 5 (Detailed Project Description). The assumptions come from acoustic literature (FHWA, 2006), a Climate Lens Assessment completed for the Project (Appendix 24A; K'alo-Stantec, 2021), and consulting experience.

Mobilization activity of the construction phase:

- Trucks: up to 500 trucks for each construction segment, assuming up to 5 trucks on a single day
- Barges: up to 10 barges for each construction segment, assuming up to 1 barge on a single day

Road construction activities of the construction phase:

- Road construction equipment
  - Excavators: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Bulldozers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Graders: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Mulchers: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Tree harvesters: up to 1 unit on a single day, assumed to operate 50% of the daytime
  - Water trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Vacuum trucks: up to 2 units on a single day, assumed to operate 40% of the daytime
  - Fuel trucks: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Mobile drills: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Loaders: up to 4 units on a single day, assumed to operate 40% of the daytime
  - Compaction equipment: up to 2 units on a single day, assumed to operate 20% of the daytime
- Transportation equipment
  - Haul trucks: up to 10 trucks on a single day, travelling from the borrow sources to the road construction site
  - Transport shuttles for workers: assuming 5 shuttles to transport 70 workers from the campsite to the road construction site each day
  - Resupply trucks: up to 100 trucks; assuming up to 1 truck on a single day
  - Resupply barges: up to 10 barges annually; assuming up to 1 barge on a single day

- Construction campsite equipment
  - Vacuum truck: up to 1 truck on a single day
  - Generator: assumed equipped with typical noise suppression, operating 50% of the daytime
  - Incinerator: blower noise, assuming ≤85 dBA at 1 m, operating 50% of the daytime
- Borrow source activities
  - Crushers: up to 2 units on a single day, assumed to operate 50% of the daytime
  - Sorting and Stockpiling: up to 10 rock trucks on a single day, assumed to operate 50% of the daytime

Operations and maintenance phase:

- Highway traffic
  - 50 vehicles per day, assuming 15% of vehicles are heavy trucks (K'alo-Stantec, 2021) and 10% of the volume is during the nighttime

The potentially noise-emitting activities that have been excluded are listed, followed by the justification for their exclusion.

- Maintenance yards: Intermittent and infrequent noise-emitting activities such as gravel loading are expected in the maintenance yards.
- Maintenance activities and vegetation control: Includes snow clearing, grading and dust control, ROW vegetation control, and culvert and bridge maintenance. These activities are considered to have negligible noise effects due to the following reasons:
  - Infrequent and seasonal nature of the activities
  - Expected to occur during the daytime period only and for a short period of time
  - Culvert and bridge maintenance equipment in most cases will be limited to a light pickup truck with negligible noise level
- Blasting events at quarries and road cuts: The blasting activities are designed to meet the Health Canada Noise Guidance threshold below which "little or no public annoyance is expected" (Health Canada, 2017) from the blasting effect, once the mitigation measures described in Section 13.4.2.2 are implemented. Due to its unique noise characteristic (Health Canada, 2017), blasting effects are not expected to act cumulatively with other noise effects of the Project, irrespective of their activity type.
- Activities at permanent quarries/borrow sources during the operations and maintenance phase: The nearest permanent proposed quarry/borrow source to the residences is located approximately 11 km away (north of Tulita), which is beyond the 5 km study area limit (note that R3 is assessed relative to a temporary borrow source, which will not require blasting activity).
- Demobilization equipment: As this task is expected to have similar effects as the mobilization task, it is not assessed separately.

13.4.2.2 Mitigation

Table 13.5 lists all mitigation measures that will reduce effects of the Project on noise. The following are key mitigation measures to be implemented to reduce noise effects:

- Blasting activities will be limited to daytime hours to the extent practical.
- Project vehicles will avoid the use of residential roads, where possible.
- Methods to reduce the powder factor will be considered (e.g., through a combination of increased hole spacing, decreased column height of explosives, increased depth of stemming material in the blasthole, variable diameter blastholes) to reduce blasting effects.
- The use of modified blasting techniques will be considered to reduce blasting effects, including use of electronic detonation instead of explosive detonation cord; use of air decking, which involves the use of an inverted cone in the blasthole to constrain energy within the rock mass; timing sequence to develop an echelon effect; and coordinating blast patterns towards a partially open face.
- Blast mats will be used when blasting near receptors sensitive to blasting effects (VC chapter), including residences within 5 km.
- Construction equipment and project vehicles will avoid the use of residential roads, where possible.
- In winter, haul trucks will use the Wrigley Winter Bypass road, shown in Figure 13.5, instead of passing through the community, if possible.
- Communities will be informed of time periods and characteristics of noise that may exceed the recommended noise threshold.
- Transportation of construction materials and equipment via barge will be used to reduce the number of trucks for construction resupply along the Mackenzie Highway (Highway #1).

The following general best practice mitigation measures will be considered:

- The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction.
- The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns.

13.4.2.3 Residual Effects

Table 13.6 summarizes the results for each of the effect parameters along with their respective threshold criteria, after the application of the mitigation measures described in Section 13.4.2.2. The calculations of these parameters follow the methodology from the Health Canada Noise Guidance (Health Canada, 2017) and Alberta Transportation Guidelines (Alberta Transportation, 2002). See Figure 13.5 for the location of the most affected receptors. Only the single most affected receptor out of the three most affected receptors identified in Section 13.4.1 is shown in the table.

Appendix 13B shows figures with the noise projection of the maximum predicted effect for the Short-Term Community Annoyance levels (L_{dn}) and Traffic Noise levels ($L_{eq-24hr}$) for each project phase.

Table 13.6 Summary of Effect Parameter Results

Project Phase	Effect Parameter	Most Affected Receptor [1]	Predicted Noise Effects at the Most Affected Receptor	Threshold Criteria [2]
Construction Phase – Construction Mobilization	Short-Term Community Annoyance (L_{dn})	R2	46 dBA	47 dBA
	Low-Frequency Noise (L_d)	R2	55 dBZ	70 dBZ
	Speech Comprehension (L_d)	R2	48 dBA	55 dBA
Construction Phase - Road Construction	Short-Term Community Annoyance (L_{dn})	R1 R3	**56 dBA** [3] 47 dBA [4]	47 dBA
	Low-Frequency Noise (L_d)	R1	**71 dBZ** [3]	70 dBZ
	Speech Comprehension (L_d)	R1	**58 dBA** [3]	55 dBA
Operations and Maintenance Phase	Long-Term Community Annoyance (%HA)	R1	0.0%	6.5%
	Low-Frequency Noise (L_d)	R1	33 dBZ	70 dBZ
	Traffic Noise ($L_{eq-24hr}$)	R1	19 dBA	65 dBA

Notes:

Bold values indicate that the noise level exceeds the threshold.

1 See Figure 13.5 for the receptor location.

2 The threshold criteria are described in Section 13.1.1.

3 The exceedances are expected to last 11 days for the short-term community annoyance parameter, and 3 days for the low-frequency noise and speech comprehension parameters.

4 Once the road construction site has moved away from Wrigley after 11 days, the most affected receptor is expected to be R3, due to its proximity to the south borrow source.

Mobilization and demobilization task of the construction phase:

- Short-Term Community Annoyance (L_{dn}): The predicted noise level at a Wrigley residential receptor closest to the construction activities, 46 dBA, is below the threshold limit of 47 dBA L_{dn}. The most affected receptors are the ones located along the path of the mobilization vehicles. The main source of noise is the mobilization trucks travelling on the highway during the summer season before each construction segment.
- Low-Frequency Noise (L_d): The predicted level, 55 dBZ, is below the threshold of 70 dBZ. Mobilization activities are not expected to cause low frequency "rattle" noise annoyance.
- Speech Comprehension (L_d): The maximum level, 48 dBA, is below the threshold of 55 dBA, indicating that mobilization activities are not expected to interfere with speech comprehension.

Road construction task of the construction phase:

- Short-Term Community Annoyance (L_{dn}): The highest predicted noise level, 56 dBA L_{dn}, is over the MNL threshold of 47 dBA L_{dn}. The most affected receptors are the ones located within 1 km of the road construction activity. The noise levels are expected to exceed the threshold for approximately 11 days while the construction activities are in proximity to Wrigley, which is below the two-month duration in the significance determination as described in Section 13.1.6. This 11-day period is estimated based on the distance to attenuate the sound propagation to below the threshold criteria at the receptors (approximately 1,200 m) and the predicted development rate as the construction activities progress north along the highway alignment (approximately 115 m per day). Afterwards, the construction activities will be further from the town (over 1 km north) for the noise levels to drop down to the threshold limit (47 dBA L_{dn}) or below, and the most affected receptors become the ones closest to the south borrow source.
- Low-Frequency Noise (L_d): The predicted noise level, 71 dBZ, is marginally over the threshold of 70 dBZ. Construction activities may result in low frequency "rattle" noise. The most affected receptors are the ones located within 450 m of the road construction activity. This effect is expected to last for approximately three days while the road construction activity is in proximity to the town of Wrigley.
- Speech Comprehension (L_d): The maximum level, 58 dBA L_d, is over the threshold limit of 55 dBA L_d. This means the construction activities are expected to interfere with speech comprehension, both indoor and outdoor. The affected receptors are the residences located within 450 m the road construction activity. This effect is expected to last for approximately three days while the road construction activity is in proximity to the town of Wrigley, which is below the two-month duration in the significance determination as described in Section 13.1.6. This three-day period is estimated based on the distance to attenuate the sound propagation to below the threshold criteria at the receptors (approximately 340 m) and the predicted development rate as the construction activities progress north along the highway alignment (approximately 115 m per day).

Operations and maintenance phase:

- Long-Term Community Annoyance (%HA): The highest predicted change in %HA result, 0.0%, is below the threshold of 6.5%. The result indicates that operations and maintenance activities are not expected to cause long-term community annoyance.
- Low-Frequency Noise (L_d): The predicted noise level, 33 dBZ L_d, is below the threshold of 70 dBZ L_d. Operations and maintenance activities are not predicted to result in low frequency "rattle" noise.
- Traffic Noise ($L_{eq-24hr}$): The highest predicted level at the closest receptor, 19 dBA $L_{eq-24hr}$, is below the threshold of 65 dBA $L_{eq-24hr}$.

13.4.3 Summary of Residual Effects

Table 13.7 summarizes the residual effects based on the characterizations described in Section 13.1.5.

- Direction: The direction for change in noise levels during all the project phases is rated adverse (A) because the phases result in a predicted increase in noise level compared to baseline conditions.
- Likelihood: The likelihood for change in noise levels during all the project phases is rated certain (CE) because the activities from all the project phases have noise-emitting sources.
- Magnitude: The magnitude for change in noise level during the construction phase is rated high (H) because the levels are expected to exceed the noise thresholds, although these high magnitudes are expected to last up to 11 days, after which the noise effect magnitude are expected to be moderate (M) because the noise levels are expected to drop below the thresholds. The magnitude during the operations and maintenance phase is rated low (L) for all parameters except Low-Frequency Noise because the levels are expected to stay within the noise thresholds and are at least 10 dB below the baseline sound levels. The magnitude is rated moderate (M) for the Low-Frequency Noise parameter because the levels are expected to stay within the noise threshold, and the baseline criteria for a low magnitude is not applicable for this parameter.
- Geographic Extent: The geographic extent for change in noise levels is expected to be limited to the LAA for each phase of the Project because beyond the LAA buffer limit of 5 km the project noise effects are expected to attenuate well below the baseline sound level due to natural atmospheric attenuation and ground absorption over distance.
- Timing: The timing in noise effect is rated as moderated sensitivity (MS) during the construction phase activities because these activities occur during the daytime period only, when people are generally less sensitive to noise. The timing in noise effect is rated as high sensitivity (HS) during the operations and maintenance phase activities because these activities also occur during the nighttime period, when people are generally more sensitive to noise than during the daytime period.

- Duration: The duration for change in noise levels during the construction phase is short-term (ST) because the construction activities at any specific location are expected to last less than one year. The duration for change in noise levels during the operations and maintenance phase is long-term (LT) because these activities will last more than one year.
- Frequency: The frequency for change in noise levels during the construction phase for most parameters, except for the speech comprehension parameter, are rated regular event (R) because the construction activities occurs at regular intervals (i.e., 12 hours during the daytime). The speech comprehension is rated irregular event (IR) because this parameter is only mainly affected by noise sources in close proximity to the receptor, which is not expected to occur regularly. The frequency for change in noise levels for the operations and maintenance phase is rated continuous (C) because the activities for this phase will occur continuously.
- Reversibility: The reversibility for change in noise levels during the construction phase is rated reversible (R) because the activities from this phase are temporary and the predicted increase in noise levels would return to baseline conditions at the end of these activities. The reversibility for change in noise levels during the operations and maintenance phase is rated irreversible (I) because the activities from this phase will continue for an indeterminate time.

For the road construction task, the high magnitude noise effects are expected to last 11 days for the short-term community annoyance, and three days for the low-frequency noise and speech comprehension as described in Section 13.4.2.3, both of which are below the two-month duration in the significance determination described in Section 13.1.6. After that, the noise effect magnitude is expected to be moderate.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement consideration of engagement input and incorporation of Traditional Knowledge.

Mitigation measures for reducing effects of the Project on noise respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K’ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats, and take into account traditional and community use of these areas. Although the noise assessment was based on proximity to permanent residences, the findings can be applied to temporary occupations such as cabins and campsites which may occur within the LAA.

Table 13.7 Residual Effects on Noise

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Construction Phase								
Short-Term Construction Noise Exposure	A	CE	H	LAA	MS	ST	R	R
Low-Frequency Noise	A	CE	H	LAA	MS	ST	R	R
Speech Comprehension	A	CE	H	LAA	MS	ST	IR	R
Operations and Maintenance Phase								
Long-Term High Annoyance	A	CE	L	LAA	HS	LT	C	I
Low-Frequency Noise	A	CE	M	LAA	HS	LT	C	I
Traffic Noise Level	A	CE	L	LAA	HS	LT	C	I

KEY

*See Table 13.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

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

N/A: Not applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

13.5 Assessment of Cumulative Effects on Noise

13.5.1 Residual Effects Likely to Interact Cumulatively

The project and physical activities inclusion list, shown in Table 4.2, identifies other projects and physical activities within the largest of the RAAs (wildlife).

Projects and physical activities have the potential to affect the cumulative sound levels if all the following conditions apply:

- The activity period overlaps with the project activity period
- Residences exist within 5 km of both the Project activities and the other activity
- The activity, to be considered noise-emitting, includes activities from stationery and mobile equipment

Where residual effects from the Project act cumulatively with residual effects from other projects and physical activities, as listed in Table 13.8, a cumulative effects assessment is undertaken to determine their significance. For each project and physical activity identified in Table 13.8 that is marked as not likely to interact cumulatively with the Project (without a check mark), a justification is provided and a cumulative effects assessment is not warranted.

The following activities are expected to interact cumulatively with the Project activities. The cumulative effects assessment for these activities is described in the next section.

- Mackenzie Highway #1
- Mackenzie Valley Winter Road (MVWR) and Délı̨nę Winter Road
- Wrigley Power Generation facility
- Tulita Power Generation facility
- Great Bear River Bridge project

No other surrounding projects or activities are expected to interact cumulatively with the Project, as explained below:

- One infrastructure activity overlaps spatially with the Project, the Enbridge Pipeline terminal station at Norman Wells, but no residences exists within the overlapping area.
- Other infrastructure, such as the Prohibition Creek Access Road and Dhu-1 Quarry are within the RAA but more than 5 km from residences, and therefore will not contribute cumulatively to noise effects.
- No oil and gas activities, mining and exploration activities, remediation activities, or staging activities are planned to occur during the time period of any of the project phases.

- A camp activity is expected at an unknown date in the future and is located within 5 km of residences in Norman Wells; however, these residences are located more than 9 km away from the nearest project activity, and thus the project effects are not expected to be cumulative at these residences.
- No geotechnical or quarrying activities are planned to occur during the time period of any of the phases of the Project. One geotechnical activity overlaps spatially with the Project, but that activity will end before the project construction phase begins near that location.

Table 13.8 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects
	Change in Noise Level
Past and Present Physical Activities and Resource Use (Base Case)	
Geotechnical	-
Oil, Gas & Seismic*	-
Infrastructure	
Mackenzie Valley Winter Road	✓
Mackenzie Highway #1	✓
Délı̨nę Winter Road	✓
Quarries and Borrow Sources	-
Mining & Exploration	-
Municipal Operations, including water, waste, power, and community development	
Wrigley Municipal Activities	✓
Tulita Municipal Activities	✓
Project-Related Physical Activities (Project Case)	
Mackenzie Valley Highway Project	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)	
Quarries	-
Infrastructure	
Great Bear River Bridge	✓
Oil and Gas	-

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

The ongoing operations and maintenance activities associated with the Mackenzie Highway #1 will continue to occur during the period of the project construction and operations and maintenance phases. Residences exist within 5 km of this activity and the Project activities. Highway #1 has traffic activities year-round and ends at the community of Wrigley, where the PDA begins. The traffic volume is estimated to be 60 to 70 vehicles per day or less, as obtained from the nearest traffic count location at the Mackenzie River Ferry (GNWT, 2020). Given the low traffic volume, the cumulative noise effect from the interaction of Highway #1 with the project activities is expected to be low.

The MVWR is built every winter and runs along the same corridor as the project highway corridor. The traffic volume, is estimated to be 50 vehicles per day, based on traffic volumes recorded at the turnoff to the Délı̨nę Winter Road (GNWT, 2020)). As this road will be replaced by the project highway, the temporal overlap will be only during the project construction phase and only during the winter. Given its low traffic volume and short temporal overlap with the Project, the cumulative noise effect from the interaction of MVWR with the project activities is expected to be low. The Délı̨nę Winter Road will continue to operate once the Project is completed, but is not expected to add traffic (i.e., traffic reflects combined use of both roadways).

The Great Bear River Bridge project within the municipal boundary of Tulita is scheduled to be completed in 2027. As such, there is a short temporal overlap with the Project. Depending on the sequence of construction of Project highway segments, there may or may not be spatial overlap with the Project's residual effects on noise. If Project construction activities within 5 km of the Hamlet of Tulita occur at the same time as the construction of the Great Bear River Bridge, cumulative effects on noise are likely to occur. These will also combine with the effects of the Tulita Power Generation Facility. There is no overlap between the Great Bear River Bridge and the Project during the operations and maintenance phase, as the bridge will become part of the highway and is assessed as such.

13.5.2 Power Generation Facility Noise Effect

13.5.2.1 Cumulative Effects Pathways

Noise effects from the Wrigley and Tulita Power Generation facilities are expected to occur from the continuous operation of the facility generators. The following information on the facilities come from the Northwest Territories Power Corporation website (NWT Power Corporation, 2022):

- Wrigley Power Generation Facility:
  - Power is supplied by three diesel generating units with a total output of 781 kilowatts (kW)
  - The solar power systems of 10 kW capacity are expected to have negligible noise emissions

- Tulita Power Generation Facility:
  - Equipped with three diesel engines with a total installed capacity of 1.1 megawatts (MW)
- Both facilities are expected to run continuously during both the daytime and nighttime

13.5.2.2 Mitigation Measures for Cumulative Effects

The following typical noise mitigation measures are assumed to be present at the Power Generation facilities:

- The generators are enclosed in typical acoustical metal buildings with doors closed year-round
- Generator cooler fans are designed to emit 85 dBA or less at 1 m
- Generator exhausts are equipped with typical hospital-grade silencers or equivalent

13.5.2.3 Residual Cumulative Effects

Among the measurable parameters listed in Table 13.2, only the long-term community annoyance parameter applies to cumulative effects assessments, because this parameter considers baseline levels as part of its calculation, for which the noise contribution from existing adjacent sources applies. The other parameters, short-term community annoyance, low-frequency noise, speech comprehension, and traffic noise, do not consider baseline levels as part of their calculations, and as such, the noise contribution from existing adjacent sources does not apply. Since the long-term community annoyance parameter only applies to the Project's operations and maintenance phase, only this phase is assessed.

Table 13.9 summarizes the results of the cumulative noise effect on long-term community annoyance along with their respective threshold criteria for the receptors that are most affected by the project activities, R1, R2 and R3 in the community of Wrigley, as identified in Section 13.4.1. Since the residences in the community of Tulita are located farther away from the project activities than the most affected receptors assessed, the Project's contribution to the cumulative effects is expected to be less for the Tulita residences, and thus these residences do not need to be assessed separately.

The highest change in %HA, 0.0%, is below the threshold of 6.5%. The result indicates that the cumulative interaction of the Wrigley Power Generation activity with the project operations and maintenance activities are not expected to cause long-term community annoyance.

Since the Project's contribution to the baseline results is a negligible change in %HA, the Project's contribution to the cumulative effect is not noted. Since the Project noise effects are expected to attenuate well below the baseline sound level beyond a 5 km distance, as described in Section 13.1.4.1, the overall regional effects are not expected to be substantial.

Table 13.9 Cumulative Effect Results on Long-Term Community Annoyance

Receptor	Baseline %HA [1]	Cumulative %HA [2]	Change in %HA [3]	Threshold Criteria for %HA
R1	1.4	1.4	0.0%	6.5%
R2	2.4	2.4	0.0%	6.5%
R3	0.6	0.6	0.0%	6.5%

Notes:

The percent highly annoyed (%HA) is determined as per Appendix F1 of the Health Canada Noise Guidance (Health Canada, 2017).

1 The %HA for the baseline condition includes the contribution of the assumed baseline sound level for the region of 38 dBA L_{dn} as described in Section 13.2.2, and the Power Generation facility sound level.

2 The %HA for the cumulative condition includes the baseline condition and the project contribution.

3 The difference between the Baseline %HA and the Cumulative %HA.

13.5.3 Great Bear River Bridge Noise Effect

13.5.3.1 Cumulative Effects Pathways

Noise effects from the Great Bear River Bridge are expected to occur from the construction of access roads, piers and bridge superstructure. The construction activities are expected to take approximately 4 years, and will be located approximately 800 m from the nearest Tulita residence. In contrast, the nearest Project segment, on the south end of the Tulita North segment, is located approximately 2,500 m northwest of the nearest Tulita residence.

The noise effects from the Great Bear River Bridge activities are assumed to be similar to the effects from the Project's construction activities (Section 13.4.2.1), and the cumulative noise effects include the following parameters:

- Short-Term Community Annoyance
- Long-Term Community Annoyance
- Low-Frequency Noise
- Speech Comprehension

13.5.3.2 Mitigation Measures for Cumulative Effects

The principal mitigation measure for cumulative effects on noise from construction of the Great Bear River Bridge project within 5 km of the Project and within the Hamlet of Tulita is to apply the mitigation measures as identified in Section 13.4, and to plan Project activities such that they do not occur at the same time as the Great Bear River Bridge Project within 5 km of Tulita, if possible.

13.5.3.3 Residual Cumulative Effects

Under the assumption that the noise effect from the construction activities of the Great Bear River Bridge project are equivalent to the Project construction activities, the noise effects from the Great Bear River Bridge activities are expected to exceed the Short-Term Community Annoyance noise threshold criteria (per Health Canada, 2017) on their own. Consequently, the cumulative effect from the Great Bear River Bridge project activities and the Project activities, where and if ,they overlap in time and space, are expected to exceed some the noise threshold criteria for the construction phase of the Project. All the noise threshold criteria are expected to be met for the operations and maintenance phase of the Project.

13.5.4 Summary of Cumulative Effects

Table 13.10 summarizes the cumulative noise effect from the power generation facility activities, the Great Bear River Bridge activities, and the project activities based on the characterizations described in Section 13.1.5.

- Direction: For the power generation facility activities, the direction for change in noise levels is rated neutral (N) because the cumulative effect results in a no-net change in measurable in noise level compared to baseline conditions. For the Great Bear River Bridge activities, the direction for change in noise levels during the construction phase of the Project is rated adverse (A) because the cumulative effect results in a negative direction in noise effect compared to baseline conditions.
- Likelihood: For the power generation facility activities, the likelihood for change in noise levels is rated certain (CE) because the activities from the power generation facilities and the Project have noise-emitting sources. For the Great Bear River Bridge activities, the likelihood is rated possible (P) for the construction phase because the Great Bear River Bridge activities may not overlap in time with the Project activities, and the magnitude of its construction activity noise effects are not certain.
- Magnitude: For the power generation facility activities, the magnitude for change in noise level is rated low (L) because the levels are expected to stay within the noise thresholds and are at least 10 dB below the baseline sound levels. For the Great Bear River Bridge activities during the construction phase of the Project, the magnitude is rated high (H) because the Great Bear River Bridge activities are expected to exceed some of the noise thresholds.
- Geographic Extent: For both the power generation facility activities and the Great Bear River Bridge activities, the geographic extent for change in noise levels is expected to be limited to the LAA because, beyond the LAA buffer limit of 5 km, the activity noise effects are expected to attenuate well below the baseline sound level due to natural atmospheric attenuation and ground absorption over distance.

- Timing: For the power generation facility activities, the timing in noise effect is rated as high sensitivity (HS) because the activities also occur during the nighttime period, when people are generally more sensitive to noise than during the daytime period. For the Great Bear River Bridge activities, the timing is rated moderate sensitivity (MS) because the Great Bear River Bridge activities are expected to occur only during the daytime period when people are generally less sensitive to noise.
- Duration: For the Great Bear River Bridge activities during the construction phase of the Project, the duration for change in noise levels is short-term (ST) because the cumulative effect from these activities and the Project activities will last less than one year. For the power generation facility activities during the operations and maintenance phase of the Project, the duration for change in noise levels is long-term (LT) because the cumulative effect from these activities and the Project activities will last more than one year.
- Frequency: For the power generation facility activities, the frequency for change in noise levels is rated continuous (C) because the activities will occur continuously. For the Great Bear River Bridge activities, the frequency is rated regular event (R) because the construction activities occur at regular intervals (i.e., expected to occur 12 hours during the daytime).
- Reversibility: For the power generation facility activities, the reversibility for change in noise levels is rated irreversible (I) because the activities will continue for an indeterminate time. For the Great Bear River Bridge activities, the reversibility is rated reversible (R) because the activities are temporary and the predicted increase in noise levels would return to baseline conditions at the end of these activities.

Table 13.10 Residual Effects on Noise

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Project Construction Phase								
Great Bear River Bridge with Project	A	P	H	LAA	MS	ST	R	R
Project Operations and Maintenance Phase								
Power Generation Facility with Project	N	CE	L	LAA	HS	LT	C	I

KEY

*See Table 13.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

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

N/A: Not applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

13.6 Determination of Significance

13.6.1 Significance of Residual Effects

The criteria that determine the effect significance is described in Section 13.1.6. Project activities have been grouped into the construction mobilization activity, the road construction activity, and the operations and maintenance phase.

During the construction mobilization activities and the operations and maintenance phase, the magnitude, duration, sensitivity, and frequency at all receptors do not meet the significance criteria. During the road construction activities, the duration, sensitivity, and frequency at all receptors do not meet the significance criteria. However, the magnitude classification at R1 (see Figure 13.5) is high for a period of 11 days which is below the two-month criteria for duration; and otherwise, the magnitude classification at all receptors is predicted to be moderate or low for the remaining time period. In consideration of the residual effect classifications, no receptor meets all the criteria of magnitude, duration, sensitivity, and frequency, for significance as defined in Section 13.1.6; therefore, the project noise effect is not significant.

13.6.2 Significance of Cumulative Effects

As described in Section 13.5, the Wrigley and Tulita Power Generation facility activities and the Great Bear River Bridge activities are the only two project and physical activities that are expected to interact cumulatively with the Project in a potentially moderate or high magnitude. As described in Section 13.5.2.3, the cumulative interaction of the Power Generation facility activities with the Project activities are not expected to cause long-term community annoyance at any receptor. As described in Section 13.5.3.3, the cumulative interaction of the Great Bear River Bridge construction activities with the Project activities are expected to exceed some the noise threshold criteria at the nearest residences in the community of Tulita, if this project occurs at the same time as the Project. Therefore, the cumulative effects are significant.

13.6.3 Project Contribution to Cumulative Effects

Since the Project's effects on noise on their own are not significant, as explained in Section 13.6.1, and the Project's noise levels result in a negligible change in percent highly annoyed over the baseline condition as described in Section 13.5.2.3, the Project's contribution to cumulative noise effect is not significant.

13.7 Prediction Confidence

The predication confidence for residual effects and cumulative effects for acoustic is moderate and is based on the accuracy of the project design information, noise source data, and sound propagation algorithm.

- Acoustic models can be revised, if necessary, when final design information is available. Conservative assumptions were used, as described in the next section.
- The various sound power levels of noise sources were established with field measurements of similar equipment, or acoustic literature. For most data samples, upper percentiles were used to be conservative.
- The Cadna/A model predicts outdoor noise in accordance with ISO 9613. The ISO 9613 sound propagation algorithms have a published accuracy of ±3 dB over source receiver distances between 100 m and 1,000 m. The accuracy for distances up to or over 1.5 km is not stated. The ISO 9613 model also produces results representative of meteorological conditions enhancing sound propagation (e.g., downwind and temperature inversion conditions). These conditions do not occur all the time; therefore, model predictions are expected to be conservative.

13.7.1 Assumptions

The following assumptions have been made to estimate the noise effects:

- The frequency of activities were obtained from acoustical literature for similar equipment (FHWA, 2006).
- The traffic speed limit is conservatively assumed to be up to 50 kilometres per hour (km/h) in communities such as Wrigley, though local by-laws will apply. This is based on vehicle speeds to be limited to 50 km/h on all unfinished project road surfaces.
- The Wrigley Winter Bypass Road is assumed to be operational during the winter season from December to March.
- The development rate of the highway sections is assumed to be evenly distributed throughout the construction period.
- The terrain within 5 km from the highway is conservatively assumed to be flat, such that there are no natural barriers between the noise source and the receptor to attenuate the sound.
- Transport shuttles for workers have a capacity of 14 passengers per vehicle.
- Highway traffic volume is 50 vehicles per day, assuming 15% of vehicles are heavy trucks (K’alo-Stantec, 2021) and 10% of the volume is during the nighttime.
- The list of maintenance equipment was obtained from the Climate Lens Assessment for the Project (K’alo-Stantec, 2021).

- Borrow source material will be transported from the borrow source that is nearest to the road construction site.
- The mobilization vehicles operate 50% of the days and the trips are evenly spread out throughout the mobilization period.
- Downwind conditions exist 100% of the time, which is more conservative than upwind or crosswind conditions.
- All operating equipment was modelled at 100% capacity even though the capacity might be less throughout the activity period.
- A ground factor of 0.7 is used in the noise model, which conservatively represents uncultivated land for both summer and winter seasons.
- The method for calculating the Power Generation facility generators sound level emissions comes from Engineering Noise Control (Bies and Hanson, 2009).
- The noise effects from the Great Bear River Bridge activities are assumed to be similar to the effects from the Project's construction activities.

13.7.2 Gaps and Uncertainties

A gap that may affect the assessment of potential effects on noise are listed below:

- No receptors (permanent residences) outside of municipalities were identified, based on the best available information at the time.

Uncertainties in the calculations are listed below:

- Sound level emissions for the noise sources have been quantified using samples found in acoustical literature (DEFRA, 2005, 2008; FHWA, 2006; FTA, 2018) and previous studies done by Stantec on similar equipment. Final values were processed as a percentile of the sample. Uncertainties are present due to the variance in the sample values.
- The sound propagation method used in the model has an uncertainty of ±3 dB at a distance between 100 m and 1,000 m. The accuracy for distances up to or over 1.5 km is not stated (ISO 9613-2).

13.8 Follow-up and Monitoring

No specific noise monitoring is proposed. Noise levels at assessed receptor locations are anticipated to be highest during the construction phase, but will be short-term. Noise monitoring is not likely to be able to lead to a timely response, and additional reasonable noise mitigation measures may not be available. The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns. Noise monitoring may be initiated on a case-by-case basis, if required.

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14.0 ASSESSMENT OF POTENTIAL EFFECTS ON TERRAIN, SOILS AND PERMAFROST

Terrain, Soils and Permafrost were selected as a Valued Component (VC) as these interrelated elements together support ecosystem functions and provide foundations to biophysical components. The VC aligns with the Subject of Note (SON) Terrain, Soils and Permafrost in the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]). The term "terrain" refers to characteristics of surficial materials and landforms (or surface expressions) and the geomorphological processes which result in the modification of surface materials and their surface expressions. These characteristics, alongside the development of soils (i.e., the uppermost unconsolidated layer of mineral and organic material) and the availability of surface water, are the foundation of northern ecosystems. Permafrost also has a fundamental importance to northern ecosystems by stabilizing certain terrain and modifying the hydrological cycle. Permafrost ecosystems, therefore, help keep ecological balance by supporting unique habitats for animal and plants.

The Mackenzie Valley Highway Project (the Project) has the potential to affect terrain, soils, and permafrost during the construction and operations and maintenance phases of the Project through pathways such as land clearing, ground disturbance and its effects on terrain, soils, physical and thermal stability, and alteration of surface and sub-surface water flow paths.

Changes to terrain, soils, and permafrost conditions may trigger changes to the surface water quantity (see Chapter 15), vegetation (see Chapter 18) fish and fish habitat (see Chapter 17), wildlife and wildlife habitat (see Chapter 19), and traditional land and resource use (see Chapter 11). These changes may occur due to specific project activities and/or from naturally occurring processes (e.g., climate change or forest fires) over the life of the Project.

The assessment of potential effects on the Terrain, Soils and Permafrost VC concludes that with the application of mitigation measures, residual effects resulting from the Project on terrain, soils, and permafrost will be adverse. Residual effects and cumulative effects are not expected to threaten the stability of local terrain, soil development, and/or soil capability, or physical and thermal stability of permafrost and therefore are predicted to be not significant.

14.1 Scope of Assessment

14.1.1 Regulatory and Policy Setting

The assessment of potential project-related effects on terrain, soils, and permafrost is guided by the ToR (MVEIRB, 2015 [PR#66]), federal and territorial guidance and, where applicable, the Sahtu Land Use Plan (SLUP).

14.1.1.1 Federal and Territorial Guidelines

The following notable federal and territorial guidance applies:

- The Government of the Northwest Territories (GNWT) Land Use Guidelines for Camp and Support facilities (GNWT, 2015a)
- The GNWT Land Use Guidelines Pits and Quarries (GNWT, 2015b)
- The GNWT Land Use Guidelines Access: Roads and Trails (GNWT, 2015c)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions by the Transportation Association of Canada (TAC, 2010)
- National Guide to Erosion and Sediment Control on Roadways Projects (TAC, 2005)
- The GNWT Erosion and Sediment Control Manual (GNWT, 2013)
- General guidance for various soils parameters is provided via the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 2007)
- Quarry Development Plan Template (GNWT, 2021)

14.1.1.2 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). Specific to permafrost, CR#10 requires that *"Any land use activity requiring a land use permit or water license must be designed and carried out in a manner that prevents and/or mitigates adverse environmental impacts resulting from the degradation or aggradation of permafrost*." Conformity Requirement #2 requires that "*The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*

Additionally, CR #14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)

- K'ą̨ą̨lǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

14.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (Consultation and Engagement), 3 (Traditional Knowledge), and 11 (Culture and Traditional Land Use) of this Developer's Assessment Report (DAR). The GNWT has recently initiated Consultation Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to terrain, soils, and permafrost**.** This feedback has been considered and summarized in Table 14.1 and has been integrated into the assessment of potential effects to terrain, soil, and permafrost and associated effects on valued resources including wildlife, vegetation, and water that follows.

14.1.3 Potential Effects, Pathways, and Measurable Parameters

Potential effects on terrain, soils, and permafrost could occur wherever project activities interact with the ground surface. For this reason, one of the key ways to address changes to terrain, soils, and permafrost is to limit ground disturbance during the Project.

The ground surface, either the organic/mineral topsoil or overall surficial materials and underlying permafrost, could be affected by several activities during the construction and operations and maintenance of the highway. Changes to terrain or soil conditions may occur due to clearing activities, set up and operation of access roads and camps, excavation of borrow materials, quarrying, excavation of road cuts, and construction of the embankment. All of these activities require travel across the ground, either along the alignment, along access roads, or working in areas of open cut in borrow sources or quarries, therefore presenting a potential effect pathway on terrain, soils, and permafrost.

To mitigate potential effects on terrain, soils, and permafrost, the construction and operation activities will be limited, to the extent possible, to within the planned footprint of the Project.

The potential effects on terrain, soils, and permafrost considered in this DAR include:

- Change in terrain conditions (including potential erosion, modification of local drainage patterns, and slope stability)
- Change in soils conditions (including physical, chemical, and biological properties)
- Change in permafrost conditions (including loss of permafrost, either from degradation of physical or thermal properties)

Table 14.1 Summary of Engagement Feedback

<table>
<tr><th>Comment</th><th>Source</th><th>GNWT Response</th><th>Where Addressed</th></tr>
<tr><td>Sahtu Dene and Métis expressed concerns that thawing permafrost will increase turbidity and solids in local streams, affecting water quality and quantity.</td><td>SRRB, 2016</td><td rowspan="5">The GNWT has identified mitigation measures to reduce effects on terrain, soils, and permafrost.
Project design will avoid ice-rich areas where possible.
Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
A fill-only construction approach will be used, except at specific locations of road cuts.
A project-specific Erosion and Sedimentation Control Plan (ESCP), Quarry Development Plan (QDP), and Permafrost Protection Plan (PPP) will be developed and implemented.
Best management practices for erosion control will be implemented according to the Erosion and Sedimentation Control Plan.
The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.</td><td rowspan="5">For mitigation measures to reduce effects of the Project on terrain, soils, and permafrost, see Table 14.5.
See also:
Section 14.4.2 (Change in Terrain Conditions)
Section 14.4.3 (Change in Soils Conditions)
Section 14.4.4 (Change in Permafrost Conditions)
Chapter 5 Table 5.2 Summary of Consideration of Community Input on Design
Chapter 10 (caribou and moose)
Chapter 11 (culture and traditional land use)
Chapter 15 (water quantity)
Chapter 16 (water and sediment quality)
Volume 5 for management plans.</td></tr>
<tr><td>Elders in the K’ásho Got’ı̨nę and Tulita regions expressed concerns about potential project effects associated with land clearing, including increased rates of thawing permafrost, leading to problems with vegetation establishment, erosion and slumping on the banks of the Sahtu waterbodies, which has previously been linked to erosion in Great Bear River and other waterbodies in the area.</td><td>Auld and Kershaw, 2005; Golder, 2015</td></tr>
<tr><td>Sahtu Region residents expressed concerns about potential project effects thawing permafrost (erosion, flooding, scouring, reduced land subsistence), which also can affect ground water and surface water; and effects to Norman Wells water quality.</td><td>SRRB, 2016</td></tr>
<tr><td>Sahtu Dene and Métis reported concern that thawing permafrost will increase turbidity and solids in local streams, affecting water quality.</td><td>SRRB, 2016</td></tr>
<tr><td>Dehcho First Nations reported increased temperatures and precipitation, changes to snow and vegetation, and effects on lake and river ice and boat access.
They stated that warmer temperatures, thawing permafrost, and other environmental changes create concerns related to the environment, including the thawing of permafrost which harbors and protects lichens and reduces the availability of lichen-rich habitats important for caribou. Additionally, forest fires are burning the moss, which leaves the permafrost poorly insulated.</td><td>Dehcho First Nations, 2011; Golder, 2015</td></tr>
</table>

Comment	Source	GNWT Response	Where Addressed
Local knowledge provided by Tulita Renewable Resources Council (TRRC) and Norman Wells Renewable Resources Council (NWRRC) TLRU study participants explained that thawing permafrost creates wetter, boggier areas where the ground was previously hard, which makes traversing the landscape to practice TLRU more difficult.	NWRRC, 2023; TRRC, 2022		
NWRRC study participants observed that weather in the TLRU study area has changed over the last few years, attributed to cumulative effects and warming temperatures, which affects the land and the permafrost and can influence the flow of creeks.	NWRRC, 2023		
TRRC study participants reported increase erosion resulting from road construction and operation along the Mackenzie Valley Winter Road (MVWR).	TRRC, 2022		
Community engagement participants stated there are increased landslides and sloughing and permafrost thawing, accelerated by climate change. Warmer temperatures, thawing permafrost, and other environmental changes create concerns related to the environment (EBA, 2011). Sahtu Dene and Métis reported that thawing permafrost, slumping ground, and shoreline erosion, effects of climate change pose additional safety risks to infrastructure, including roads, and buildings, as well as risks to traditional economies, and TLRU.	SLUPB, 2022; EBA, 2011); April to July 2022 Engagement		

Comment	Source	GNWT Response	Where Addressed
Community engagement participants expressed concern about erosion and the steepness of the MVWR. They identified Seagrams Creek, Blackwater Creek, Strawberry Creek, Gotcha Creek, the Délı̨nę Winter Road turnoff, and the area north of Big Smith Creek as specific areas of concern.	August 2021 Engagement; April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		

Table 14.2 summarizes the potential effects of the Project on terrain, soils, and permafrost; the pathways by which they may trigger changes in terrain, soils, and permafrost conditions; and the measurable parameters for evaluating these effects. Potential effects and measurable parameters were selected based on professional judgment, recent environmental assessments for road projects in the Northwest Territories (NWT), and lessons learned from other similar projects. Where potential effects are not able to be measured quantitatively, visual observations serve as a trigger to undertaking further investigation, which may include site-specific collection of quantitative data.

Table 14.2 Potential Effects, Effects Pathways, and Measurable Parameters for Terrain, Soils, and Permafrost

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in terrain conditions (including potential erosion, modification of local drainage patterns, and slope stability)	• Terrain stability issues resulting from ground disturbance (e.g., at locations of road cuts, borrow sources and quarries) • Potential water erosion and sediment delivery following vegetation clearing and exposure of surficial materials to erosive factors	• Ground surface elevation (metres [m]) • Visible changes in sediment loads in streams, turbidity (nephelometric turbidity units) • Visual observations of changes to terrain conditions, including seepage, erosion and/or ponding, mass movement features and processes (e.g., cracks, flow features, slumping) • Site-specific survey of extents and elevations
Change in soils conditions, capability (including physical, chemical, and biological properties)	• Loss of soils from road construction • Change in soil reclamation suitability from construction activities and reclamation activities at borrow sources and quarries • Soil compaction, rutting, and pulverization from vehicle/equipment traffic during mobilization/ demobilization, site clearing, and/or construction-related activities along the right-of-way (ROW) at borrow sources and quarries • Potential soil contamination due to accidental spills (detailed in accidents and malfunctions, Chapter 25)	• Loss of soils from road construction (volume in cubic metres [m^3]) • Soil reclamation suitability, such as coarse fragment content or soil organic matter on reclaimed borrow sources and quarries • Visual observations of rutting or compaction including mixing of soil horizons, excessive build-up of mud on vehicle tires, formation of puddles, excessive tracking of mud during stripping and reclamation activities of borrow sources and quarries • Visual observations of soil pulverization during stripping and reclamation activities at borrow sources and quarries • Analytical testing of soil contamination

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in permafrost conditions (physical and thermal properties)	• Permafrost thaw resulting from vehicle traffic and clearing during construction • Permafrost thaw resulting from construction-related activities (including granular extraction, excavation of road cuts, and construction of embankment and culverts) • Permafrost thaw resulting from changes to local drainage pattern, erosion and/or ponding along the embankment during construction, operations and maintenance activities (including effects of snow distribution on ground thermal regime)	• Active layer depths (centimetres [cm]) • Air and ground temperature (degrees Celsius [°C]) • Ground surface elevation (m) • Visual observations of thaw settlement, ponding, vegetation change, or thermokarst (i.e., the process by which characteristic landforms result from the thawing of ice-rich permafrost)

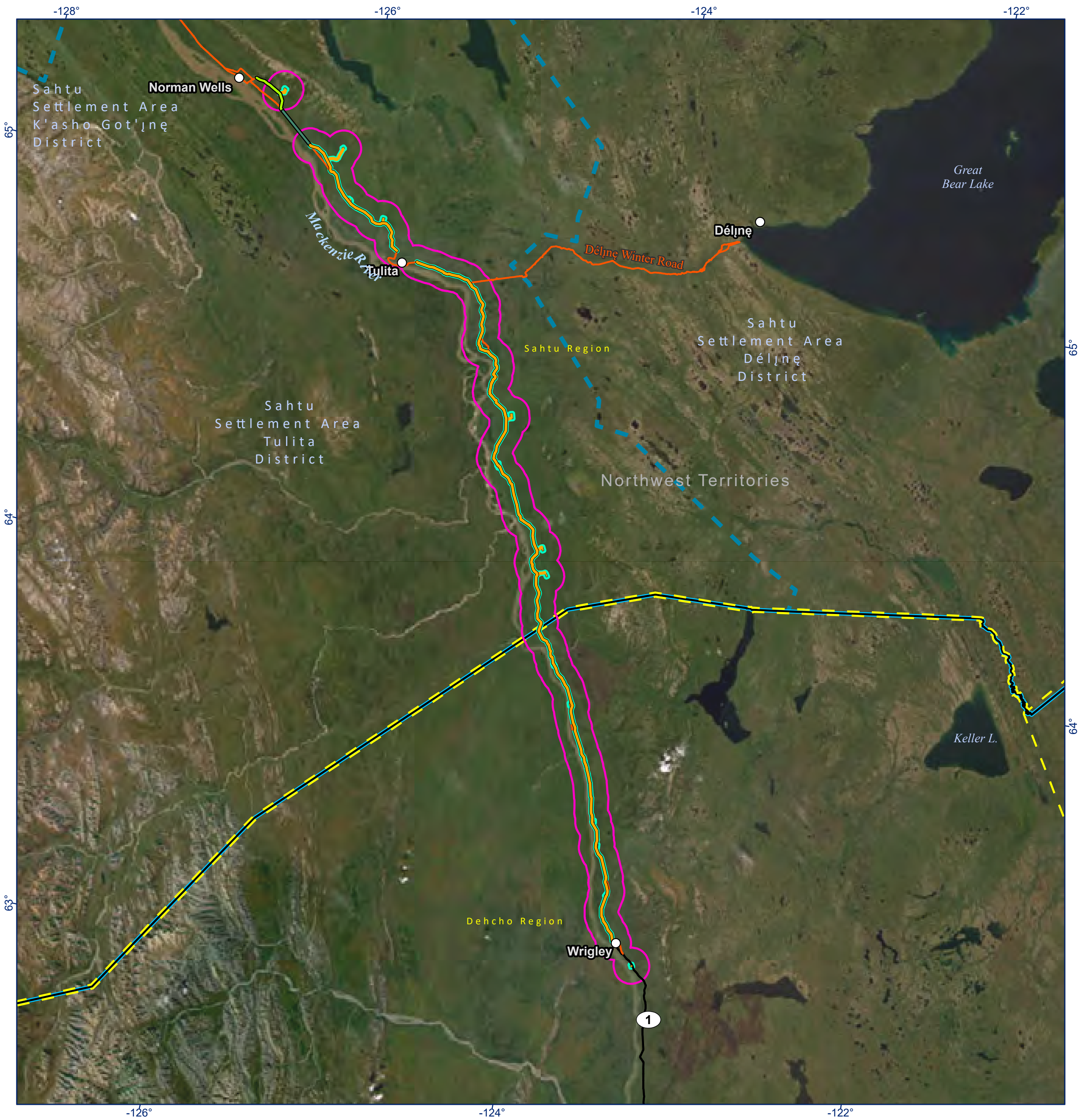
14.1.4 Boundaries

The spatial and temporal boundaries used to assess potential effects on terrain, soils, and permafrost are described in Sections 14.1.4.1 and 14.1.4.2, respectively.

14.1.4.1 Spatial Boundaries

The Project development area (PDA), local assessment area (LAA), and regional assessment area (RAA) for the assessment of effects on terrain, soils, and permafrost are shown on the Project Overview map (see Figure 14.1). These spatial boundaries are used to assess Project effects, including residual and cumulative effects, on terrain, soils, and permafrost within a representative region surrounding the Project.

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway ROW, laydown and staging areas, maintenance yards, construction camps, and borrow sources and quarries sites with access roads with a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects on terrain, soils and permafrost (direct or indirect) are expected to occur. The LAA for terrain, soils, and permafrost is a 0.5 kilometre (km) buffer on either side of the proposed road alignment route centerline, access roads, and quarry and borrow source extents (Figure 14.1).
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and cumulative effects. The RAA is an approximate 5 km buffer around the PDA (Figure 14.1). This buffer is used to capture regional scale landscapes that could potentially be affected cumulatively by the Project and other past, present, and reasonably foreseeable projects.



- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Territorial Boundary

0 10 20 Kilometres

(At original document size of 8.5x11)
1:1,750,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/3/2023
TR by OP on 8/3/2023

Client/Project
144903025-0143 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
14.1

Title
Terrain, Soils and Permafrost Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

14.1.4.2 Temporal Boundaries

Effect on terrain, soils, and permafrost will be evaluated in relation to specific project phases and activities. The temporal boundaries for this assessment include:

- **Construction phase:** The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the alignment will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase**: The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

14.1.5 Residual Effects Characterization

Potential residual effects of the Project on terrain, soils, and permafrost are characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 14.3). The criteria describe the potential residual effects that remain after mitigation measures have been implemented.

Table 14.3 Characterization of Residual Effects on Terrain, Soils and Permafrost

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** a residual effect that moves measurable parameters of terrain, soils, and permafrost in a negative direction relative to baseline **Neutral –** no net change in measurable parameters for the terrain, soils, and permafrost relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** the residual effect is almost certainly not to occur **Possible –** the residual effect could occur **Certain –** the residual effect will certainly occur

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**No measurable or observable change –** no qualitative or quantitative change in the effect can be noted **Low –** effect slightly exceeds baseline conditions but has no effect on ecological function **Moderate –** effect exceeds baseline conditions and has some effect on ecological function **High –** effect exceeds baseline conditions and may cause a loss of ecological function
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** residual effects are restricted to the PDA **LAA –** residual effects extend into the LAA **RAA –** residual effects interact with those of other projects in the RAA
Timing[1]	Considers when the residual effect is expected to occur, where relevant to the VC.	**No sensitivity -** effect does not occur during a sensitive time for soils (e.g., effect occurs during wintertime when soils are frozen) **Moderate sensitivity -** effect may occur during a somewhat sensitive period (e.g., during early spring or late fall when soils are still snow covered and/or frozen or partially frozen) **High sensitivity -** effect occurs during a highly sensitive period (e.g., during the summer period when terrain, soils, and permafrost are the most susceptible to ground disturbance)
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	**Short-term –** the residual effect is restricted to one year in duration or less **Medium-term –** the residual effect extends through the construction of the Project (may be up to 20 years) **Long-term –** the residual effect extends beyond the construction of the Project (greater than 20 years)
Frequency	Identifies how often the residual effect occurs and how often during the Project or in a specific phase	**Single event** – occurs as a single occurrence **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

Note:

[1] Sensitive times are mainly related to seasonality (with respect to air and ground thermal conditions) rather than the timing of the different phases of the Project. For example, potential residual effects on terrain, soils, and permafrost are more likely to occur (or have an increased significance and lead on to other effects) during thawing season than during the winter.

14.1.6 Significance Definition

A significant residual effect on terrain, soils, and permafrost is one that, following the application of avoidance and mitigation measures, threatens the stability of local terrain, soil development, and/or soil capability, as well as physical and thermal stability of permafrost.

14.2 Existing Conditions for Terrain, Soils and Permafrost

Existing conditions for terrain, soils, and permafrost within the LAA and RAA have been detailed in the Terrain, Soils and Permafrost Technical Data Report (TDR; Appendix 14A; K'alo-Stantec, 2023). This report was developed with the objective of presenting baseline information, as well as providing a basis for the suitable design and construction of the highway. Key subjects covered in the TDR include:

- Regional overview (physiography and bedrock geology)
- Surficial materials and landforms
- Soil types, including great group or subgroup
- Permafrost, ground thermal conditions, and ground ice conditions (including climate change considerations)
- Geomorphological processes and geological hazards

The TDR also provides information for the proposed and alternate borrow sources and quarries locations (including land ownership), proposed access routes, overall terrain conditions, and expected material quality, as well as the presence/absence of terrain-related constraints and geological hazards.

14.2.1 Methods

Baseline conditions for terrain, soils, and permafrost were obtained from three sources: a compilation and review of existing data, terrain mapping, and a reconnaissance site visit (specific to conditions at the borrow and quarry sources).

Information sources consulted as part of the data review included the following (see Appendix 14A [K'alo-Stantec, 2023] for complete source information):

- Project Description Reports (PDRs) completed for the Sahtu Region and Dehcho Region
- TLRU and Traditional Knowledge information
- Existing soils and surficial geology mapping
- Open-source borehole database
- Geotechnical investigation reports conducted for the 1970s roadway alignment
- Granular material inventory reports completed for the local communities and surrounding lands

- Geotechnical pipeline route investigations completed for private industry
- Reports from recent geotechnical investigations conducted in support of the Mount Gaudet Access Road (MGAR; kilometre markers [KM] 695 to 711) near Wrigley and Prohibition Creek Access Road (PCAR)
- Scientific literature, publications, and data relevant to terrain, soils, and permafrost conditions in the Mackenzie Valley

Terrain mapping was completed at a 1:10,000 scale in the LAA. Mapping was conducted in the ArcGIS platform using aerial photography, ortho-imagery, and light detection and ranging (LiDAR) data available for the Project. A map book presenting the terrain mapping is included in Appendix 14A (K'alo-Stantec, 2023). As part of the mapping, relatively homogeneous terrain units (or polygons) were delineated based on:

- Surficial materials (e.g., till, glaciolacustrine)
- Surface expression (e.g., hummocky, fan)
- Depth to bedrock (e.g., veneer, blanket) or stratigraphic composition (i.e., identifying the expected subsurface material)
- Slopes and geomorphological processes (e.g., groundwater seepage, mass wasting)

The reconnaissance site visit focused on collecting information at prospective borrow sources and quarries to inform recommendations concerning future detailed investigations required for advancing the project design. Information gathered as part of the visit included descriptions of topographic site conditions, rock and material types, soil drainage conditions, permafrost, presence of environmental constraints, and overall accessibility of the sites for future development. These visual observations were supplemented by limited water and rock sampling for screening of metal leaching and acid rock drainage potential, and limited soil and rock sampling for the assessment of the overall material suitability for borrow source development.

14.2.2 Overview

14.2.2.1 Regional Overview

From north to south, the Project spans the Taiga Plains Low Subarctic, Taiga Cordillera Low Subarctic, and Boreal Cordillera Level III ecoregions, each distinguished by different landscapes and degrees of climatic factors. The area is separated into two main physiographic regions consisting of the Mackenzie Plain and the Franklin Mountains.

The dominant geological units consist of Devonian-aged sedimentary bedrock, predominantly sandstone, shale, limestone, and dolostone (Okulitch and Irwin, 2014). Exposed rocks and rugged bedrock-controlled terrain are generally limited to the easternmost section of the RAA (i.e., towards the west flank of the Franklin Mountains), with most of the LAA overlaid by a thick mantle of surficial material. There are a few exceptions, including shallow bedrock at river crossings and shallow or exposed bedrock alongside Mount Gaudet north of Wrigley, and Bear Rock (Petınıʔah) across from Tulita.

14.2.2.2 Surficial Materials and Landforms

Published surficial geology mapping identifies glaciolacustrine materials, till (moraine), colluvium, alluvial materials, glaciofluvial materials, eolian materials, bedrock, and organic materials within the RAA (Duk-Rodkin, 2002; Duk-Rodkin and Couch, 2004; Duk-Rodkin and Huntley, 2009; Côté et al., 2013; GSC, 2019a, 2019b). The Mackenzie Plain, which covers most of the area immediately east from the Mackenzie River (Deh Cho), hereafter referred to as Mackenzie River, is primarily covered by a thick sequence of morainal and glaciofluvial deposits, in several areas overlaid by a veneer (<1 m) to a blanket (>1 m) of glaciolacustrine sediments. Following glacial retreat these deposits have been modified by geomorphic processes, including the development of recent drainage features (from tributary rivers to gully systems and seepage flow paths), the slow and/or rapid downslope movements of materials (e.g., soil creep and landslides), and the reworking of fine-grained surficial deposits by eolian activity. Organic soils are present throughout the RAA, especially above poorly to very poorly drained fine-grained soils.

The landscape is more rugged along the Franklin Mountains (i.e., eastern most portion of the RAA, above the Mackenzie Plain), where the weathering of bedrock-controlled terrain (mainly limestone and dolomite) has contributed to the accumulation of a mantle of colluvial materials along the base of major slopes. Large fluvial fans, characteristically poorly drained and marked by seasonal seepage following snowmelt, are commonly found along the tributary streams or large gully systems.

14.2.2.3 Soils

Two soil orders, Cryosols and Brunisols, are present in the PDA, LAA and RAA. Cryosols are mineral or organic materials that have perennially frozen material (permafrost) within 1 m of the surface, while Brunisols are mainly associated with coarse-textured and/or well-drained surficial materials absent of permafrost.

14.2.2.4 Permafrost

Permafrost is defined as ground (soil or rock) that remains at or below zero degree Celsius (0 °C) for at least two years (Harris et al., 1988). The Project spans the extensive discontinuous permafrost (predominantly near Norman Wells), intermediate discontinuous permafrost (e.g., Mackenzie Plain area), and sporadic discontinuous permafrost (area surrounding Wrigley) zones (Heginbottom et al., 1995; Heginbottom, 2000). Climate is the predominant element controlling this broad distribution of permafrost along the Project, followed by other factors such as topography, soils characteristics, vegetation, snow cover, and surface water.

Permafrost may be absent or found at greater depth beneath large bodies of water (including rivers and lakes). Discontinuous permafrost is associated with warm ground temperatures and thermally sensitive permafrost conditions. The distribution of permafrost within both the RAA and LAA is difficult to predict as it is dependent on multiple variables, including topography, soil and vegetation characteristics, snow cover, and geothermal gradient. Along the PDA and LAA, permafrost is expected to be more predominant in low-lying, often imperfect to poorly drained, fine-grained soils (e.g., glaciolacustrine sediments, clay till) than in areas of well-drained, often coarse-grained soils (e.g., glaciofluvial deposits). These terrain types were mapped and described in Appendix 14A (K'alo-Stantec, 2023). Similarly, permafrost is more likely to be present in forests with high canopy closure, elevated peat plateaus, and in soils with thick organic horizons.

Permafrost can be classified into two types based on the relative amount of ice within the ground: ice-rich (thaw-sensitive) and ice-poor (thaw-stable). The type of permafrost that is of interest when constructing infrastructure is ground that is ice-rich (thaw-sensitive). Fine-grained soils (predominantly silt and clay) that contain visible ice are considered thaw-sensitive. Coarse-grained soils (predominantly sand and gravel) and bedrock that do not contain excess ice are considered thaw-stable.

Warming in the North has triggered changes that are affecting both infrastructure and the livelihood of communities. Terrain hazards, especially permafrost degradation, are anticipated to be exacerbated by the effects of climate change. The progressive increase in mean annual temperatures is expected to accelerate the thawing of permafrost. Along a transportation corridor like the Mackenzie Valley Highway, permafrost degradations could lead to the increased occurrence of soil instability and ground movements (e.g., heaving, thawing, sinkholes, potholes, and settlement issues).

Local knowledge provided by TRRC and NWRRC study participants explained that thawing permafrost creates wetter, boggier areas where the ground was previously hard, which makes traversing the landscape to practice TLRU more difficult (NWRRC, 2023; TRRC, 2022). NWRRC study participants observed that weather in the Sahtu Area has changed over the last few years, attributed to cumulative effects and warming temperatures, which affects the land and the permafrost and can influence the flow of creeks (NWRRC, 2023). Dehcho First Nations identified warmer temperatures, thawing permafrost, and other environmental changes create concerns related to the environment, including the thawing of frost which harbors and protects lichens and reduces the availability of lichen-rich habitats important for caribou (Dehcho First Nations, 2011). Sahtu Dene and Métis reported that thawing permafrost will increase turbidity and solids in local streams, affecting water quality (NWRRC, 2023; SRRB, 2016). Additionally, Sahtu Dene and Métis reported concerns about potential project effects exacerbating permafrost thawing, slumping ground, and shoreline erosion; in conjunction with effects of climate change potential project effects can pose additional safety risks to infrastructure, including roads, and buildings, as well as risks to traditional economies, and TLRU (SLUPB, 2022). Elders in the K'ásho Got'įnę and Tulita regions also noted concerns about potential project effects associated with land clearing, including increased rates of thawing permafrost, leading to problems with vegetation establishment, erosion and slumping on the banks of the Sahtu waterbodies, which has previously been linked to erosion in Great Bear River and other waterbodies in the area (Auld and Kershaw, 2005; Golder, 2015).

14.3 Project Interactions with Terrain, Soils and Permafrost

Table 14.4 identifies, for each potential effect, the physical activities and components of the Project that have the potential to interact with terrain, soils, and permafrost. Interactions that have the potential to result in effects on terrain, soils, and/or permafrost within the LAA or RAA are indicated by a check mark. These interactions are discussed in detail in Section 14.4, in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for activities not expected to interact with terrain, soils, and/or permafrost is provided following the table.

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are described in Chapter 25.

Table 14.4 Project-Environment Interactions with Terrain, Soils and Permafrost

Physical Activities	Timing	Environmental Effects		
		Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	–	–	–
Establishment and operation of camps	Year-round	–	✓	✓
Site preparation of ROW, access, and workspaces	Winter	–	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓
Material haul	Year-round	–	–	–
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	✓	✓
Road base placement, compaction, and surfacing	Summer	–	–	–
Water withdrawal to support construction activities	Year-round	–	–	–
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–	–

Physical Activities	Timing	Environmental Effects		
		Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material haul and stockpiling	Summer	–	–	–
Operation of, and activities at, maintenance yards	Year-round	–	–	✓
Water withdrawal for dust control	Summer	–	–	–
Employment and contracted goods and services[1]	Year-round	–	–	–
Presence and public use of the highway	Year-round	✓	✓	✓
Highway and access road maintenance, including snow clearing, repair, grading, dust control	Year-round	–	–	✓
Vegetation control	Summer	–	–	–
Bridge and culvert maintenance	As needed	–	–	–

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

The potential interactions between project activities and the environment were considered for the construction phase and the operations and maintenance phase of the Project. The identification of project activities and their potential interactions was based on engagement with Indigenous Governments, Indigenous Organizations, and other affected parties, the professional judgment of technical specialists involved in the assessment, and a review of known existing conditions. The selection of interactions is also informed by the potential effects and effects pathways for each VC as described in Section 14.1.3.

Mobilization and demobilization of project equipment is not expected to interact with terrain, soils, and permafrost as equipment will be transported by barge on the Mackenzie River during the open-water season, the Mackenzie Highway #1, or by the MVWR in the winter to designated staging areas, as well as along the existing disturbances and infrastructure (i.e., including newly built embankment as it is being constructed). Aside from the clearing and grubbing (where needed) of the ROW in winter, there will be no mobilization or demobilization of equipment across undisturbed terrain as part of the construction, operation, and maintenance of the Project.

The placement of road base, compaction and surfacing, as well as hauling of waste, water, or borrow material (either granular or crushed rock), is not expected to interact with terrain, soils, and permafrost because these activities will be undertaken on already constructed embankment or workspaces.

During operations and maintenance, water withdrawal for dust control activities is not anticipated to result in interactions with terrain, soils, and permafrost as this will occur intermittently and will not cause ground disturbance. Likewise, activities associated with culvert and bridge maintenance are likely to occur on previously constructed embankment without disturbance to surrounding areas.

Employment and contracted goods and services activities are not expected to result in a change in terrain, soils, and permafrost for the lifetime of the Project as there is no pathway for these activities to interact with terrain, soils, and permafrost.

14.4 Assessment of Residual Effects on Terrain, Soils and Permafrost

This section discusses the interaction pathways for the project activities identified in Table 14.4 (Section 14.3) that have the potential to affect a change in terrain, soils, or permafrost conditions. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on terrain, soils, and permafrost are identified in Table 14.5. These residual effects and associated analytical assessment techniques are described.

Table 14.5 Potential Effects and Mitigation Measures for Terrain, Soils and Permafrost

Effect Name	Effect Pathway	Mitigation Measures
Change in Terrain Conditions	• Terrain stability issues resulting from ground disturbance (e.g., at locations of road cuts)	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas. • A fill-only construction approach will be used, except at specific locations of road cuts. • To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded. • The slope of the cut or fill will have a horizontal to vertical ratio accounting for the geotechnical properties of the materials.
	• Potential water erosion and sediment delivery following vegetation clearing and exposure of surficial materials to erosive factors	• A Project-specific ESCP will be developed and implemented. Erosion and drainage patterns will be observed and documented per the Erosion and Sedimentation Control Plan. • Best management practices for erosion control will be implemented according to the Erosion and Sedimentation Control Plan • Erosion and sedimentation control measures will be regularly inspected and maintained. Erosion and sedimentation control measures and structures will be repaired if damage occurs. • Sedimentation and erosion control measures will be regularly inspected to confirm they are performing as intended. These measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measures. • Runoff control methods will be used to protect permafrost soils, including but not limited to: the diversion of water entering the site, modification of slope surfaces, reduction of slope gradients, controlling flow velocity, providing adequate or increased drainage, and diverting flows away from exposed soil areas for mitigating permafrost degradation. • Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. • Clearing will not be conducted during high rainfall or runoff events.

Effect Name	Effect Pathway	Mitigation Measures
Change in Soil Conditions (including physical, chemical and biological properties)	• Loss of soils from road construction	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). • Tree roots will be grubbed only in areas required for construction or stripping. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water.
	• Changes to soil structure, porosity, organic matter, and reclamation suitability resulting from soil compaction, rutting, and pulverization from vehicle/equipment traffic, site clearing, and/or construction-related activities on borrow areas	• Construction on cleared ground will be conducted during dry or frozen conditions, or will use rig matting to reduce soil compaction, rutting, and erosion. • Organic material and topsoil will be set aside for use during reclamation, to the extent possible. • If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible. • Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction. • Soil stripping operations in borrow areas will be conducted under the guidance of a qualified person. • Closure and reclamation will promote re-establishment of vegetation ground cover. • Site grading at closure will approximate pre-development conditions. • Soil stripping will be postponed on borrow areas during wet weather or thawing conditions to reduce deterioration in soil conditions. • Soils stripping will be postponed on borrow areas on coarse textured soil during windy conditions to reduce deterioration of soil conditions.

Effect Name	Effect Pathway	Mitigation Measures
Change in permafrost conditions (physical and thermal properties)	• Permafrost thaw resulting from vehicle traffic and site clearing during construction	• The Project will follow measures in the PPP. • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads). • A fill-only construction approach will be used, except at specific locations of road cuts. • Erosion control products and methods will be used to limit erosion of fine-grained soils per the GNWT Erosion and Sediment Control Manual (GNWT, 2013). • Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas. • To promote the stability of cuts and fills on slopes, fill material will be compacted and the tops of cut slopes will be rounded. • The slope of the cut or fill will have a horizontal to vertical ratio accounting for the geotechnical properties of the materials. • Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost. • Clearing will be completed by hand, where required, to prevent damage to the ground. • A minimum of 10 cm of packed snow or ice will be used on winter access roads. • Construction equipment will be operated on designated winter roads or constructed embankment only. • During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain. • Ice-rich soils or materials that are susceptible to physical erosion encountered during excavation will be covered to reduce permafrost degradation. • Where possible, cleared material will be mulched and spread over cleared areas within the project footprint to protect the soil and permafrost. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to reduce permafrost degradation and protect the soils from erosive factors of water. • If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible.

Effect Name	Effect Pathway	Mitigation Measures
Change in permafrost conditions (physical and thermal properties) (cont'd)	• Permafrost thaw resulting from construction-related activities (including granular extraction, excavation of road cuts, and construction of embankment)	• The Project will follow measures in the QDP to reduce ponding, erosion, and damage to permafrost during quarry operations and closure. • The Project will follow measures in the PPP to reduce ponding, erosion and damage to permafrost. • The stability of permafrost over time will be monitored. • The pit floor of borrow areas/quarries will be sloped to reduce ponding of water. • Excavations and developed borrow sources will be visually monitored throughout the summer and fall to observe for physical erosion resulting from the degradation of permafrost. If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities. • Excavations will be contoured prior to closure to reduce steep slopes. • Project design will avoid ice-rich areas where possible. • If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities. • Construction equipment will be operated on designated winter roads or constructed embankment. • Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost. • Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes. • During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain. • The area of direct ground disturbance will be minimized by following the pre-existing winter road alignment to the extent possible. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water. • The embankment will be constructed predominantly using a "fill approach" with minimal disruption to the subgrade rather than a "cut and fill" approach; however, road cuts will be needed where grades at a steep valley approach can be reduced by cutting into the hill slope. • During spring, summer, and fall, suitable equipment will be used to prevent effects on sensitive terrain.

Effect Name	Effect Pathway	Mitigation Measures
Change in permafrost conditions (physical and thermal properties) (cont'd)	*See above*	• Use of equipment on highly saturated soil will be avoided, where possible. • Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
	• Permafrost thaw resulting from changes to local drainage pattern, erosion, and/or ponding along the embankment (including effects of snow distribution on ground thermal regime)	• Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. • Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert. • Snow accumulation and runoff alongside the highway will be monitored visually. Snow removal methods will be modified if needed in areas presenting excessive snow accumulation/runoff. • Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches.
	• Permafrost thaw resulting from natural conditions and geoprocesses (e.g., forest fires, climate change)	• A project-specific PPP will be developed and implemented to monitor the stability of the permafrost over time.

14.4.1 Analytical Assessment Techniques

Potential effects on terrain, soils, and permafrost were assessed by comparing existing baseline conditions in the LAA and RAA (as summarized in Section 14.2 and described in detail in the TDR [Appendix 14A; K'alo-Stantec, 2023]) to conditions anticipated to occur with construction of the Project. Existing baseline conditions were obtained from reviewing data obtained from a literature review (i.e., including reports, maps, and available relevant databases) as well as from the terrain mapping conducted for the project LAA. These are considered the most important data sources from which potential effects, and the success of mitigation measures, can be assessed.

The terrain mapping completed for the LAA uses a formal classification system that uses expert judgement, experience, and training in the identification and delineation of geomorphological landforms and processes visible on the Earth's surface to interpret and classify a landscape (Resources Inventory Committee, 1996; Howes and Kenk, 1997). Although focusing on surficial geology, landforms, and geoprocesses, this data often forms the basis to the interpretation of soil and permafrost properties (including their expected distribution). This information forms the basis for many derivative assessments and analyses that in turn can inform the expected performance or effects of the Project on the environment.

Effects on terrain, soil conditions, and permafrost were assessed by comparing baseline conditions to the expected conditions resulting directly from road construction and indirectly from changes in drainage and reclamation activities. Potential effects were also assessed by reviewing similar assessments conducted for other all-season highway projects in the NWT (e.g., Tłı̨chǫ Highway [MVEIRB, 2018], Prairie Creek All Season Road [CZC, 2015], Inuvik to Tuktoyaktuk Highway [Kiggiak EBA, 2011]). Changes in soil conditions were qualitatively assessed based on professional judgement on soil reclamation suitability, compaction, rutting, pulverization, and contamination processes. Changes in permafrost conditions were also qualitatively assessed based on professional judgement and available data obtained as part of the description of baseline conditions.

The assessment of potential effects on terrain, soils, and permafrost does not include a failure modes analysis. The potential failure modes associated with a highway built over permafrost may include (but are not limited to) differential thaw settlement, loss of soil strength and localized slumping. These are expected to be closely related to the local distribution of ground ice, and will be further influenced by the locations of ground disturbances, such as those associated with road cuts. As the design does not yet incorporate site-specific geotechnical information, the assessment of effects is based on best available information. Additional geotechnical information to inform design will be collected once there is certainty of the alignment routing corridor (upon completion of the environmental assessment).

14.4.2 Change in Terrain Conditions

14.4.2.1 Effects Pathways

Project activities could result in changes in terrain conditions, both during the construction and operations and maintenance of the infrastructure. The project construction will require that all equipment, materials, fuel, camps, and other supplies be mobilized to designated construction start locations. Although the mobilization of equipment itself is not expected to generate effects on the local terrain due to the use of existing roads (both all-season and winter roads), activities such as clearing of the ROW, workspaces, borrow sources, and quarries has the potential to interact with terrain conditions. The same applies to excavation at borrow sources, quarries, or road cuts, embankment construction, and culvert installation. In this context, ground disturbance is a direct effect which results in the alteration or displacement of soils, and therefore also changing terrain conditions.

Indirect effects on terrain conditions may also occur, mainly through alteration to the movement of surface water. For example, the newly built embankment can form a barrier to the movement of unchannelized surface water. The modified topography will create new preferential paths for surface water drainage that often do not match with the natural surface water drainage pattern. Water running along the uphill toe of the road for some distance (i.e., instead of across it) could generate physical and thermal erosion. Locations where the water is finally directly downslope can also be affected, in some cases potentially triggering changes in material strength and leading slope instabilities. Aside from a change in hydrology and surface water runoff, an increased erosion potential could be linked to changes in vegetation conditions, change in topography or slopes, a change in material strength, or a change in ground thermal regime (discussed under permafrost). Localized erosion may occur along the road embankment, at the stream crossings or other areas where the erosive action of water (including along poorly-define flow paths identified as part of the TDR terrain mapping) may take place.

Knowing that the PDA, in some areas, crosses terrain susceptible to mass movement (landslides), the Project has the potential to reactivate old landslides or to initiate new ones. Although such features can reactivate on their own, ground disturbance can increase the likelihood of landslide reactivation. Grading, excavation, or removal of surface vegetation can trigger landslides. Alteration of natural flow paths can also lead to landslides; for example, if the road reroutes surface water drainage into a marginally stable area, slope instabilities could result. Similarly, if natural slopes are altered or if a section of the road cuts into the supporting toe of an old landslide, that cut could result in the slide reactivating, even if it is not a slope in permafrost soils.

14.4.2.2 Mitigation

Standards, best management practices, and mitigation measures are expected to prevent or reduce changes in terrain conditions resulting from the Project. Potential effects will be mitigated through management practices applied during design, construction, operations, and reclamation, while site-specific mitigation may be required in certain circumstances. The mitigation strategy will overlap across several interrelated VCs for which the effect pathways are similar (e.g., mitigation of soil surface erosion addresses effects on vegetation, soils, permafrost, surface water, and sediment quality). Following construction, the need for additional mitigation will be determined by monitoring.

Refer to Table 14.5 for a list of mitigation measures that will address effects on terrain, soils, and permafrost. Key mitigation measures to prevent or reduce changes to terrain conditions include the following:

- The Project will follow measures in the PPP (see Volume 5).
- The Project will follow measures in the ESCP. Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended (see Volume 5).
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Clearing of new areas will be completed when the ground is frozen. Clearing will be completed by hand, where required, to prevent damage to the ground.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. Modification to the location or number of drainage culverts will be determined in consultation with the Engineer as based on observed site conditions.
- A fill-only construction approach will be used, except at specific locations of road cuts.

14.4.2.3 Residual Effects on Terrain Conditions

Potential residual effects of the Project on terrain conditions were characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (see Table 14.6).

Based on the implementation of best practices, as well as adherence to the standards, mitigations, and procedures outlined in the ESCP, the effects on terrain conditions are expected to be restricted to the footprint of the road and borrow areas. Because of the construction of permanent access roads, borrow sources, quarries, and of the highway itself, the effects on terrain are expected to be long term and irreversible.

14.4.3 Change in Soils Conditions

Road construction can negatively affect physical and chemical properties of soil due to the direct loss of soil from road and permanent borrow/quarry construction and changes soil conditions such as structure, porosity, permeability, organic matter content, and chemical conditions resulting from soil stripping, stockpiling, and replacement on areas designated for closure and reclamation.

Construction and operations and maintenance can negatively affect physical and chemical properties of soils due to contamination resulting from accidental spills.

The effect of accidental spills and releases on soils is addressed in Chapter 25, Accidents and Malfunctions.

14.4.3.1 Effects Pathways

Road construction will entail clearing of the ROW and access roads and placing woven geotextile, 300 millimetres (mm) blast rock, and 50 mm and 20 mm granular rock over native soils. Construction will require the development of both temporary and permanent quarries/borrow as a source of crush rock and granular material and temporary support infrastructure and workspaces, including camps, maintenance yards, laydown and staging areas, fuel storage areas, and in places, a winter travel lane.

Construction, operations and maintenance, and reclamation activities from the Project could affect soil conditions in the following ways:

- Clearing and grubbing of the ROW, as well as road and permanent quarry/borrow construction, will result in the direct loss of soils
- Temporary borrow/quarry and workspace development, including land clearing, soil salvage, storage, and replacement could result in changes to soil structure, porosity, organic matter, and reclamation suitability from admixing, soil compaction, rutting, and pulverization

14.4.3.2 Mitigation

Best practices and avoidance measures identified in the ESCP, as well as soil-specific mitigation measures, will be implemented during construction and operation of the Project to lessen the effects of the Project on soil conditions.

Refer to Table 14.5 for a list of mitigation measures that will address effects on terrain, soils, and permafrost. Key mitigation measures that will prevent or reduce changes to soils conditions include the following:

Loss of Soil from Road Construction and Permanent Borrow Sources and Quarries

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).
- Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas.
- Tree roots will be grubbed only in areas required for construction or stripping. Grubbing will preserve soil surface organic material.

Soil Admixing, Compaction, Rutting, Pulverization, and Reclamation Suitability

- Clearing of new areas will be completed when the ground is frozen.
- Clearing will not be conducted during high rainfall or runoff events.
- Clearing will be completed by hand, where required, to prevent damage to the ground.
- Organic material and topsoil will be set aside for use during reclamation, to the extent possible.
- Undisturbed areas will be avoided until they are scheduled for stripping to limit unnecessary soil degradation and compaction.
- Soil salvage will be postponed during wet weather or high winds to prevent erosion and/or damage to the soil structure.
- Soil stripping operations in borrow areas will be conducted under the guidance of a qualified person.

14.4.3.3 Residual Effect on Soils Conditions

Road construction and the ancillary development of permanent borrow sources and quarries will result in the direct loss of soil even if the Project will largely follow the existing MVWR. The use of existing borrow sources and quarries (where applicable) will, however, reduce the need for disturbing new ground. Effects of direct loss of soil are restricted to the PDA, long-term, and irreversible.

Development of temporary quarries/borrow and temporary workspace will result in soil disturbance and possible changes to soil structure, porosity, organic matter, and soil reclamation suitability. The progressive reclamation of these access road and temporary borrow sources, however, will make those effects on soils to be reversible. Effects are expected to be restricted to the PDA, short-term, and reversible with implementation of mitigations.

14.4.4 Change in Permafrost Conditions

14.4.4.1 Effects Pathways

Permafrost, especially that which is ice-rich, is highly sensitive to ground disturbance and changes in ground temperature. This is particularly true of the warm discontinuous permafrost found within the PDA, although the extent of localized permafrost degradation is difficult to predict as it is dependent on multiple variables including surface temperature, soil properties, and the initial permafrost temperature conditions.

Permafrost is vulnerable to both thermal erosion and physical erosion of surficial materials (i.e., including both organic and mineral soils).

- Physical erosion is characterized as the mobilization of soil particles by water flow and subsequent deposition as sediment. Vulnerability to physical erosion is similar in permafrost and non-permafrost areas.
- Thermal erosion is characterized as the thawing of permafrost or seasonally frozen ground. Frozen ground containing ice will thaw and settle and the discharge water will flow over saturated soil.

Although thermal erosion may or may not result in physical erosion, physical erosion generally increases the vulnerability to thermal erosion.

Within the PDA, LAA, and RAA, the terrain, soils, and permafrost are in their most vulnerable state in the spring, summer, and fall when the air/surface temperature are high and the active layer is thawing or thawed. Travel over ground when the ground is in this vulnerable state can damage the soil and vegetative surface and cause deformation of the ground surface (particularly in areas of soft, fine-grained soils and peat). This can then lead to compaction and rutting of organic layers and topsoils, and creation of uneven topography favorable to the collection of surface water.

Physical changes caused from ground disturbance could result in an increase in ground surface temperature and a corresponding increase in the depth of the active layer and subsequent thawing of ice-rich soil, slope and soil instability, erosion/sedimentation, and subsidence of the ground surface. Earthwork activities in thaw-sensitive permafrost may require the removal of the organic layer and cutting into the ground (e.g., during borrow extraction or excavation of road cuts). These activities may potentially expose permafrost, which in areas of ice-rich permafrost could cause subsidence and water ponding, excessive erosion and sedimentation, thawing, and settlement. These changes may affect terrain stability and cause mass movements alongside the highway (either slow and progressive or rapid).

Once constructed, the highway surface and embankment slopes will have a lower albedo (i.e., lower reflection of solar radiation) when compared to the natural undisturbed and vegetated ground surface. In a similar way, the slope and orientation characteristics of the embankment could be influential on the amount of energy that the future road will receive from the sun. This increased absorption of solar radiation could lead to modification of the thermal balance of the underlying permafrost over time. In warm permafrost, the edges of the embankment tend to allow the permafrost beneath to thaw, sometime causing ponding along the embankment toe (especially where seepage may occur), while in the middle of the embankment the permafrost may be preserved or even grow (i.e., permafrost aggradation into the embankment). The newly built embankment also may affect local thermal balance of the permafrost by allowing snow drift buildup. The increased snow accumulation can have many effects, including an effect on ground temperatures (i.e., due to the thermal insulation of the snow cover, which reduces heat loss in the embankment shoulders and toes), an increase of the active layer thickness and surface subsidence, increase of soils water content, and ultimately a modification of local vegetation communities alongside the embankment (de Grandpré et al., 2012).

14.4.4.2 Mitigation

The Project will follow measures in the PPP and ESCP. Permafrost and sedimentation and erosion control measures will be regularly inspected to confirm they are performing as intended (see Volume 5). The ESCP incorporates standards, best management practices, and mitigation measures to prevent or reduce potential changes to permafrost conditions, and will be guided by the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015d)
- The GNWT, Department of Transportation – Erosion and Sediment Control Manual (GNWT, 2013)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions (TAC, 2010)

Refer to Table 14.5 for a list of mitigation measures that will address effects on terrain, soils, and permafrost. Key mitigation measures that will prevent or reduce permafrost degradation include the following:

- The embankment will be constructed predominantly using a “fill approach” with minimal disruption to the subgrade rather than a “cut and fill” approach; however, road cuts will be needed where grades at a steep valley approach can be reduced by cutting into the hill slope.
- Erosion control products and methods will be used to limit erosion of fine-grained soils per the GNWT Erosion and Sediment Control Manual (GNWT, 2013).
- Where possible, cleared material will be mulched and spread over cleared areas within the Project footprint to protect the soil and permafrost.
- Project design will avoid ice-rich areas where possible.
- Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
- Positive drainage will be maintained within quarry floors.
- If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice.

14.4.4.3 Residual Effect on Permafrost Conditions

One of the key goals of the project design is to develop permanent infrastructure that reduces potential negative effects on the environment and that is resilient to climate change. This requires understanding the local terrain, soils, and permafrost conditions and selecting a final highway alignment that follows competent and least-sensitive ground available along the route. However, to some degree, building on permafrost is unavoidable, and some localized permafrost degradation is inevitable (e.g., in sensitive terrain where ice-rich soils might be present) due to the change in thermal regime resulting from ground disturbance and ongoing effects of climate change. Effects are therefore expected to be long-term as the road will be permanent, and irreversible as a return to baseline conditions will not be achievable.

With the implementation of best practices, as well as adherence to the mitigations, procedures, and strategies outlined in the ESCP and PPP, however, adverse effects of the Project onto the permafrost are anticipated to be limited geographically (e.g., areas of ice-rich, thaw-sensitive permafrost).

14.4.5 Summary of Residual Effects on Terrain, Soils and Permafrost

Residual effects resulting from the Project on terrain, soils, and permafrost conditions after mitigation are implemented will certainly occur. These effects are predicted to be adverse (e.g., changes in drainage conditions, loss of soils from road construction, localized modification of the ground thermal regime); however, with an overall magnitude expected to vary from low to moderate (i.e., depending on the effect pathway). The geographic extent of direct effects will be the PDA for terrain and soil conditions and the PDA and LAA for permafrost conditions. Effects will be ongoing during construction and operations and maintenance and are assumed irreversible in relation to expected changes in permafrost conditions due to the indefinite duration of operation of the Project.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to permafrost, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for protection of soils, terrain and permafrost will protect the rock formation of the Petiniʔah (Bear Rock) CZ, and are intended to respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats.

Table 14.6 Residual Effects on Terrain, Soils and Permafrost

Residual Effect	Residual Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Terrain conditions	A	C	L	PDA	NS[1]	LT	IR	I
Change in Soils conditions	A	C	M	PDA	NS[1]	LT[2]	IR	I[3]
Change in Permafrost conditions	A	C	M	LAA	MS-HS	LT	C	I

KEY

* See Table 14.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMOC: No Measurable or Observable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: Low sensitivity
MS: Moderate sensitivity
HS: 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

Notes:

1 Assumes that activities such as vegetation clearing and/or soil stripping do not occur at a sensitive period (e.g., thawing or wet soil conditions).

2 Short-term for construction at any one point. Effects of soil contamination could be long-term.

3 Loss of soil under constructed road and permanent quarries/borrow sources will be irreversible, while the effects of soil contamination may be reversible. Changes to soil conditions from admixing, compaction, rutting, pulverization, and reclamation suitability that may occur and during the stripping and reclamation activities of temporary quarries and borrow areas is reversible.

14.5 Assessment of Cumulative Effects on Terrain, Soils and Permafrost

14.5.1 Residual Effects Likely to Interact Cumulatively

Existing environmental conditions reflect cumulative effects on terrain, soils, and permafrost from past and present projects and physical activities. Past and present projects and physical activities that have been or are being carried out have influenced the existing conditions for terrain, soils, and permafrost (Section 14.4). The assessment of cumulative effects focuses on the same three interconnected adverse residual project effects, as previously assessed. They consist of a change in terrain conditions, a change in soils conditions, and a change in permafrost conditions.

Table 14.7 presents project and physical activity inclusion lists, which identify other past, present, and reasonably foreseeable projects and physical activities within the RAA.

Where adverse residual effects from the Project act cumulatively with those from other past, present, or reasonably foreseeable projects and physical activities, a cumulative effects assessment is undertaken to determine their significance.

Table 14.7 Projects with the Potential to Contribute to Cumulative Effects

Other Projects and Physical Activities with Potential for Cumulative Effects on Soils, Terrain and Permafrost	Environmental Effects		
	Change in Terrain Conditions	Change in Soils Conditions	Change in Permafrost Conditions
Past and Present Physical Activities and Resource Use (Base Case)			
Geotechnical	–	–	–
Oil, Gas & Seismic*	–	–	–
Infrastructure			
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓	✓
Canyon Creek All Season Access Road	✓	✓	✓
Prohibition Creek Access Road	✓	✓	✓
Norman Wells Pipeline	–	✓	✓
Mackenzie Valley Fibre Link	–	✓	✓
Délı̨nę Winter Road	✓	✓	✓
Mackenzie Highway #1	✓	✓	✓
Quarries and Borrow Sources			
HRN Quarry	✓	✓	✓
Little Bear River Quarry			

Other Projects and Physical Activities with Potential for Cumulative Effects on Soils, Terrain and Permafrost	Environmental Effects		
	Change in Terrain Conditions	**Change in Soils Conditions**	**Change in Permafrost Conditions**
Mining & Exploration	–	–	–
Municipal Operations, including water, waste, power, and community development			
Wrigley Municipal Activities	–	–	–
Tulita Municipal Activities	–	–	–
Norman Wells Municipal Activities	–	–	–
Project-Related Physical Activities (Project Case)			
Mackenzie Valley Highway Project	✓	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)			
Quarries			
Dhu-1 Quarry	✓	✓	✓
Infrastructure			
Great Bear River Bridge	✓	✓	✓
Oil and Gas			
Enbridge Maintenance Camp	–	–	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

Similar to the Project, interactions between other projects and physical activities with terrain, soils and permafrost are anticipated where there will be physical disturbance of vegetation or ground surface. Checkmarks are given for those other projects and activities.

In some cases, the effects of other projects and physical activities are anticipated to affect only soils and permafrost, but not terrain (e.g., the Mackenzie Valley Fibre Link and Norman Wells Pipeline). For some other projects and physical activities, such as municipal operations, works have been developed in consideration of geotechnical conditions to reduce long-term effects on terrain, soils and permafrost, and take into account municipal plans.

Oil, gas and seismic projects, past and present geotechnical projects, as well as mining and exploration projects are not expected to interact with terrain, soils and permafrost as their footprint, timing, and/or location is generally different from the current project. Whenever, their footprint overlaps (i.e., whenever other projects footprints overlap the PDA or LAA, their respective activities are likely to occur on previously constructed embankment without disturbance to surrounding areas, therefore not contributing to residual effects.

14.5.2 Change in Terrain Conditions

14.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on terrain conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project (see Section 14.4.2.1). Those include potential ground stability issues resulting from activities involving ground disturbance, as well as potential water erosion and sediment delivery following vegetation clearing and exposure of surficial materials to erosive factors.

14.5.2.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on terrain conditions are the same as those presented in Table 14.5 and Section 14.4.2.2.

14.5.2.3 Cumulative Effects

The effect on terrain conditions from all projects and physical activities in the RAA is considered low and limited to the immediate area of ground disturbance of each project. Many projects and associated activities have the potential for both direct and indirect effects and the effects are expected to be long-term as most projects and activities will be long-term or permanent. However, there will be few adverse cumulative effects on terrain conditions in the RAA.

14.5.3 Change in Soil Conditions

14.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on soil conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including the direct loss of soil and changes in soil structure, porosity, organic matter, or reclamation suitability as discussed in Section 14.4.3.1.

14.5.3.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on soil conditions are the same as those presented in Table 14.5 and Section 14.4.3.2.

14.5.3.3 Cumulative Effects

Cumulative effects on changes to soil conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways.

The effect on soil conditions from all projects and physical activities in the RAA is considered low. Many projects and associated activities have the potential for both direct and indirect effects and the effects are expected to be long-term as most projects and activities will be long-term or permanent. However, there will be few adverse cumulative effects on the overall distribution of soil or the soil landscape in the RAA.

14.5.4 Change in Permafrost

14.5.4.1 Cumulative Effects Pathways

Potential cumulative effects on changes in permafrost arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including permafrost thaw from vehicle traffic, site clearing, construction-related activities, and changes to ground surface conditions including local drainage patterns, erosion, and/or ponding, as discussed in Section 14.4.4.1.

14.5.4.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on permafrost thaw are the same as those presented in Table 14.5 and Section 14.4.4.2.

14.5.4.3 Cumulative Effects

Cumulative effects on changes to permafrost conditions arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways. Lessons learned from previous linear projects are well-documented. Essentially, ground disturbance which involved eliminating or greatly reducing plant growth or affecting the organic topsoil generally resulted in increased permafrost thaw. Once the vegetative cover is physically damaged and/or the mineral soil is exposed, the increased thaw is often accompanied by erosion. The application of design and construction standards, best management practices, and mitigation measures to prevent or reduce changes in permafrost conditions, however, can greatly limit potential negative effects.

The effect on permafrost conditions from all projects and physical activities in the RAA is considered low. Many projects and associated activities have the potential for both direct and indirect effects and the effects are expected to be long-term as most projects and activities will be long-term or permanent. However, there will be few adverse effects on the abundance and distribution of permafrost in the RAA.

14.5.5 Summary of Cumulative Effects

Cumulative effects on terrain, soils, and permafrost from past, present, and reasonably foreseeable projects and activities will certainly occur. These effects are predicted to be adverse in direction and low in magnitude. The geographic extent of direct effects will be the PDA.

Effects for many projects and activities will persist for the long-term due to the long operating life of many projects and activities. For many of these project and activities, effects will be ongoing during construction and operation and may be reversible or irreversible. The timing of potential residual cumulative effects on permafrost is considered highly sensitive as they are assumed more likely to occur during a specific portion of the year (e.g., during the thawing season).

Table 14.8 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Terrain Conditions	A	C	L	RAA	MS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will have a low magnitude contribution to cumulative effects on changes to terrain conditions at the RAA level.							
Change in Soil Conditions	A	C	L	RAA	MS	LT	IR	I
Contribution from the Project to the residual cumulative effect	The Project will have a low magnitude contribution to cumulative effects on changes to soil conditions at the RAA level.							
Change in Permafrost Conditions	A	C	L	RAA	HS	LT	C	I
Contribution from the Project to the residual cumulative effect	The Project will have a low magnitude contribution to cumulative effects on changes to permafrost conditions at the RAA level.							

KEY

* See Table 14.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

Magnitude:
NMOC: No Measurable or Observable Change
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: Low sensitivity
MS: Moderate sensitivity
HS: High sensitivity

N/A: Not applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

14.6 Determination of Significance

14.6.1 Significance of Residual Effects

A significant adverse residual effect on terrain, soils and permafrost is one that, following the application of avoidance and mitigation measures, threatens the long-term stability of terrain and permafrost, as well as the ability of soils to support the vegetation. To some degree, effects such as thermal erosion or the thawing of permafrost is inevitable due to the change in thermal equilibrium that will be triggered by the construction. These effects, wherever they occur, are expected to be localized and of low magnitude. The extent of localized changes to terrain, soils and permafrost is difficult to predict, however, most likely to correspond to areas where surface disturbance will occur (i.e., PDA). Far from all areas of surface disturbance are likely to be prone to residual effects. Activities to be undertaken on already disturbed terrain, for examples, are not expected to be affected.

When accounting for the methods, strategies, and monitoring efforts aimed at preventing or mitigating negative impacts due to the disturbance of permafrost, the effects on terrain, soils, and permafrost are considered not significant.

14.6.2 Significance of Cumulative Effects

A significant adverse cumulative effect on terrain, soils, and permafrost is defined the same as for residual effects. Many past, present, and reasonably foreseeable projects and activities will have adverse effects on changes to terrain, soils, and permafrost conditions. However, a large amount of the area in the RAA will not be affected and the cumulative effects on terrain, soils, and permafrost are predicted to be not significant.

14.6.3 Project Contribution to Cumulative Effects

The Project is predicted to make a low contribution to cumulative effects on changes to terrain, soils, and permafrost.

14.7 Prediction Confidence

Based on professional judgement, the overall quality of publicly available and project data, and the experience learned from similar projects, as well as the expected effectiveness of mitigation measures, the prediction confidence in assessing potential effects for terrain, soils, and permafrost is considered to range from moderate to high.

This mainly is because it is difficult to accurately determine the magnitude of potential effects due to the overall limited measurable criteria and indicators of changes. The potential localized variability of permafrost conditions is a good example (e.g., presence/absence of permafrost, localized occurrence of ice-rich permafrost). Nevertheless, the data gathered to describe baseline conditions are considered sufficient to support the statement that cumulative effects on terrain, soils, and permafrost are predicted to be not significant.

14.7.1 Assumptions

It is assumed that the construction of the embankment will be conducted using a "fill approach" with minimal disruption to the subgrade rather than a "cut and fill" approach. This excludes a few locations where road cuts may be needed to reduce the grades by cutting into the hill slope (e.g., at a steep valley approach). This key assumption is important to the evaluation of potential effects on terrain, soils, and permafrost as the ground disturbance associated with road cuts is often a source of instabilities. The potential failure modes associated with a highway built over permafrost are therefore expected to be closely related to the local distribution of ground ice. Such failure modes may include (but not limited to) differential thaw settlement, loss of soil strength and localized slumping.

The prediction confidence is also based on the highway design/construction approach, as well as implementation of best practices and adherence to mitigations, procedures, and strategies outlined in the ESCP and PPP. Data used to assess and evaluate the presence of thaw-sensitive terrain is typically acquired through geotechnical field investigations (e.g., through installation and monitoring of ground thermistors). Such instrumentation exists along the project, with data updates expected to be obtained on an annual basis. This information will be incorporated into the final design to minimize potential effects to the permafrost. It is as part of future design activities that the final construction methodology and timing will be established and that the final contingency plans to the potential degradation of local permafrost will be established.

The overall limited availability of site-specific geotechnical data relevant to the distribution of ground ice along the PDA is not influencing the prediction confidence as conservative assumptions on the potential presence of permafrost were taken in the assessment of potential residual effects.

14.7.2 Gaps and Uncertainties

Aside from the terrain mapping conducted for the LAA, a literature review was used to establish baseline conditions for terrain, soils, and permafrost. Several distinct data sources were consulted, including documents and reports, open-source databases, and existing regional mapping data. A reference list of reviewed literature is included in Section 7.1 of the Terrain, Soils and Permafrost TDR (Appendix 14A; K'alo-Stantec, 2023).

Potential gaps in the availability of site-specific subsurface information are expected to be addressed as part of future geotechnical field investigation and follow-up highway design activities to be undertaken within the alignment routing corridor.

14.8 Follow-up and Monitoring

Monitoring is the continuation of observation, measurement, or assessment of environmental conditions at and surrounding the Project and its components or activities. Objectives of permafrost monitoring may include:

- Verify compliance with terms and conditions of authorizations
- Verify embankment integrity and performance
- Identify areas where snow accumulation may be contributing permafrost degradation
- Verify effectiveness of permafrost protection measures
- Identify areas of terrain instability in the PDA
- Evaluate stability of terrain and permafrost over time

Components to be monitored have been determined based on regulatory requirements, environmental importance, sensitivity and vulnerability, and past experience.

Monitoring plans included in the ESCP and PPP (see Volume 5) will describe sampling, observation and measurement schedule, locations and procedures, quality control, and reporting requirements, where applicable. The plans will also provide details on the location, design, methods (e.g., parameters to be measured), applicable regulatory instruments, and schedule.

Examples of monitoring activity conducted to identify changes in terrain, soils, and/or permafrost conditions include the following:

- Visual observations of embankment performance (e.g., signs of cracking, sloughing) and the effectiveness of roadway design and mitigation measures with regard to modification of drainage conditions (e.g., presence of ponding water or winter icings)
- Visual observations of the effectiveness of soil stripping and reclamation strategies specific to quarries and borrow areas
- Where permafrost is encountered and where practicable, monitoring of the thermal regimes to assess if the embankment performs as designed.

See Section 9 of the draft PPP in Volume 5. Additional monitoring requirements, if identified as part of the project approval and permitting, will be incorporated into the PPP.

14.9 References

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15.0 ASSESSMENT OF POTENTIAL EFFECTS ON WATER QUANTITY

Project construction, operation, and maintenance activities have the potential to affect water quantity. In recognition of this interaction, and the water quality and quantity Subject of Note in the Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), Water Quantity was selected as a Valued Component (VC). Potential effects on water quantity may affect (or be affected by) other VCs, including water and sediment quality (see Chapter 16), fish and fish habitat (see Chapter 17), vegetation and wetlands (see Chapter 18), and terrain, soils, and permafrost (see Chapter 14).

The assessment of potential effects on water quantity concludes that with the application of mitigation measures, residual effects resulting from the Mackenzie Valley Highway (the Project) on water quantity will be adverse. Based on the predicted magnitude and geographic extent of residual effects, and the experience and judgement of qualified professionals, residual effects and cumulative effects on water quantity are predicted to be not significant.

15.1 Scope of Assessment

15.1.1 Regulatory and Policy Setting

The assessment of potential project-related environmental effects on water quantity is guided by the ToR (MVEIRB, 2015 [PR#66]), federal regulations and guidelines, and the Sahtu Land Use Plan (SLUP).

15.1.1.1 Federal and Territorial Legislation and Guidelines

The Northwest Territories *Waters Act* and regulations apply to the Project. The Mackenzie Valley Land and Water Board (MVLWB) regulates the use of water (including groundwater) and disposal of waste into watercourses through the issuance of water licences. The Sahtu Land and Water Board (SLWB) will be responsible for issuing the water licence for any segment of the Project wholly within the Sahtu Region. Water licensing criteria are set out in the Waters Regulations and include the following licensing requirements for direct water use (including groundwater):

1. Water use under 100 cubic metres (m^3) per day: licence not required
2. Water use between 100 m^3 and 300 m^3 per day: Type “B” licence required
3. Water use greater than 300 m^3 per day: Type “A” licence required

The Waters Regulations also require a Type "B" licence to be obtained for watercourse training, which includes culvert installations over watercourses greater than 5 metres (m) in width.

There is no groundwater use planned for the Project. However, groundwater withdrawal (use) may be required if borrow source or quarry excavations extend below the groundwater table. In this case, a water licence associated with this groundwater use may be required.

Federal and territorial guidance documents most pertinent to water quantity are:

- Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (Fisheries and Oceans Canada [DFO], 2013):
- Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO, 2010):
- Northern Land Use Guidelines - Pits and Quarries (GNWT, 2015)

15.1.1.2 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of watershed management in CR#5:

"The SLWB and/or MVLWB must ensure that the Project:

a) does not substantially alter quality, quantity, or rate of flow for waters that flow on, through, or adjacent to Sahtu Settlement Lands; and

b) is subject to mitigation measures to minimize potential impacts on surface and groundwater that flow into CZs [Conservation Zones], SMZs [Special Management Zones], or PCI [Proposed Conservation Initiatives]."

Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*, and CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 20213), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

15.1.2 Influence of Engagement

The Government of the Northwest Territories (GNWT) has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (consultation and engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to water quantity and water resources. This feedback has been considered and summarized in Table 15.1 and has been integrated into the assessment of potential effects on water quantity that follows. Drinking water is considered within the assessment of potential effects on water and sediment quality in Chapter 16.

Table 15.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Participants of the Norman Wells Renewable Resources Council (NWRRC) TLRU study reported that the water quantity (levels) at Canyon Creek, Prohibition Creek and Vermilion Creek has been lower in recent years and study participants are concerned about cumulative effects to creeks if water is taken from those areas for project construction, and operations and maintenance. The NWRRC study participants reported that Canyon Creek previously contained several small ponds and was an ideal location for camping, however, the area has completely dried up.	NWRRC, 2023	The GNWT has identified mitigation measures to reduce the effects of the Project on water quantity. Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013), which is generally limited to less than 10% of the available flow or volume for all users. Monitoring will be undertaken to confirm the Project is meeting licence conditions. The Project will follow measures in the Permafrost Protection Plan (PPP) to reduce ponding, erosion, and damage to permafrost. Erosion and drainage patterns will be observed and documented in support of the Erosion and Sedimentation Control Plan (ESCP).	For mitigation measures to reduce effects of the Project on water quantity see Table 15.8 See also: Section 15.4.2 (Changes in Streamflows) Section 15.4.3 (Changes in Lake Volumes) Section 15.4.4 (Change in Groundwater Quantity) Chapter 10 (caribou and moose) Chapter 17 (fish and fish habitat) Chapter 19 (wildlife and wildlife habitat) Chapter 20 (birds and bird habitat) Volume 5 for management plans
Dehcho First Nations reported many factors influencing water quantity in the Dehcho Region, noting that the region is getting warmer and wetter overall, with more rainfall in August and September and even into October, resulting in higher water levels on smaller rivers and streams.	Dehcho First Nations, 2011		
Sahtu Elders have linked decreasing water levels to a reduction in fish and wildlife habitat, as well as creating additional challenges for water navigation, travel, and fishing, and expressed concerns about potential project effects to water quality and quantity in the Sahtu Region including contamination, which could be far reaching due to the speed at which surface and groundwater flows; patterns of surface water flow and potential groundwater changes; increased sediment from vegetation clearing along waterbodies from effects of blasting, runoff and thawing permafrost (erosion, flooding, scouring, reduced land subsistence), which also can affect groundwater and surface water. Change in water quantity could also affect the conditions for current use, potentially resulting in avoidance by Indigenous harvesters.	Dessau, 2012 (PR#13); Golder, 2015		
Community engagement participants reported that water levels in Mackenzie River (Deh Cho) change depending on ice levels and driftwood build-up in Mackenzie Mountains.	August 2021 Engagement		

Comment	Source	GNWT Response	Where Addressed
Sahtu land users have observed that declining water levels have reduced fish and wildlife habitat, and has created additional challenges for water navigation, travel and fishing due to drying of water bodies (e.g., Moose Lake[1]).	Golder, 2015	*(cont'd from above)* The Project does not propose to take water from lakes on the west side of Mackenzie River (Deh Cho). The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.	*See above*
Community members in the Sahtu Region have expressed concerns for water operation withdrawals from lakes near *Dehdéleį̨ǫ Tué* (Sucker Lake/Three Day Lake) as lakes in the area are shallow.	Golder, 2015		
Community engagement participants expressed concern about water sources used during project construction maintenance because they provide habitat for wildlife and fish. Participants identified locations of suitable water sources for the Project.	April to July 2022 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement		
Sahtu harvesters reported powerful ice breaks during the spring break around the area of the proposed Great Bear River Bridge site that influence surface water quantity in the Sahtu Region; however, NWRRC study participants reported that large chunks of ice are no longer carried down the rivers because the water has been too low to move.	Golder, 2015; NWRRC, 2023; TRRC, 2022		

Note:

[1] The location of Moose Lake was not disclosed in the report.

15.1.3 Potential Effects, Pathways and Measurable Parameters

The Project has the potential to cause changes in streamflows, lake volumes, and groundwater quantity (Table 15.2). Streamflow is measurable with parameters such as the mean monthly and annual flow rate, and annual peak and low flows. Potential changes in streamflow may occur through changes to surface drainage patterns (either directly [e.g., by blocking natural streams] or indirectly through project interaction with terrain, soils, and permafrost, including borrow extraction and changes to snow distribution); erosion and sediment deposition; potential glaciation and icings at watercourse crossings; or water withdrawals during construction and operations and maintenance (Table 15.2).

Table 15.2 Potential Effects, Effects Pathways and Measurable Parameters for Water Quantity

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in streamflows	• Changes to surface drainage patterns either directly (e.g., blocking natural streams) or indirectly through project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution) • Erosion and sediment deposition • Potential for glaciation and icings at watercourse crossings • Water withdrawals	Mean monthly and annual flow rates; annual peak and low flows (cubic metres per second [m^3/s])
Change in lake volumes	• Water withdrawals	Volume of lakes (m^3) or lake levels (m)
Change in groundwater quantity	• **Excavation:** Excavation of a borrow source, quarry, or road cut may result in a change in groundwater levels (direct effect) and a change in groundwater discharge to streams, lakes, or wetlands (indirect effect) • **Ground Disturbance:** The construction of the highway may alter ground surface characteristics such that the groundwater recharge rate over disturbed areas may change (direct effect) • **Permafrost Degradation:** The construction of the highway will alter ground surface characteristics that may result in permafrost degradation (direct effect), a change in active layer thickness or increased connection to sub-permafrost groundwater systems (indirect effects), and a change in groundwater flow to or from streams, lakes, or wetlands (indirect effects)	Groundwater levels measured as elevation in metres above sea level (m asl)

Potential changes in lake volumes may occur as a direct effect of water withdrawals during construction and operations and maintenance (Table 15.2). The pathways for potential changes in streamflows may also indirectly affect lake volumes through the change in streamflows.

Changes to groundwater quantity refer to a change in groundwater flow rate or direction, which can be measured indirectly by a change in groundwater levels from existing conditions. A change in groundwater quantity may be caused by excavations, or by ground disturbance during clearing site activities, borrow source and quarry development, embankment construction, and the presence of the highway. These activities can also cause permafrost degradation that in turn would cause a change in groundwater flow.

These potential effects, corresponding effects pathways, and measurable parameters for water quantity are summarized in Table 15.2.

15.1.4 Boundaries

15.1.4.1 Spatial Boundaries

Potential project-related changes to surface water quantity are assessed relative to the following areas:

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur (Figure 15.1). The water quantity LAA is the area within a 1 kilometre (km) buffer of the preliminary alignment route centerline, quarries and borrow sources and associated access roads. The buffer was extended to the west to include the mainstem of Mackenzie River (Deh Cho) and potential water sources for construction of the Mackenzie Valley Winter Road (MVWR). The LAA is divided into a northern section (i.e., Tulita to the northern most extent of the Project) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the project alignment at the Hamlet of Tulita to account for the Great Bear River Bridge (not part of the Project).
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and potential cumulative effects. The surface water quantity RAA is defined as the area within approximately 15 km of the PDA (Figure 15.1).

- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Surface Water Local Assessment Area
- Surface Water Regional Assessment Area
- Groundwater Local Assessment Area
- Groundwater Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Mackenzie River Sub-Basin

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/7/2023
TR by CS on 8/7/2023

Client/Project
144903025-0139 REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
15.1

Title
Water Quantity Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

Potential project-related changes to groundwater quantity are assessed relative to the following areas:

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway ROW, laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. The groundwater quantity LAA is a 0.5 km buffer of the preliminary alignment route centerline, quarries and borrow sources and associated access roads (Figure 15.1). The LAA is divided into a northern section (i.e., Tulita to the northern most extent of the Project) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the project highway alignment at the Hamlet of Tulita to account for the Great Bear River Bridge (not part of the Project).
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and potential cumulative effects. The groundwater quantity RAA is the area within approximately 5 km of the PDA or the mainstem of the Mackenzie River (Deh Cho), whichever is closer (Figure 15.1). The Mackenzie River (Deh Cho) is a regional groundwater flow divide (K'alo-Stantec, 2022b) that will limit the influence of project activities on one side of the river to groundwater on the other.

15.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases:

- **Construction phase:** The Project will take approximately 10 years to construct, over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments: Wrigley to the Dehcho/Sahtu border (102 km); Tulita south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (PCAR) (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** Operations and maintenance will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, quarries and borrow sources not needed for operations and maintenance will occur during the construction phase.

15.1.5 Residual Effects Characterization

Potential residual effects of the Project on water quantity are characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 15.3). Likewise, quantitative measures or, where applicable, descriptions of qualitative measures, are provided in Table 15.3.

Table 15.3 Characterization of Residual Effects on Water Quantity

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse –** A residual effect that moves measurable parameters of water quantity in a negative direction relative to baseline **Neutral –** No net change in measurable parameters for water quantity relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** The residual effect is almost certainly not to occur. **Possible –** The residual effect could occur. **Certain –** The residual effect will certainly occur.
Magnitude[1,2]	The amount of change in measurable parameters or the valued component (VC) relative to existing conditions	**Surface Water Quantity** **No Measurable Change –** Changes in streamflow compared to existing conditions (i.e., streamflow without project effects) are less than 5% (i.e., changes are within the range of uncertainty in hydrologic data measurement and analysis). For lake volumes, water withdrawals within the limit of existing licences are considered to have no measurable change. **Low (<10%) –** Changes in streamflow or lake volume are greater than the "no measurable change" threshold, but less than 10% compared to existing conditions (within the natural variability of existing conditions). **Moderate (10-20%) –** Changes in streamflow or lake volume compared to existing conditions are between 10% and up to 20%. **High (>20%) –** Changes in streamflow or lake volume compared to existing conditions are greater than 20%.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude[1,2] (cont'd)		**Groundwater Quantity** **No Measurable Change –** Seasonal groundwater levels are consistent with baseline conditions (i.e., they are within the range of potential inter-annual groundwater level variations). **Low –** Seasonal groundwater levels deviate from the range of potential inter-annual groundwater level variations by less than 1 m. **Moderate –** Seasonal groundwater levels deviate from the range of potential inter-annual groundwater level variations by 1 – 2 m. **High –** Seasonal groundwater levels deviate from the range of potential inter-annual groundwater level variations by greater than 2 m
Geographic Extent	The geographic area in which a residual effect occurs	**PDA –** Residual effects are restricted to the PDA. **LAA –** Residual effects extend into the LAA. **RAA –** Residual effects interact with those of other projects within the RAA.
Timing	Considers when the residual effect is expected to occur, where relevant to the VC	**No Sensitivity –** Seasonal aspects are unlikely to affect water quantity. **Low sensitivity -** Effect does not occur during a sensitive time for surface water or groundwater. **High sensitivity -** Effect occurs during a highly sensitive period. For surface water, the highly sensitive period is during winter (from freeze-up to spring-thaw) when streamflows are low. For groundwater, the highly sensitive period is from spring thaw to autumn freeze-up, when terrain, soils, and permafrost are the most susceptible to ground disturbance).
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	**Short-term –** The residual effect is restricted to one year in duration or less. **Medium-term –**The residual effect extends through the construction of the Project (20 years). **Long-term –** The residual effect extends beyond the construction of the Project and/or during operations (greater than 20 years).
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event** – The residual effect occurs once. **Multiple irregular event –** The residual effect occurs at no set schedule. **Multiple regular event –** The residual effect occurs at regular intervals. **Continuous –** The residual effect occurs continuously.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
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.

Notes:

1 The 5% uncertainty in hydrologic data measurement and analysis is based on professional judgment. The 10% threshold for the (low) magnitude of potential changes in streamflows and lake volumes are informed by guidance documents (e.g., DFO, 2010, 2013) and professional judgement. The 20% threshold for the (high) magnitude changes in streamflows and lake volumes is based on professional judgment.

2 For example, at the time of water withdrawal, if existing streamflow (i.e., measured steamflow just upstream of a withdrawal point) is 1 cubic metre per second (m^3/s), water withdrawals of less than 0.1 m^3/s will be considered low magnitude (i.e., the change is less than 10%).

15.1.6 Significance Definition

For surface water quantity, the significance of residual effects is determined by the qualified professionals based on their experience and professional judgment, as well as the characterization of residual effects as described in Table 15.3. The following general considerations (along with professional judgement) are applied in determining significance:

- If the magnitude of the effect is low (<10%), the effect is not significant.
- For moderate (10-20%) magnitude effects, if the geographic extent of the effect is confined to the PDA or LAA, the effect is likely to be not significant.
- For high (>20%) magnitude effects, significance evaluation will be based on geographic extent, duration, frequency, and reversibility.

Consideration of these attributes for the evaluation of a significant, or not significant effect relies heavily on professional judgement.

For groundwater quantity, the significance of potential residual effects will be determined based on the characterization of residual effects as outlined in Table 15.3 using the following criteria:

- If the magnitude of the effect is no measurable change or low, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect is confined to the PDA or LAA, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect extends to the RAA, the effect is significant.
- If the magnitude of the effect is high, the significance evaluation of the effect will be based on the characterization of the effect’s geographic extent, duration, and reversibility.

Consideration of these attributes for the evaluation of a significant, or not significant effect relies heavily on professional judgement.

The preceding definition of significance applies to groundwater quantity as a resource. Indirect effects from a change in groundwater quantity on other VCs are not evaluated in this chapter.

15.2 Existing Conditions for Water Quantity

To support the assessment of effects of the Project on surface water quantity, existing information within the LAA and RAA has been described and evaluated in the Surface Water Quantity technical data report ([TDR]; Appendix 15A; K'alo-Stantec, 2022a).

The TDR includes 27 local watersheds that had been identified as watersheds of interest in previous surface water quantity studies (Golder, 2015; IORVL, 2004). From those 27 watersheds (i.e., tributaries of the Mackenzie River [Deh Cho] which the Project will cross), 13 watersheds can be identified as major drainages based on the criterion of watershed area being greater than 100 square kilometres (km^2; Golder, 2015). However, the TDR describes all those 27 previously identified watersheds of interest.

Existing conditions for groundwater quantity within the LAA and RAA have been detailed in the Hydrogeology Technical Data Report ([TDR]; Appendix 15B; K'alo-Stantec, 2022b). This report presents the groundwater system existing conditions and provides a conceptual model of local and regional groundwater flow systems to use in the evaluation of potential project effects. Key subjects covered in the Hydrogeology TDR include:

- Permafrost influence on groundwater flow (Section 4.2.3)
- Surficial geology hydrostratigraphy (Section 4.3)
- Bedrock geology hydrostratigraphy (Section 4.4)
- Groundwater as a resource (Section 4.6)
- Conceptual model of the groundwater flow system (Section 5)

15.2.1 Methods

Existing data were collected from Water Survey of Canada (WSC) hydrometric stations in the region, and previously published documents were reviewed (including documented Traditional Knowledge [TK]). K'alo-Stantec (2022a; Appendix 15A) characterized hydrologic indices (i.e., mean annual runoff [MAR], monthly distribution of annual runoff, peak flows, and low flows) for the watersheds of interest identified within a study area, which is the same as the RAA. Further, K'alo-Stantec (2023a, 2022c; Appendix 15C and Appendix 15D) provided a preliminary water availability assessment for 23 streams and 24 water bodies (i.e., lakes, ponds, basins) in the LAA. Methods used for these preliminary estimates are described in K'alo-Stantec (2023a, 2022c; Appendix 15C and Appendix 15D).

In addition, existing TK and TLRU (e.g., TRRC, 2022) was reviewed, and a literature review of water quantity-related information to characterize existing hydrological and hydrogeological conditions within the LAA and RAA (Appendix 15A and Appendix 15B [K'alo-Stantec, 2022a, 2022b]).

Based on the data compiled during the TK, TLRU, and literature review, K'alo-Stantec completed hydrostratigraphic interpretations of soils and bedrock geological units intersected by the Project and developed regional and local conceptual models of the groundwater flow system in the vicinity of the Project (a conceptual hydrogeological model).

15.2.2 Summary of Flows in Major Streams Intersected by the Project

The MAR identified in the TDR ranges from 151 millimetres (mm) to 220 mm (Appendix 15A; K'alo-Stantec, 2022a). Likewise, although it is assumed that major drainages with watershed area of greater than 100 km^2 are perennial, it is not known with certainty what drainages with watershed areas of less than 100 km^2 are perennial and which ones are seasonal.

A summary of annual flow estimates in 23 major streams intersected by the PDA is provided in Table 15.4. Location of these streams and detailed, preliminary month-by-month flow and water availability predictions are provided in Appendix 15C and Appendix 15D (K'alo-Stantec, 2023a, 2022c).

Data presented in the TDR are intended to be used for environmental assessment and do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) requires a study tailored for such purposes. Additional data will need to be collected to support applications for authorization to use water sources for withdrawal to demonstrate availability of water at time of withdrawal in accordance with applicable guidelines (e.g., DFO, 2010, 2013).

Sahtu Region land users have observed that declining water levels have reduced fish and wildlife habitat, and has created additional challenges for water navigation, travel and fishing due to drying of water bodies (Golder, 2015). NWRRC TLRU study participants reported that Canyon Creek previously contained several small ponds and was an ideal location for camping; however, the area has completely dried up (NWRRC, 2023).

Participants of the NWRRC TLRU study reported the water in Canyon Creek, Prohibition Creek, and Vermilion Creek is shallower in recent years, and concern were raised about potential cumulative effects to creeks if water is taken from those areas for project construction and operations and maintenance (NWRRC, 2023). Dehcho First Nations have also indicated many factors influencing water quantity in the Dehcho Region, noting that the region is getting warmer and wetter overall, with more rainfall in August, September, and October, resulting in higher water levels on smaller rivers and streams (Decho First Nations, 2011).

Table 15.4 Summary of Preliminary Flow Estimates in Major Streams Assessed for Water Availability (K'alo-Stantec, 2023a, 2022c)

Watercourse Location [1]	Location Alignment (KM)	Watershed Area (km^2)	Mean Annual Discharge (m^3/s)	Maximum Monthly Discharge[2] (m^3/s)
Hodgson Creek Bridge	695.6	358	2.04	9.6
Ochre River Bridge	725.7	1,207	9.71	49.6
Whitesand Creek Bridge	733.8	346	1.64	8.8
Big Strawberry Creek Culvert	748.5	59	0.30	1.9
Small Strawberry Creek Culvert	748.6	49	0.25	1.6
Vermillion Creek South Bridge	752.3	68	0.34	2.2
Bob's Canyon Creek Culvert	755.3	9	0.06	0.4
Dam Creek Bridge	764.8	110	0.54	3.3
Blackwater Bridge	785.3	10,716	62.8	230
Steep Creek Bridge	816.5	154	0.75	4.4
Devil's Canyon Bridge	828.4	21	0.12	0.8
Saline River Bridge	831.9	317	1.51	8.1
Seagrams Creek Bridge	844.3	57	0.29	1.9
Little Smith Creek Bridge	852.3	439	2.08	10.8
Big Smith Creek Bridge	872.1	1,076	6.38	33.7
Gotcha Creek Bridge	912.7	155	0.75	4.4
Twelve Mile Creek Bridge	922.0	42	0.22	1.4
Four Mile Creek Culvert	931.5	17	0.10	0.7
Great Bear River at Tulita[3]	937.2	158,400	584	682
Jungle Ridge Creek Bridge	967.8	60	0.33	2.1
Notta Creek Bridge	971.5	65	0.33	2.1
Vermillion Creek North Bridge	973.4	92	0.46	2.8
Prohibition Creek Bridge	984.0	86	0.45	2.76

Notes:

1 Locations are shown in Figure 1.2 of K'alo-Stantec (2023a; Appendix 15C).

2 Maximum Monthly Discharge typically occurs in May (the exception is Blackwater River where maximum monthly discharge occurs in June; K'alo-Stantec, 2023a; Appendix 15C).

3 The Great Bear River is not in the LAA; however, the Great Bear River was assessed in K'alo-Stantec (2023a; Appendix 15C).

15.2.3 Summary of Available Under-Ice Lake Water Volumes

Available information was compiled from a preliminary assessment of lakes potentially to be used for water withdrawal within the LAA. For the purposes of preliminary water availability calculations, all waterbodies with open water maximum depths greater than 1.5 m (the maximum ice depth in the region; DFO, 2010) are considered potential fish habitat. Lakes shallower than this would freeze to the lakebed in winter.

Maximum ice thickness in the LAA is expected to be about 1.5 m (DFO, 2010). Given this expected maximum thickness, DFO winter withdrawal guidance is summarized in Table 15.5. To apply these criteria, maximum lake depth and lake volume are needed.

Table 15.5 Fisheries and Oceans Canada (DFO) Winter Water Withdrawal Guidance for Ice-Covered Waterbodies Applied to Lakes in the LAA

Maximum Open Water Depth	DFO Protocol Guidance (applies to ice-covered waterbodies)
Shallower than 1.5 m	"exempt from 10% maximum withdrawal limit" Interpreted as withdrawals cannot occur when ice is at its maximum thickness, and withdrawals may occur based on site-specific conditions when ice thickness is less than its annual maximum.
Deeper than 1.5 m, and shallower than 3.0 m	Waterbodies are "particularly vulnerable to the effects of water withdrawal" Interpreted as withdrawals should not occur.
Deeper than 3.0 m	"total water withdrawal… is not to exceed 10% of the available water volume"

Note:
Guidance is from DFO, 2010.

Volume estimates were based on actual surveyed results (if available). Although the MVLWB's method for small-scale projects (MVLWB, 2021) applies to small-scale projects, for reference, estimations were also made using this method. Results are summarized in Table 15.6. Additional study, such as bathymetric survey, will be required to be completed to support licencing of water sources selected for construction and/or operations and maintenance where volume is currently noted as "unknown." For location of these waterbodies and detailed results of these preliminary estimates, refer to Appendix 15C (K'alo-Stantec, 2023a).

Table 15.6 Summary of Estimates for Available Under-Ice Volume of Lakes Preliminarily Assessed for Water Withdrawal (K'alo-Stantec, 2023a)

Name[1]	Alignment (KM)[2]	Max Depth (m)		Volume Available for Withdrawal based on DFO, 2010[4]	Volume Available for Withdrawal Estimated from Surface Area (MVLWB, 2021)[5]	Comment
		Surveyed	Coarse[3]			
WS Wrigley	686.5	-	-	-	90,207	Volume unknown
WR2	702.2	5.1	-	4,277	36,496	-
WR3	718.8	-	2.9	-	53,383	Volume unknown
WR4	721.8	-	2.9	-	3,640	Volume unknown
WS791	791	-	-	-	3,639	Volume unknown
WR5	798.8	2.1	-	-	20,017	Too shallow to withdraw
WR6	804	3.4	-	682	79,647	-
WR7	810.1	-	1.5	-	20,726	Too shallow to withdraw
WR8	820	15.2	-	126,553[f]	25,174	-
WR9	826.6	2.2	-	-	1,962	Too shallow to withdraw
WR10	835	15.1	-	3,084[f]	1,316	-
WR11	839.5	1.9	-	-	4,365	Too shallow to withdraw
WR12	863	2.3	-	-	743,243	Too shallow to withdraw
WR13	876.3	1.7	-	-	71,477	Too shallow to withdraw
WR16	882.5	4.9	-	4,899[f]	5,663	-
WR18	892	9.3	-	22,937[f]	138,544	-
WR893	893	-	-	-	19,009	Volume unknown
WR19	903	3.8	-	1,181[f]	3,595	-
WR20	908.9	2.6	-	-	359,597	Too shallow to withdraw

Name[1]	Alignment (KM)[2]	Max Depth (m)		Volume Available for Withdrawal based on DFO, 2010[4]	Volume Available for Withdrawal Estimated from Surface Area (MVLWB, 2021)[5]	Comment
		Surveyed	Coarse[3]			
WR22	916	-	3.4	-	225,436	Volume unknown
WR21	921.3	-	5.2	-	3,061	Volume unknown
WR948	948.4	-	-	-	1,646	Volume unknown
WR25	944.6	21.7	-	316,381 [6]	46,113	-
WR28	950.4	14.8	-	74,686	20,449	-

Notes:

[1] Locations are shown in Figure 1.3 of K'alo-Stantec (2023a; Appendix 15C)

[2] Approximate mid-point of each lake along the project alignment (kilometre marker)

[3] From Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.

[4] 10% of under ice water volume calculated assuming 1.5 m thick ice.

[5] 10 centimetre drawdown of lake based on waterbody surface area

[6] from Golder (2008)

"-" Data not available

15.2.4 Conceptual Hydrogeological Model

Groundwater flow systems are generally conceptualized as nested regional, intermediate, and local scale systems (Toth, 1963). Regional groundwater flow systems develop from large-scale topographic, physiographic, and geologic features (such as the Central Mackenzie Valley [CMV], larger than the RAA). Local groundwater flow systems develop from smaller-scale variation of topography and geologic features and local flow (i.e., within the PDA and/or LAA) is often dominated by one component of the regional flow system (Freeze and Cherry, 1979). The predominant features of the conceptual groundwater model of the CMV and the PDA, as it traverses the Mackenzie Plain from Wrigley to Norman Wells, include the following (K'alo-Stantec, 2022b):

- The PDA is largely within the discharge zone of regional groundwater flow-paths that extend from recharge areas beyond the RAA within the Franklin and McConnell Mountain Ranges.

- Surficial geology within the RAA is predominately low permeability glaciolacustrine (43.0%) and till (21.3%) with smaller fractions of moderate to high permeability alluvial (15.3%), colluvium 9.4%), and glaciofluvial (5.9%) sediments and other (5.1%) materials.
- Surficial geology within the LAA includes low permeability till (23.3%) and glaciolacustrine (20.6%) materials, moderate to high permeability organic (15.3%), glaciofluvial (14.1%), colluvium (11.0%), eolian (6.1%), and fluvial (4.9%) materials, and (4.2%) other materials.
- Surficial geology along the PDA includes low permeability glaciolactustrine (25.8%) and till (21.3%) materials, moderate to high permeability glaciofluvial (19.5%), organic (12.7%), eolian (7.6%), fluvial (6.4%), and colluvium (5.8%) materials, and (0.9%) other materials.
- Low permeability glaciolacustrine and till deposits, if present, will act as a barrier to local and regional groundwater discharge and artesian (above ground surface) pressure conditions have the potential to develop in underlying stratigraphy.
- Permafrost, where it exists, is expected to be a barrier to groundwater flow and will separate the groundwater flow system into shallow, seasonal, supra-permafrost flow within the active layer and deeper, perennial sub-permafrost flow components. The degree to which this separation exists is expected to increase north along the PDA as the presence of permafrost increases from sporadic discontinuous (10-35% of land area) near Wrigley, through intermediate discontinuous (35% to 65% of land area), to extensive discontinuous (65% to 90% of land area) permafrost near Norman Wells.
- Where extensive discontinuous permafrost is present, interaction between supra-permafrost and sub-permafrost groundwater flow systems may be limited to taliks, regions of thawed strata that allow fluid flow. Taliks within the CMV may be concentrated along regional fault trace and fracture systems where regional flow gradients prevent permafrost from becoming established, and beneath large lakes and streams. Regional groundwater discharge likely occurs predominately through these perennial conduits.
- Permafrost, where it exists, will limit the volume of local groundwater recharge (i.e., occurring within the RAA, LAA, and/or PDA) that reaches the sub-permafrost groundwater system. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost.
- Permafrost, where it exists, limits groundwater flow within the RAA to the shallow supra-permafrost flow component. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost. Groundwater flow limited to the supra-permafrost component limits overall groundwater storage and results in rapid groundwater discharge to surface following spring melt or precipitation events.
- Borrow source excavations target glaciofluvial and fluvial materials for construction fill that also tend to be high permeability and well drained. These characteristics limit the formation of ground ice and may reduce the compartmentalizing effect of permafrost where present in these materials.

15.3 Project Interactions with Water Quantity

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are not considered project interactions and are described in Chapter 25.

Project activities that have the potential to interact with water quantity are identified with a check mark in Table 15.7.

Table 15.7 Project-Environment Interactions with Water Quantity

Physical Activities	Timing	Environmental Effects		
		Change in Streamflows	Change in Lake Volumes	Change in Groundwater Quantity
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	–	–	–
Establishment and operation of camps	Year-round	✓	✓	–
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	–	✓
Material haul	Year-round	✓	✓	–
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	–	–
Road base placement, compaction, and surfacing	Summer	✓	✓	–
Water withdrawal for construction activities	Year-round	✓	✓	–
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	–	✓
Employment and contracted goods and services[1]	Year-round	–	–	–

Physical Activities	Timing	Environmental Effects		
		Change in Streamflows	Change in Lake Volumes	Change in Groundwater Quantity
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material haul and stockpiling	Summer	✓	–	–
Operation of, and activities at, maintenance yards	Year-round	✓	✓	–
Water withdrawal for dust control	Summer	✓	✓	–
Employment and contracted goods and services[1]	Year-round	–	–	–
Presence and use of the highway	Year-round	✓	–	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓	–
Vegetation control	Summer	✓	✓	–
Bridge and culvert maintenance	As needed	✓	✓	–

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, “Employment and contracted goods and services” have been introduced as an additional component under each project phase.

The activities listed below were excluded, and the reasons for such exclusions are provided:

- Mobilization of equipment, materials, and fuel, resupply and demobilization: These activities will use established transportation systems and constructed roads. No water use or water diversion will be required.
- Employment and contracted goods and service: These activities do not have a physical interaction with water quantity.
- Activities involving water withdrawal, such as camp operations, embankment construction, and dust control, will not interact with groundwater quantity as groundwater will not be sourced for water uses.

Activities that disturb the land cover and terrain and require excavation (e.g., site preparation activities, borrow source and quarry development, embankment and quarry access road construction, and road cuts) have the potential to affect surface drainage patterns and groundwater quantity and cause erosion and sedimentation, thereby potentially also affecting streamflow and/or lake volume. Similarly, closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces include alteration of land cover (i.e., vegetation) which may affect the surface drainage pattern and groundwater quantity and cause erosion and sediment deposition.

Culvert installation and the presence of the highway can lead to an alteration of the natural surface drainage pattern and affect streamflow if conveyance capacity of a culvert is not sufficient, or the culvert is installed incorrectly. Potential glaciation and icings can reduce the conveyance capacity of the culverts during spring and lead to changes in surface drainage patterns. Likewise, culverts may alter the hydraulics, and thereby the erosion and sediment deposition processes of a stream.

Changes in streamflow and/or lake volume may occur as a result of activities which require water withdrawal for consumption or use. These activities include:

- Establishment and operation of camps
- Site preparation of ROW, access, and workspaces
- Material haul, which requires water for dust suppression
- Water withdrawal for construction activities
- Water withdrawal for dust control

Project activities that may indirectly affect groundwater quantity through permafrost degradation include those activities requiring excavation and ground disturbances, when they occur in areas underlain by permafrost, and by the presence of the highway itself.

15.4 Assessment of Residual Effects on Water Quantity

Based on project interactions with the environment identified in Table 15.7, the Project may affect water quantity. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on surface water quantity are identified in Table 15.8.

Potential residual effects that may persist after application of mitigation measures, as well as the qualitative assessment techniques used to evaluate these effects, are described in the subsections.

Table 15.8 Potential Effects and Mitigation Measures for Water Quantity

Potential Effect	Effect Pathway	Mitigation Measures
Change in streamflows	• Changes to surface drainage patterns either directly (e.g., blocking natural streams) or indirectly through project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution) • Erosion and sediment deposition • Potential for glaciation and icings at watercourse crossings • Water withdrawals	• Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns (i.e., limit inter-watershed water routing). • Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches. • The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost. Detailed mitigation measures to reduce the effects on terrain, soil, and permafrost are described in Chapter 14 (terrain, soils and permafrost). • Erosion and drainage patterns will be observed and documented in support of the ESCP. • Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet. • Culverts will be designed and constructed to maintain water flow and fish passage. Drainage culverts will be installed according to specifications to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects. • Ice in culverts will be thawed by steaming, where needed to maintain flow. • Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert. • Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013).

Potential Effect	Effect Pathway	Mitigation Measures
Change in lake volumes	Water withdrawals	• Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013).
Change in Groundwater Quantity	**Excavation:** Excavation of a borrow source, quarry, or road cut may cause the following: a decline in groundwater levels (direct effect) and a reduction in groundwater discharge to streams, lakes, or wetlands (indirect effect).	• A fill-only construction approach will be used except at specific locations of road cuts. • Borrow sources will not be located in areas where there is a high groundwater table. • Borrow source floors will be sloped to reduce ponding of water. • Quarry operations will be located a minimum of 100 m from the ordinary high-water mark of any waterbody. • Excavations will be contoured prior to closure to reduce steep slopes. • Positive drainage will be maintained within quarry floors. • Measures to manage borrow source water will be included in the Quarry Development Plan (QDP). • The QDP will include measures to assess and mitigate, if needed, potential effects of excavation on groundwater quantity for each borrow source and quarry site. These plans will outline required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quantity. • Use mitigation measures listed under Ground Disturbance as applicable.
	Ground Disturbance: The construction of the highway will alter ground surface characteristics such that the groundwater recharge rate over affected areas may change (direct effect).	• The Project will use previously disturbed areas for project activities and infrastructure and workspaces, to the extent practical. • The area of direct ground disturbance will be limited by following the pre-existing MVWR to the extent possible. Clearing will be limited to areas required for construction and safe operations. • A fill-only construction approach will be used except at specific locations of road cuts. • Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible. • Clearing will be completed by hand in sensitive areas (e.g., in riparian areas), where required, to prevent damage to the ground.

Potential Effect	Effect Pathway	Mitigation Measures
Change in Groundwater Quantity (cont'd)		• Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost. • Travel of vehicles will be confined to existing roads and trails as much as possible to avoid disturbing vegetated areas. • Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water. • If surface organic material must be removed for construction, it will be stockpiled and re-applied where possible. • Removal of vegetation will be limited to the ROW and workspaces.
	Permafrost Degradation: The construction of the highway will alter ground surface characteristics that may result in permafrost degradation (direct effect), a change in active layer thickness or increased connection to sub-permafrost groundwater systems (indirect effects), and a change in groundwater flow to or from streams, lakes, or wetlands (indirect effects).	• Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost. • Disturbance of the active layer during construction and maintenance activities will be avoided where possible. • Construction equipment will be operated on designated winter roads or constructed embankment only. • Clearing of new areas will be completed when the ground is frozen. • Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes. • The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost. • Ice-rich soils or materials that are susceptible to physical erosion will be covered to reduce permafrost degradation. • Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.

Potential Effect	Effect Pathway	Mitigation Measures
Change in Groundwater Quantity (cont'd)		• Runoff control methods will be used to protect permafrost soils, including diversion of water entering the site; the modification of slope surfaces, the reduction of slope gradients, controlling flow velocity, providing adequate or increased drainage, and diverting flows away from exposed soil areas for mitigating permafrost degradation. • Modification to the location or number of drainage culverts will be determined in consultation with the Engineer as based on observed site conditions. • Excavations and developed borrow sources will be visually monitored throughout the summer and fall to confirm there is no physical erosion resulting from the degradation of permafrost. • If ice-rich permafrost is identified during quarrying activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities as per quarry operations plans. • Use mitigation measures listed under Excavation and Ground Disturbance, as applicable.

15.4.1 Analytical Assessment Techniques

Potential project-related effects were evaluated with consideration of the following:

- The anticipated success of mitigation measures
- The level of sensitivity of surface water quantity (at the watershed scale) to potential effects
- A review of surface water effects assessments for similar all-season highway projects in the NWT (i.e., Tłı̨chǫ Highway [GNWT, 2016], Prairie Creek All Season Road [Canadian Zinc Co., 2015], and Inuvik to Tuktoyaktuk Highway [Kiggiak-EBA, 2011])

The hydrogeological conceptual model (Section 15.2.4) was a fundamental tool used to assess the effect of project activities upon groundwater quantity.

This assessment of residual effects follows a qualitative approach that relies on professional judgement to evaluate potential project-related changes to water quantity. Additional considerations in the evaluation of potential residual effects included the anticipated success of mitigation measures which are designed to be protective of the environment.

15.4.2 Changes in Streamflows

15.4.2.1 Effects Pathways

The pathway mechanisms through which residual effects on streamflows may occur are summarized in Table 15.2 and Table 15.8 and described:

- Changes to surface drainage patterns may be either due to the highway blocking natural streams, or an indirect result of project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution). Project interactions with terrain, soils, and permafrost are described and assessed in detail in Chapter 14.
- Erosion and sediment deposition has the potential to affect the capacity of streams to convey streamflow. Erosion effects are described and assessed in detail in Chapter 16.
- Glaciation and icings at watercourse crossings have the potential to reduce their capacity to convey peak flows and cause ponding upstream of the road.
- Water withdrawals during construction and operations and maintenance reduce natural streamflow in streams.

15.4.2.2 Mitigation

Design-based mitigation to reduce or eliminate changes in streamflow are summarized in Table 15.8. In this section, mitigation measures are organized according to the effect pathway they target.

Water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013). This mitigation measure will target the water withdrawals pathway. Particularly, DFO (2013) guidance is:

- Cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a natural flow regime have a low probability of detectable negative effects on ecosystems.
- "Cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of effects on ecosystems that support fisheries." Periods below 30% MAD were identified as 'highest risk'.

These mitigation measures for water withdrawal are considered effective at reducing potential effects on water quantity from changes in streamflow.

Multiple design mitigation measures will be in place to avoid changes to surface drainage patterns. In particular, mitigation measures that are anticipated to be successful in eliminating the potential measurable changes in streamflow at the watershed scale include the following:

- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns (i.e., limit inter-watershed water routing).

- Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches.
- The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost. Detailed mitigation measures to reduce the effects on terrain, soil, and permafrost are described in Chapter 14 (terrain, soils and permafrost).

Culverts will be designed and constructed to maintain water flow and fish passage. Design mitigation measures for the erosion and sediment deposition pathway are anticipated to be successful in eliminating the potential measurable changes in streamflow at the watershed scale due to the erosion and sediment deposition pathway. These measures are as follows:

- Erosion and drainage patterns will be observed and documented in support of the ESCP.
- Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
- Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert.

To eliminate the potential effect of glaciation and icings pathway on conveyance capacity of the culverts, and thereby on streamflow:

- Drainage culverts will be installed according to specifications to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects.
- Ice in culverts will be thawed by steaming, where needed to maintain flow.

15.4.2.3 Residual Effects

After the application of mitigation measures, the Project is anticipated to have residual effects on streamflows as a result of water withdrawals; however, the mitigation measures are anticipated to eliminate the effects of other pathways to streamflows beyond practically measurable thresholds at the watershed scale.

With the implementation of mitigation measures, the residual effects on streamflows during the construction and operations and maintenance phases are predicted to be low (<10%) magnitude and limited to the LAA. That is, the magnitude of change in discharge rates of the Mackenzie River (Deh Cho) downstream of the LAA is not predicted to be measurable (i.e., not >5% of natural flow as per Table 15.3).

Timing of water withdrawals and their potential effect on streamflows can be sensitive, particularly if water withdrawals occur when streamflows are decreasing near the 30% of mean annual discharge threshold guided by DFO (2010), or during the freeze-up or thaw seasons, which may have icing implications.

Water withdrawals and water use occur for multiple project activities as described in Section 15.3. As such, the effects on streamflow are considered long-term (although water use volumes will be reduced after the construction phase; Section 5.4.11) and the frequency is categorized as multiple irregular events. Effects are predicted to be reversible following cessation of water withdrawal activities.

15.4.3 Changes in Lake Volumes

15.4.3.1 Effects Pathways

Water withdrawals from lakes during construction and operations and maintenance have the potential to reduce the volume of lakes (Table 15.2 and Table 15.8).

15.4.3.2 Mitigation

Water withdrawal from lakes will be within the limits of water licences and in accordance with DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013). MVLWB (2021) is not directly applicable because it only relates to small-scale projects.

15.4.3.3 Residual Effects

After the application of mitigation measures, water withdrawal pathway is still anticipated to have residual effects on lake volumes. However, given compliance with DFO measures, changes in lake volumes are predicted to remain under 10% and protective of littoral habitat, and therefore the residual effects on lake volumes during the construction and operations and maintenance phases are predicted to be of low magnitude. The geographic extent of residual effects on lake volumes are limited to the LAA (i.e., the volumes of lakes outside the LAA are not anticipated to be affected by the Project).

Timing of water withdrawals and their potential effect on lake volumes can be sensitive, particularly if water withdrawals occur during winter (November to April when lake volumes are reduced due to ice cover).

Water withdrawals and water use occur for multiple project activities, as described in Section 15.3. As such, the effects on lake volumes are considered long-term (although water use volumes will be reduced after the construction phase; Section 5.4.11) and the frequency is categorized as multiple irregular events. However, residual effects are predicted to be reversible following cessation of water withdrawal activities, which may be seasonal or localized to the area of construction.

15.4.4 Change in Groundwater Quantity

15.4.4.1 Effects Pathways

Potential project effects on groundwater quantity, resulting from applicable effect pathways (i.e., excavation, ground disturbance, and permafrost degradation), depend on the hydrogeological characteristics of the area where the effect occurs.

15.4.4.1.1 Excavation

Excavations, if they advance below the groundwater table in permafrost-free areas, will result in the flow of groundwater into the excavation that must be removed (e.g., pumped out). If personnel will be working within the excavation (i.e., as could be expected in a borrow source or quarry), additional pumping must occur to lower the groundwater level below the floor of the excavation to have safe working conditions. As a result, groundwater levels near the excavation will decline and the excavation will become a local sink for groundwater flow.

The groundwater level change will be greatest at the excavation and will logarithmically decline as distance from the excavation increases. The area of the groundwater system affected by the groundwater level change is the excavation's cone of depression. Groundwater discharge to wetlands, streams, or lakes within the cone of depression may begin to decrease, or water from these environments may begin to infiltrate to ground, as a result of groundwater withdrawal.

Excavations, if they do not advance below the groundwater table, will result in a topographic depression to which surface flow and runoff may be directed. As a result, ground recharge may increase in the vicinity of the excavation and, where permafrost exists, permafrost degradation may occur.

15.4.4.1.2 Ground Disturbance

Ground disturbance activities may alter the characteristics of the ground surface such that the rate of incident precipitation or melt water that infiltrates to the groundwater system (recharge) may change. In permafrost-free areas, ground disturbance activities can be expected to increase groundwater recharge by decreasing water loss from evapotranspiration. The magnitude of the increase will depend, in part, on the permeability of local sediments. Approximately 47% of the PDA is underlain by low-permeability glaciomarine and till deposits (Section 15.2), and a potential increase in recharge from ground disturbance may be limited by the presence of these sediments. Conversely, ground disturbance in areas underlain by moderate to high permeability glaciofluvial, organic, eolian, fluvial, and colluvium materials (approximately 52% of the PDA, Section 15.2) may experience increased recharge.

15.4.4.1.3 Permafrost Degradation

Project activities that may affect groundwater quantity through permafrost degradation may occur along the entire PDA, but effects are more likely to occur where permafrost is classified as extensive continuous (65% to 90% of the land area; i.e., primarily in the northern half of the PDA [K'alo-Stantec, 2023b]).

Excavation, where permafrost exists, will remove ground cover and sediment layers, expose previously insulated stratigraphy to thaw-freeze conditions, and create a local topographic low. These changes may increase the thickness of the active layer near the excavation and/or promote ponding, which may cause additional permafrost degradation and an increased connection between supra- and sub-permafrost groundwater systems.

Vegetation and topsoil act as a thermal buffer that reduces ground surface heat loss in the winter and radiative heat penetration in the summer (Burgess and Smith, 2000). Ground disturbance where permafrost exists, as presented in Chapter 14 (terrain, soils and permafrost), will remove this buffer and increase the depth that seasonal thaw-freeze fluctuations penetrate. Thermokarst landforms, drainage pattern alteration, and an increase in the thickness of the active layer may result.

The presence of the road embankment may cause permafrost degradation by impeding slope drainage. The proposed road embankment will intersect westward-flowing drainage systems that ultimately discharge into the Mackenzie River (Deh Cho) (TRRC, 2022). Snowmelt and the seasonal thaw of the active layer result in considerable runoff that may encounter the upgradient side of the embankment. If the embankment is not adequately designed to allow water to pass, ponding may occur along its upgradient edge.

Ponded surface water will thaw underlying permafrost and thaw ground ice if these are present, which may cause thermokarst subsidence, create a topographic low, and in turn promote further ponding. The end effect on groundwater quantity of sustained ponding is the degradation of underlying permafrost and ground ice such that a hydraulic connection between supra- and sub-permafrost groundwater systems (Section 15.2) may be formed.

15.4.4.2 Mitigation Measures

Design-based mitigation measures to reduce or eliminate adverse effects on groundwater quantity are summarized in Table 15.8, organized according to the effect pathway the mitigation targets (i.e., excavation, ground disturbance, and permafrost degradation).

Additional mitigation measures to limit ground disturbance activities, such as the removal of vegetation and/or topsoil for road construction, are provided in the ESCP (see Volume 5). Additional detail on mitigation measures to limit the degradation of permafrost are provided in the PPP (see Volume 5).

15.4.4.3 Residual Effect on Groundwater Quantity

With the application of mitigation measures summarized in Table 15.8, the Project is likely to result in a change in groundwater quantity (i.e., a residual effect).

Project-related activities that change the conditions of the existing groundwater flow system (Table 15.7) will have an effect on groundwater quantity and on hydraulically connected surface water environments. Since these environments exist in balance with the recharge and discharge components of the existing groundwater flow system, there are no scenarios in which a project activity causes a positive or neutral effect on unaffected, existing groundwater conditions. Therefore, the characterization of the type of residual effect on groundwater quantity is defined as 'adverse' (Table 15.3).

Other residual effect characterizations defined for a change in groundwater quantity (Table 15.3) are discussed in terms of the pathway that cause the effect.

15.4.4.3.1 Excavation

The magnitude of groundwater level change associated with an excavation depends on the final depth of the excavation, whether the excavation extends below the groundwater table, and whether the excavation occurs where permafrost exists. Since the depth of the excavations anticipated by the Project are unknown, the magnitude of groundwater level change and the size of the associated cone of depression are uncertain. However, avoiding borrow material where groundwater levels are close to ground surface (Table 15.8) will reduce excavation below the groundwater table and reduce the magnitude of groundwater level decline. Additionally, planning for water management, as part of each site-specific QDP (Table 15.8), will provide a framework to manage and mitigate groundwater inflow and discharge to the environment should an excavation proceed beneath the groundwater table.

While a regional distribution of permafrost is available for the Project (K'alo-Stantec, 2022b), the distribution of permafrost at specific borrow source or quarry targets is unclear. However, where excavations proceed in permafrost, the low-permeability and confining nature of permafrost can be expected to reduce the development of a large cone of depression.

The magnitude of groundwater level change occurring from project excavations is expected to range from low to moderate within the PDA, no measurable change to low within the LAA, and no measurable change within the RAA. These expectations are consistent with a logarithmic reduction in groundwater level change as distance from the excavation increases (Section 15.4.4). Residual effects from excavation are not anticipated to extend beyond the LAA (i.e., 500 m) because excavation for borrow source, quarry, and road cut activities, based on past project experience and professional judgement, are generally too shallow to result in a cone of depression extending more than 500 m. The likelihood of a large cone of depression developing from excavations for this Project is further reduced since excavations may not extend below the groundwater table (no cone of depression) or they may occur in permafrost (limited cone of depression).

Residual effects associated with excavations are not expected to be sensitive to timing since borrow source, quarry, and road cut excavations will operate year-round and result in permanent changes in topography. As a result, the duration, frequency, and reversibility of associated residual effects are expected to be long-term, continuous, and irreversible, respectively.

15.4.4.3.2 Ground Disturbance

The magnitude of groundwater level change associated with ground disturbance will depend on the area affected. If the mitigation measures listed in Table 15.8 are employed, such as limiting project work to the PDA and limiting the removal of vegetation to the width of the ROW, ground disturbance will be locally limited to the PDA, which is a small fraction of the ground surface area within the LAA and RAA. The affected area will be further reduced since 47% of the PDA is underlain by low-permeability glaciomarine and till deposits that can be expected to restrict recharge (Section 15.2.4). As a result, the magnitude of the groundwater level change associated with project ground disturbance activities is anticipated to be no measurable change to low.

The residual effects from project activities with a ground disturbance pathway that can be remediated (e.g., temporary camp locations) are expected to be medium-term (e.g., during the construction phase), continuous, and reversible. Effects related to ground disturbance caused by permanent changes, such as the presence of the highway, are expected to be long-term, continuous, and irreversible.

Residual effects associated with ground disturbance activities are not expected to be sensitive to timing as a result of mitigation measures taken to reduce effects on groundwater quantity that specifically address sensitive timing (e.g., new areas will be cleared when the ground is frozen, Table 15.8).

15.4.4.3.3 Permafrost Degradation

The magnitude of groundwater level change associated with permafrost degradation (indirect effect) is difficult to predict but will depend, in part, on the effectiveness of the PPP and the mitigation measures contained therein. A key component of the PPP will be adequate drainage culverts or other design infrastructure used to convey surface runoff and supra-permafrost (active layer) groundwater flow through the embankment and reduce ponding on the upgradient edge.

The magnitude will also depend on the permeability of the underlying sediments. Low permeability glaciomarine and till deposits (approximately 47% of the PDA) will continue to act as confining layers, in the absence of permafrost, by resisting recharge and encouraging surface runoff. Where the PDA intersects moderate to high permeability alluvial, colluvium, or glaciofluvial materials (approximately 52% of the PDA) containing permafrost and ground ice, there is greater potential for these materials to drain or store water that previously flowed as surface runoff.

If the PPP is used effectively, the magnitude of the groundwater level change associated with permafrost degradation for the Project is anticipated to be low to moderate, moderate being consistent with the residual effect of the Project on permafrost degradation (direct effect) discussed in Chapter 18 (terrain, soils and permafrost).

Permafrost degradation is expected to be limited to the PDA and LAA. Southern areas of the PDA are less likely to be affected than northern areas. Because the road embankment is intended to be a permanent infrastructure feature, residual effects from associated permafrost degradation are long-term, continuous, and irreversible.

Residual effects from activities associated with the permafrost degradation pathway are not expected to be sensitive to timing as mitigation measures taken to reduce effects on groundwater quantity specifically address sensitive timing (e.g., new areas will be cleared when the ground is frozen, Table 15.8).

15.4.5 Summary of Residual Effects

With mitigation measures in place, residual effects from the Project on water quantity are anticipated to occur in the form of changes in streamflows, changes in lake volumes, and changes in groundwater quantity. These residual effects are predicted to be adverse in direction. Adverse effects on streamflows and lake volumes are predicted to be of low (<10%) magnitude and occur within the LAA with a long-term duration (i.e., the construction and operations and maintenance phases). Timing of the effects can be sensitive, and effects can be irregular, but they are reversible.

Residual effects resulting from the Project on groundwater quantity after mitigation is implemented will occur and these effects are predicted to be adverse in direction. The magnitude and geographic extent of residual effects depend on the pathway mechanism that causes the effect as follows:

- Residual effects on groundwater quantity from excavations are expected to have magnitudes that range from low to moderate within the PDA and no measurable change to low within the LAA. These effects are expected to be continuous and irreversible but geographically limited to the LAA.
- Residual effects of the Project from ground disturbance include no measurable change to low magnitude, continuous, and reversible and irreversible changes to groundwater quantity that are geographically limited to the PDA.
- Residual effects of the Project from permafrost degradation include low to moderate magnitude and irreversible changes to groundwater quantity that are geographically limited to the LAA.

A summary of residual effects on water quantity is provided in Table 15.9. With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to watershed management, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for reducing effects on water quantity respects the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) as areas with important ecological habitats, and takes into account the Project's location within Tulita's community drinking water source catchment.

Table 15.9 Residual Effects on Water Quantity

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Changes in Streamflows	C/O	A	P	L	LAA	HS	LT	IR	R
Changes in Lake Volumes	C/O	A	P	L	LAA	HS	LT	IR	R
Change in Groundwater Quantity	C/O	A	P	NMC[1,2] L[1,2,3] M[1,3]	PDA[1,2,3] LAA[1,3]	NS	MT[2] LT[1,2,3]	C	R[2], I[1,2,3]

KEY

*See Table 15.3 for detailed definitions

Project Phase:
C: Construction
O: Operations and Maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
LS: Low sensitivity
HS: High sensitivity

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

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

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Applies to the excavation effects pathway (Section 15.4.4.1)

2 Applies to the ground disturbance effects pathway (Section 15.4.4.1)

3 Applies to the permafrost degradation effect pathway (Section 15.4.4.1)

15.5 Assessment of Cumulative Effects on Water Quantity

15.5.1 Residual Effects Likely to Interact Cumulatively

Other projects and activities within the RAA may interact with the Project and cumulatively affect water quantity. A project inclusion list of such past, present, and foreseeable projects and activities is provided in Table 15.10 and shown in Figures 4.1 and 4.2.

Where adverse residual effects from the Project on water quantity have the potential to act cumulatively with those from other projects and physical activities, this potential has been identified with check marks in Table 15.10. The projects and activities listed below were excluded from cumulative effects assessment:

- Geotechnical assessment activities within the Hamlet of Tulita, upstream of confluence with Great Bear River, are not anticipated to have measurable effects on the Mackenzie River (Deh Cho) streamflows or interact with effects of the Project on groundwater.
- Existing quarries and borrow sources (i.e., Little Bear River Quarry and Sand Bar Quarrying) are on the west side of the Mackenzie River (Deh Cho), and therefore will not interact with the Project to affect surface water or groundwater quantity.
- Mining exploration and oil and gas projects located on the west side of the Mackenzie River (Deh Cho) are excluded from the cumulative effects assessment as their effects will not interact with residual effects on water quantity.

Other past, present, and foreseeable projects and activities in Table 15.10 have the potential to interact with the project activities and cumulatively affect streamflows and groundwater quantity. These include the oil, gas and seismic projects east of the Mackenzie River (Deh Cho); MVWR; Canyon Creek All Season Access Road; municipal operations at Wrigley, Tulita, and Norman Wells; Dhu-1 Quarry; Great Bear River Bridge; and Prohibition Creek Access Road. Only the municipal activities and Dhu-1 Quarry have potential to also affect lake volumes, as the other projects do not use lakes as water withdrawal sources.

These projects and activities have the potential to interact with water quantity through surface drainage pattern, erosion and sediment deposition, excavation, terrain disturbance, glaciation and icings, and water withdrawal pathways.

Table 15.10 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects		
	Change in Streamflows	**Change in Lake Volumes**	**Change in Groundwater Quantity**
Past and Present Physical Activities and Resource Use (Base Case)			
Geotechnical	–	–	–
Oil, Gas & Seismic*			
Tulita 2D Seismic Program	✓	✓	–
Windy Island Drilling Program	✓	–	–
Infrastructure			
MVWR, including bridges and bridge-sized culverts	✓	✓	✓
Canyon Creek All Season Access Road	✓	–	✓
Norman Wells Pipeline	–	–	✓
Mackenzie Valley Fibre Link	–	–	✓
Prohibition Creek Access Road	✓	–	✓
Quarries and Borrow Sources			
HRN Quarry	–	–	✓
Mining & Exploration	–	–	–
Municipal Operations, including water, waste, power and community development			
Wrigley Municipal Activities	✓	✓	–
Tulita Municipal Activities	✓	✓	–
Norman Wells Municipal Activities	✓	✓	–
Project-Related Physical Activities (Project Case)			
Mackenzie Valley Highway Project	✓	✓	–
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)			
Quarries			
Dhu-1 Quarry	✓	✓	✓
Infrastructure			
Great Bear River Bridge	✓	–	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects		
	Change in Streamflows	**Change in Lake Volumes**	**Change in Groundwater Quantity**
Oil and Gas			
Enbridge Maintenance Camp	✓	–	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with Project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

15.5.2 Changes in Streamflows

15.5.2.1 Cumulative Effects Pathways

Similar to effects pathways of the Project (see Section 15.4.2.1), the pathway mechanisms through which residual cumulative effects on streamflows may occur are described:

- Changes to surface drainage patterns may be either due to directly blocking natural streams, or an indirect result of project interaction with terrain, soils, and permafrost (including borrow extraction and changes to snow distribution).
- Erosion and sediment deposition has the potential to affect the capacity of streams to convey streamflow.
- Glaciation and icings at watercourse crossings have the potential to reduce their capacity to convey peak flows and cause ponding upstream of the road. The icings could impact watercourse crossings if the water source producing the icing is contributing continuously. Furthermore, ponding that may result upstream of the road could cause permafrost degradation and localized thermokarst subsidence.
- Water withdrawals reduce natural streamflow in streams.

15.5.2.2 Mitigation for Cumulative Effects

No additional mitigation measures are recommended to reduce or eliminate cumulative effects on streamflow beyond those measures presented in Section 15.4.2.2 and Table 15.8, namely that cumulative changes to streamflows will not exceed 10% of the flow. It is assumed that water withdrawals associated with future projects and activities would obtain the necessary approvals and adhere to applicable DFO guidelines.

15.5.2.3 Cumulative Effects

Similar to the residual effects of the Project (see Section 15.4.2.3), it is anticipated that after the application of mitigation measures, cumulative effects on streamflows due to potential changes in surface drainage patterns, erosion and sediment deposition, and/or glaciation and icings at watercourse crossings will be negligible. However, even with application of mitigation measures, cumulative effects associated with water withdrawal will remain.

These cumulative residual effects on streamflows during the construction and operations and maintenance phases are predicted to be of low (<10%) magnitude. Within the LAA, the relative contribution from the Project to the cumulative residual effect cannot be quantified because quantified magnitudes of change in streamflows due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of cumulative effects is low (i.e., as long as the MVWLB considers cumulative withdrawal of less than 10% when assessing the water licence applications).

The geographic extent of these cumulative effects on streamflows is limited to the LAA. That is, the magnitude of change in discharge rates of the Mackenzie River (Deh Cho) downstream of the LAA is not predicted to be measurable (i.e., not >5% of natural flow as per Table 15.3).

Timing of water withdrawals and their potential effect on streamflows can be sensitive, particularly if water withdrawals occur during winter (i.e., under ice conditions) or during the freeze-up or thaw seasons, which may have icing implications.

The effects on streamflow are considered long-term and the frequency is categorized as multiple irregular events. Cumulative effects are predicted to be reversible following cessation of water withdrawal activities.

15.5.3 Changes in Lake Volumes

15.5.3.1 Cumulative Effects Pathways

Similar to that assessed for project effects, it is assumed that the mechanism for cumulative changes in lake volumes is through water withdrawals.

15.5.3.2 Mitigation for Cumulative Effects

No additional mitigation measures are recommended to reduce or eliminate cumulative effects on lake volumes beyond those measures presented in Section 15.4.2.2 and Table 15.8, namely that cumulative water withdrawal will not exceed 10% of the under-ice volume. It is assumed that water withdrawals associated with future projects and activities would obtain the necessary approvals and adhere to applicable DFO guidelines.

15.5.3.3 Cumulative Effects

The cumulative residual effects on lake volumes during the construction and operations and maintenance phases are predicted to be of low (<10%) magnitude. Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified because quantified magnitudes of change in lake volumes due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of cumulative effects is low (i.e., as long as the MVLWB considers cumulative withdrawal of less than 10% when assessing the water licence applications).

The geographic extent of these cumulative effects on lake volumes is limited to the LAA. That is, the volume of lakes outside the LAA are not anticipated to be affected by the Project, and therefore the Project will not have cumulative effects on lake volumes outside the LAA.

Timing of water withdrawals and their potential cumulative effect on lake volumes can be sensitive, particularly if water withdrawals occur during winter (i.e., under ice conditions when lake volumes are reduced).

The effects on lake volumes are considered long-term and the frequency is categorized as multiple irregular events. Cumulative effects are predicted to be reversible following cessation of water withdrawal activities.

15.5.4 Change in Groundwater Quantity

15.5.4.1 Cumulative Effects Pathways

Residual effects on groundwater quantity arising from past, present, and reasonably foreseeable future projects and physical activities include the same effects pathways as those resulting from the Project (Section 15.4.4); ground disturbance and permafrost degradation. Effects occurring through these pathways will only act cumulatively with the residual effects of the Project if they extend into the project LAA, since project effects are not anticipated to extend beyond the LAA.

15.5.4.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on groundwater quantity from excavation, ground disturbance, and permafrost degradation pathways include those presented in Table 15.8. No additional mitigation measures are recommended to reduce or eliminate the cumulative effects on groundwater quantity beyond those measures presented. It is assumed that other projects and activities have or would apply similar mitigation measures to those presented in Table 15.8.

15.5.4.3 Cumulative Effects

Residual effects from the Project to groundwater quantity are not anticipated to extend to the RAA and therefore are not expected to contribute to cumulative effects within the RAA.

The residual effects of other past or present projects on baseline groundwater quantity conditions with the Project LAA are difficult to determine. Existing groundwater quantity data (groundwater levels) was lacking at a level of detail required to characterize baseline conditions beyond general statements on regional and local groundwater flow systems (Section 15.2).

Reasonably foreseeable projects and developments include the Dhu-1 Quarry, the Great Bear River Bridge, and the Prohibition Creek Access Road.

The Dhu-1 Quarry is a permitted quarry source 1.6 km from the project PDA and the Dhu-2 quarry is a proposed alternate quarry source 3.1 km from the PDA (Chapter 5). The quarries are located approximately 2 km from one another. Residual effects on groundwater quantity, should quarry excavation at these two sources extend below the groundwater table, are expected to be similar to the residual effects of other excavations (Section 15.4.4). The maximum extent of groundwater level change is expected to be 500 m or less (Section 15.4.4.3), and residual effects from the quarries are not expected to act cumulatively.

The Great Bear River Bridge and Prohibition Creek Access Road projects are either outside the LAA or the continuation of the same overall linear infrastructure as the Project, to the extent they will be designed to the same highway standard (Section 5.3.2). As a result, residual effects from these projects are not expected to act cumulatively with the Project.

Therefore, the magnitude of cumulative effects are expected to range from no measurable change to moderate within the LAA, consistent with the assessment completed for residual effects. Likelihood, sensitivity, timing, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

15.5.5 Summary of Cumulative Effects

With mitigation measures in place, cumulative residual effects on water quantity are anticipated to occur in the form of change in streamflows, change in lake volumes, and change in groundwater quantity (Table 15.11).

Cumulative effects on surface water quantity are predicted to be adverse and of low (<10%) magnitude. The effects are anticipated to occur within the LAA with a long-term duration (i.e., the construction and operations and maintenance phases). Timing of the effects can be sensitive, and effects can be irregular, but they are reversible.

Cumulative effects on groundwater quantity are predicted to be adverse in direction and range from no measurable change to moderate in magnitude. Cumulative effects will occur in the LAA and persist for the long term due to the long operational period and permanent changes to the environment imposed by of many of these projects. For many of these project and activities, cumulative effects will likely be irreversible.

Table 15.11 summarizes the Project cumulative effects on water quantity.

Table 15.11 Summary of Cumulative Effects on Water Quantity

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Residual Cumulative Change in Streamflows	A	P	L	LAA	HS	LT	IR	R
Contribution from the Project to the residual cumulative effect	Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified (see Section 15.5.2.3). Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.							
Residual Cumulative Change in Lake Volumes	A	P	L	LAA	HS	LT	IR	R
Contribution from the Project to the residual cumulative effect	Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified (see Section 15.5.3.3). Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.							
Change in Groundwater Quantity	A	P.	NMC[1], L[1,2,3], M[2,3]	PDA[1,2], LAA[2,3],	NS	LT	C	I
Contribution from the Project to the residual cumulative effect	The Project contribution to cumulative effects on changes to groundwater quantity is expected to be no measurable change at the RAA level.							

KEY

*See Table 15.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
NS: No sensitivity
LS: Low sensitivity
HS: 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

Notes:

1 Applies to the ground disturbance effects pathway (Section 16.4.3.1)
2 Applies to the excavation effects pathway (Section 16.4.3.1)
3 Applies to the permafrost degradation effect pathway (Section 16.4.3.1)

15.6 Determination of Significance

15.6.1 Significance of Residual Effects

Residual effects of the Project on surface water quantity include low magnitude, reversible changes in streamflows and lake volumes that are geographically limited to the LAA (Table 15.9).

Based on these characterizations, as well as the significance definition in Section 15.1.6, residual effects on surface water quantity are predicted to be not significant.

Based on the characterizations of residual effects outlined in Table 15.11 and summarized in Section 15.4.4, and the significance definition in Section 15.1.6, residual effects on groundwater quantity are predicted to be not significant.

15.6.2 Significance of Cumulative Effects

Cumulative residual effects on surface water quantity include low magnitude, reversible changes in streamflows and lake volumes that are geographically limited to the LAA. Based on these characterizations, as well as the significance definition in Section 15.1.6, these cumulative residual effects on surface water quantity are predicted to be not significant.

Cumulative residual effects on groundwater quantity range from no measurable change to moderate effects geographically limited to the LAA, Cumulative residual effects on groundwater quantity are possible, and expected to be long-term, continuous, and irreversible. Based on these characterizations, as well as the significance definition in Section 15.1.6, cumulative effects on groundwater quantity are predicted to be not significant.

15.6.3 Project Contribution to Cumulative Effects

Within the LAA, contribution from the Project to the cumulative residual effect on surface water quantity cannot be quantified because quantified magnitudes of change in lake volumes due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of cumulative effects is low (i.e., as long as the MVWLB considers cumulative withdrawal of less than 10% when assessing the water licence applications).

Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.

The contribution of residual effects of the Project to cumulative effects on groundwater quantity within the LAA are expected to range from no measurable change to moderate in magnitude, consistent with the assessment of residual effects (Section 15.4.4).

The Project is not expected to contribute measurably to cumulative effects within the RAA since residual effects of the Project are anticipated to be limited to the LAA.

15.7 Prediction Confidence

For surface water quantity, if it is confirmed that the design of the Project will apply the mitigation measures for water quantity (particularly those listed in the assumptions, Section 15.7.1), the prediction confidence will be moderate. If such a confirmation cannot be provided, the prediction confidence will be low. Additional confirmation of lake volumes will improve confidence in residual effects predictions and field data will be required to be collected to support construction licence applications.

For groundwater quantity, confidence in the assessment of potential residual effects is increased by considering that the Project will not use groundwater for water supply and does not require excavations that extend far below the groundwater table. As a result, many common pathways to significant residual changes in groundwater quantity are not present.

Confidence in the assessment of potential effects on groundwater quantity is reduced based on the following:

- A lack of existing conditions groundwater quantity data from which to characterize potential residual effects.
- The long, linear disturbance nature of the Project results in the project PDA crossing a variety of conceptual groundwater flow systems, the variability of which limits the potential to describe or define these systems in detail.

In summary, the prediction confidence in assessing potential project effects on groundwater quantity is low to moderate based on this discussion and reliance on professional judgement.

15.7.1 Assumptions

Results of this effects assessment are dependent on effective implementation of mitigation measures, described in Section 15.4 and summarized in Table 15.8. Particularly, successful implementation the following mitigation measures are critical to the validity of these effects assessment results:

- Water withdrawal will be within the limits of water licences that will be in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013).
- There will be sufficient drainage culverts installed along the roadway to facilitate water movement and maintain drainage patterns (i.e., limit inter-watershed water routing).
- Culverts will be designed and installed as per hydrotechnical recommendations to maintain flow and fish passage, and as based on observing performance during construction.
- Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert.

- Drainage culverts will be installed according to specifications to accommodate storm events and maintain drainage patterns, and in consideration of site-specific icing/glaciation effects.
- The Project will follow measures in the PPP to reduce ponding, erosion, and damage to permafrost.
- Erosion and drainage patterns will be observed and documented in support of the ESCP.
- Sediment control measures will be in place prior to construction activities and before the spring melt/freshet.

15.7.2 Gaps and Uncertainties

Some existing condition data requirements of the ToR (MVEIRB, 2015) were not available for this assessment. These include:

- The extent of connectivity of existing water resources to adjacent watercourses, including any potential seasonal variation: This would be a potential issue where the drainage divide between two flat catchments is not well defined. However, the Project interacts with streams at the lowest end of their catchments where the flow is well channelized and natural inter-catchment flow is less common. Therefore, it is reasonable that such inter-catchment flows were not documented in the literature reviewed, and such flows would not be relevant to this effects assessment.
- A description of ephemeral streams located within or near the boundaries of the study area(s): It is not known with certainty what drainages with watershed areas of less than 100 km^2 are perennial and which ones are seasonal/ephemeral. Additional data will need to be collected to support applications for authorization to use water sources for withdrawal to demonstrate availability of water in accordance with applicable guidelines (e.g., DFO, 2010, 2013). Winter flow measurements are required to be collected from streams and winter under-ice volume will need to be determined for lakes.
- A description of naturally occurring icings: A key design-based mitigation measure is the installation of drainage culverts according to specifications to accommodate storm events and maintain drainage patterns and in consideration of site-specific icing/glaciation effects. To implement this mitigation, further project design will need to consider naturally occurring icings and the uncertainty in their magnitude of effect.
- A description of channel and bed morphology and stability, and a description of bank stability and areas of erosion for major drainages: The hydrotechnical assessment and fish and fish habitat assessment reports (see Appendix 22A; K'alo-Stantec, 2022d; Tetra Tech, 2021, 2022) provide this information for minor crossings where the Project will construct new crossing structures. These assessment reports did not include major drainages because these major drainages have existing bridges and will not be altered or replaced as part of the Project.

- For major drainages, a description of sediment load (suspended and bed load): As mentioned, the Project does not include alteration of existing bridges on major drainages. At minor drainages, although sediment loads have not been directly discussed, channel assessment has been conducted in the hydrotechnical assessment and fish and fish habitat assessment reports (see Appendix 22A; K'alo-Stantec, 2022d; Tetra Tech, 2021, 2022). In addition, potential effects of the Project on sediment quality have been assessed in Chapter 16.
- For major drainages, a description of active and historical floodplains: As mentioned, the Project does not include alteration of existing bridges on major drainages.
- Existing groundwater quantity data (groundwater levels) to characterize baseline conditions such that neither quantitative nor qualitative definitions of residual effects characterizations (Table 15.3) for groundwater quantity could be confidently developed.

As explained, data gaps (compared to the ToR [MVEIRB, 2015] requirements) do not materially change this effects assessment if the mitigation measures are effectively implemented as assumed in Section 15.7.1.

Uncertainties in input data that feed into the design can cause uncertainty in effectiveness of the design-based mitigation measures. Hydrologic input data with uncertainty include:

- Existing monthly streamflows, peak flows, and lake volumes (Appendix 15A and Appendix 15C [K'alo-Stantec, 2022a, 2023a] are based on estimates)
- Channel bed material and bank stability near crossings
- Effects of icing on conveyance capacity of culverts

While the abovementioned hydrologic input data are uncertain under existing conditions, such uncertainties are likely more considerable for future conditions with potential changes to climate, land cover, and drainage.

In addition, the dimensions and depths of the borrow source and quarry excavations are currently unknown. These variables will affect the effect pathway and the magnitude, geographic extent, duration, and reversibility of the residual effect on the groundwater quantity in the vicinity of the excavation. If borrow source, quarry, or road cut excavations extend below the groundwater table (uncertainty), a water licence to permit groundwater withdrawal may be required (GNWT, 2015).

15.8 Follow-up and Monitoring

Streamflow and lake level monitoring programs will be undertaken to confirm the low (<10%) effect of water withdrawals on streamflows and lake volumes. Likewise, existing winter under-ice volume will need to be determined for lakes. The need for monitoring programs, as well as their details (e.g., location, frequency, and parameters of measurement) will be determined during the water licence application process.

The monitoring programs should verify the effectiveness of design-based mitigation measures (e.g., culverts accommodating storm events with icing effects) both for existing and future conditions (i.e., with potential climate and land cover changes).

Monitoring plans for ground disturbance and permafrost degradation are included in the ESCP and the PPP that will describe sampling procedures, quality control and assurance programs, laboratory methods and protocols, laboratory accreditations, and reporting requirements, where applicable. The plans will also provide details on the location, design, methods (e.g., parameters to be measured), applicable regulatory instruments, and schedule for the follow-up and monitoring programs.

Management plans will be developed to assess and mitigate potential residual effects of excavation on groundwater quantity for each borrow source and quarry site, as required by the GNWT (2015). These plans will provide an adaptive management framework that outline required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quantity or other VCs.

15.9 References

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16.0 ASSESSMENT OF POTENTIAL EFFECTS ON WATER AND SEDIMENT QUALITY

The Mackenzie Valley Highway Project (the Project) has the potential to affect water and sediment quality in watercourses (e.g., streams, rivers, muskeg, and lakes) and groundwater quality during the construction, and operations and maintenance phases of the Project. Water resources that may be affected by the Project include those which will be downstream or downgradient of (or in proximity to) project components such as quarries, borrow sources, construction camps, and the highway itself.

Water and Sediment Quality was selected as a Valued Component (VC) because of its importance in supporting aquatic life, wildlife, human health, and community well-being. Changes in water or sediment quality can have negative effects on aquatic habitat and drinking water quality and may adversely affect the quantity and/or quality of food for wildlife and humans. The assessment of water and sediment quality contributes to the Subject of Note water quality and quantity as identified in the Terms of Reference ([ToR]; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [PR#66]).

Protection of water quality in the Mackenzie Valley is of high cultural importance. Watercourses intersected by the Project are traditionally used as sources of sustenance, including drinking water and for harvesting of fish. Groundwater is valued as a potential source of water for human consumption and for its intrinsic links with aquatic environments.

This chapter assesses the potential effects of the Project on surface water quality, groundwater quality and on sediment quality in the aquatic environment. The potential for project-related changes in water and/or sediment quality to cause adverse effects on ecological receptors, human health, traditional land use, and community well-being is assessed separately for other VCs: Chapter 9 (human health and community wellness; non-traditional land and resource use), Chapter 10 (caribou and moose), Chapter 11 (cultural use), Chapter 17 (fish and fish habitat), and Chapter 19 (wildlife and wildlife habitat).

The assessment of potential effects on water and sediment quality concludes that with the application of mitigation measures, residual effects resulting from the Project on water and sediment quality will be adverse. Residual effects will not result in a persistent measurable change in surface water quality and sediment parameters that adversely affect ecological and/or human receptors. Changes to groundwater quality are predicted to be low in magnitude. The assessment concludes that residual effects and cumulative effects on water and sediment quality are predicted to be not significant.

16.1 Scope of Assessment

16.1.1 Regulatory and Policy Setting

The regulatory requirements associated with water quality include federal and territorial laws and policies, as well as water quality guidelines. Additionally, specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023).

16.1.1.1 Federal and Territorial Legislation and Guidelines

The federal *Fisheries Act*, in particular Sections 34 through 42, regulates fisheries and addresses water pollution. Section 36 prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized under regulations. As defined in Section 34(1)(a) of the *Fisheries Act*, a deleterious substance is "*any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water*."

The Government of the Northwest Territories (GNWT) is responsible for managing water resources in the Mackenzie Valley through the administration of the *Waters Act* and regulations. The territorial *Waters Act* is administered by the Department of Environment and Climate Change and regulates water quality through water usage and disposal of waste in water bodies. Within the Mackenzie Valley and Sahtu Region, water quality regulation is shared by the Mackenzie Valley Land and Water Board (MVLWB) and the Sahtu Land and Water Board (SLWB), for projects where a water licence is required. There are no regulations under the *Waters Act* prescribing water quality standards. Therefore, the following water quality guidelines (standards) are applied to surface water and groundwater quality:

- Canadian Council of Ministers of the Environment (CCME) Guidelines for the protection of Freshwater Aquatic Life (CWQG-FAL) (CCME, 2022)
- Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSQG-FAL; CCME, 2022)
- Federal Environmental Quality Guidelines (FEQGs) for the protection of aquatic life in fresh water and sediment (CCME, 2022; Environment and Climate Change Canada [ECCC], 2022a)
- The Alberta Environment and Parks (AEP) Environment and Sustainable Resource Development (ESRD) Tier 1 Groundwater Remediation Guidelines (AEP, 2022).
- Health Canada's Drinking Water Quality Guidelines (HC DWQG) and Recreational Water Quality Guidelines (HC RWQG) apply to potable water and recreational waters (Health Canada, 2012, 2020)

The intent of these guidelines and standards is to protect freshwater aquatic life and human health by providing concentrations of substances (e.g., metals, nutrients, major anions) below which adverse effects are generally not expected to occur. Because guidelines for the protection of freshwater aquatic life are more stringent than water quality guidelines for the protection of wildlife, they are also considered protective of wildlife receptors. However, these guidelines and standards are generic and applied across Canada (or in the case of the Tier 1 guidelines, Alberta). Therefore, site-specific conditions that can influence the bioavailability and/or toxicity of a substance to ecological or human receptors (e.g., water chemistry or the sensitivity of specific biological receptors to the substance) aren't always adequately represented in a generic guideline. In some cases, site-specific water quality objectives are developed to more appropriately assess the potential for adverse effects than generic guidelines.

16.1.1.2 Sahtu Land Use Plan

The SLUP's CRs include consideration of:

- Community engagement and Traditional Knowledge (CR#2): *"2) The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge."*
- Watershed management (CR#5): The SLWB and/or MVLWB must ensure that the Project: *"a) does not substantially alter quality, quantity, or rate of flow for waters that flow on, through, or adjacent to Sahtu Settlement Lands; and b) is subject to mitigation measures to minimize potential impacts on surface and groundwater that flow into CZs [Conservation Zones], SMZs [Special management Zones], PCI [Proposed Conservation Initiatives] and EPAs [Established Protected Areas]."*
- Drinking water (CR#6): *"1) Any land use activity that would result in the contamination of surface or groundwater within community catchments is prohibited; 2) Where there is reasonable potential for any land use activity to affect a downstream drinking water source: a) the affected community must be informed and engaged with respect to potential impacts, the design of mitigation measures and monitoring programs; b) baseline water quality data must be collected from the drinking water source prior to the start of any activity; and c) regular water quality testing of the source watershed must be conducted to monitor potential impacts."* (SLUPB, 2023).

Additionally, CR#14 requires that the Project be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ą̨lǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

16.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (consultation and engagement), 3 (Traditional Knowledge), and 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, and through a review of publicly available TLRU information, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to water and sediment quality and drinking water resources. This feedback has been considered and summarized in Table 16.1 and has been integrated into the assessment of potential effects on water and sediment quality and drinking water resources that follows.

Table 16.1 Summary of Engagement Feedback

<table>
<tr><th>Comment</th><th>Source</th><th>GNWT Response</th><th>Where Addressed</th></tr>
<tr><td>Engaged Indigenous Governments, Indigenous Organizations and other affected parties identified locations of water resources important for drinking water near the Project.</td><td>Golder, 2015; Norman Wells Renewable Resources Council (NWRRC), 2023; Tulita Renewable Resources Council (TRRC), 2022</td><td rowspan="2">The GNWT has considered this information in the selection of water sources to be considered for the Project. For example, owing to concerns raised, Trout Lake near Bear Rock (Petınıʔah) has been removed as a water source.

Water withdrawal will be within the limits of water licences and in accordance with the Fisheries and Oceans Canada (DFO) measures to protect fish and fish habitat (e.g., DFO, 2010, 2013) and other applicable guidance.

The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical, to limit new disturbances.

Water quality will be monitored during culvert installation in accordance with the Fish and Fish Habitat Protection Plan (FFHPP).

The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments, Indigenous Organizations, and other affected parties.

The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning.</td><td rowspan="2">For information about drinking water sources identified by engaged Indigenous Governments and Indigenous Organizations, and other affect parties, see Section 16.2.2 (Table 16.4)

See also:

Section 5.4.11

Section 11.2.3.8 for additional information about water sources

Chapter 17 (fish and fish habitat)

Volume 5 (management plans)</td></tr>
<tr><td>Engagement participants recommended using silty water sources for road maintenance to avoid drinking water sources; sourcing water should also not affect fish and fish habitat.</td><td>April to July 2022 Engagement</td></tr>
</table>

Comment	Source	GNWT Response	Where Addressed
Sahtu Region residents have expressed concerns about potential project effects on water quality and quantity in the Sahtu Region including contamination, which could be far reaching due to the speed at which surface and groundwater flows; patterns of surface water flow and potential groundwater changes; increased sediment from vegetation clearing along waterbodies from effects of blasting, runoff and thawing permafrost (erosion, flooding, scouring, reduced land subsistence), which also can affect groundwater and surface water; and can potentially effect surface water in Norman Wells.	Dessau, 2012 (Public Registry [PR]#13); Golder, 2015	The GNWT has identified mitigation measures to reduce the effects of the Project on water quality. The Project will follow mitigation measures in the Erosion and Sedimentation Control Plan (ESCP) to reduce potential effects on water quality. This includes applying best management practices (BMPs) according to the GNWT's Erosion and Sediment Control Manual (GNWT, 2013a). The Project will follow mitigation measures in the Permafrost Protection Plan (PPP) to reduce ponding, erosion, and damage to permafrost. Water quality will be monitored during culvert installation in accordance with the FFHPP. The Project will implement the Spill Contingency Plan (SCP) to reduce the potential for effects on water quality from unplanned releases. The Project will follow measures in the Quarry Development Plans (QDP) for each quarry and borrow source to reduce potential effects on water quality. Water only will be used for dust suppression, except as provided for in the GNWT Guideline for Dust Suppression.	For mitigation measures to reduce effects of the Project on water quality, see Table 16.6. See also: Section 16.4.2 Section 16.4.3 Chapter 25 (Assessment of Potential Accidents or Malfunctions) Volume 5 (management plans)
Community engagement participants explained that the water is changing, attributed to sedimentation. Participants also noted that the water is getting warmer and explained that there is radium in Great Bear River.	August 2021, Engagement; April to July 2022 Engagement		
Participants of the NWRRC TLRU study raised concerns regarding the quality of water in Fort Good Hope and reported that the water along the shoreline appears to have an oily sheen (While Fort Good Hope is not located near the Project, NWRRC study participants shared concerns about previous developments, in the TLRU study area, specifically oil drilling that occurred at Bluefish Creek, which study participants have attributed to be the cause of water quality decline in the TLRU study area leading down to Fort Good Hope).	NWRRC, 2023		

Comment	Source	GNWT Response	Where Addressed
Participants of the NWRRC TLRU study reported that Prohibition Creek has been known to contain too many minerals at times for drinking.	NWRRC, 2023	*(cont'd from above)* The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments, Indigenous Organizations, and other affected parties. The GNWT will work with Sahtu Renewable Resources Board (SRRB) and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the study areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.	
Participants of the NWRRC TLRU study reported concerns from local Sahtu harvesters about potential project effects on open-water sources from vehicle breakdown, specifically near Bear Rock (Petınıʔah), which have potential to cause contamination, or affect the flow of water in Great Bear River.	TRRC, 2022		
Participants of the NWRRC TLRU study discussed experiences of environmental contamination from vehicle fluid leaks and spills that have occurred along the MVWR in the TLRU study area and raised concerns about potential project effects from vehicle operations and mechanical equipment contaminating open water resources during construction and operation of the Project.	NWRRC, 2023		
Community engagement participants expressed concern about blasting, which may contaminate water and affect food sources and food chains. Some land users stated that they will no longer eat fish from Mackenzie River (Deh Cho) because of oil and gas activity in the area.	November to December 2022 Engagement		

Comment	Source	GNWT Response	Where Addressed
Elders, land users and community members in the Sahtu Region previously expressed concern about potential project effects on human health through water and air quality, and consequently the health of the region's wildlife, fish, and vegetation.	Golder, 2015		
A number of drinking water resources relative to the Project that have been identified Sahtu Dene and Métis by through a review of publicly available literature, and project-specific TLRU studies in the PDA, LAA, and RAA.	Golder, 2015; NWRRC, 2023; TRRC, 2022		
Participants of the NWRRC TLRU study reported that the water quantity (levels) at Canyon Creek is too low to use as a drinking water source, however Canyon Creek used to be a good source of drinking water.	NWRRC, 2023		

16.1.3 Potential Effects, Pathways and Measurable Parameters

The Project has the potential to cause changes in water and sediment quality in waterbodies located within the Local Assessment Area (LAA) and Regional Assessment Area (RAA), which are defined in Section 16.1.4. Potential effects on surface water, groundwater, and sediment quality are measurable changes of chemical parameters that extend beyond the variability of existing conditions that may potentially exceed relevant water quality guidelines for the protection of human receptors (e.g., drinking water and recreational water quality guidelines) and ecological receptors (e.g., guidelines for the protection of freshwater aquatic life).

Changes in surface water and sediment quality may result from increased suspended sediment loading into the aquatic environment due to land disturbances, such as the removal of vegetation and/or topsoil for road construction, instream works at water crossings, and dustfall. Measurable water quality parameters used to monitor suspended sediment loading include total and dissolved metals, phosphorus, major ions, water hardness (as calcium carbonate [$CaCO_3$]), total suspended solids (TSS), and nephelometric turbidity units (NTU). Visual observation of sedimentation is also used to monitor suspended sediment loading in waterbodies.

Changes to surface water, groundwater, and sediment quality may occur due to excavation and runoff and seepage from project-specific quarries, borrow sources, stockpiles, and highway components (e.g., road base materials) constructed of crushed rock and granular materials from quarries and rock cuts. Crushed rock may potentially contribute to acid rock drainage (ARD) and metal leaching (ML), and the transport of nitrogen blasting residues to the aquatic environment. Measurable water quality parameters used to monitor water and sediment quality potentially influenced by ARD/ML and blasting residues include total and dissolved metals, major ions, pH, and nitrogen species (e.g., total nitrogen, ammonia, nitrate, and nitrite).

The Project does not propose to use groundwater as a water source and will not discharge solid or liquid effluent to the environment. As a result, the only direct effect the Project may have on groundwater quality is the unintended release of substances (e.g., spills or accidents). Potential effects on water and sediment quality from unintentional releases are addressed in Chapter 25 (accidents and malfunctions). However, the Project may indirectly affect groundwater quality through a change in groundwater flow patterns or rates through excavation, ground disturbance, or permafrost degradation pathways (Section 15.4.4.1). A change in groundwater flow via one of these pathways may result in mixing of previously separate groundwater flow pathways that change the quality of the resulting flowpath.

Table 16.2 summarizes the potential effects of the Project on water and sediment quality, the pathways in which the effects may occur, and the measurable parameters used to monitor and assess the magnitude, geographic extent, and duration of potential effects.

Table 16.2 Potential Effects, Effects Pathways, and Measurable Parameters for Water and Sediment Quality

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Changes to surface water and/or sediment quality	Erosion and sedimentation due to the following land disturbances: • Clearing of vegetation in the project footprint • Instream works at water crossings (e.g., culvert installation) • Alteration of permafrost	• pH (in pH units), conductivity (microsiemens per centimeter [µS/cm]), turbidity (NTU), total suspended solids (TSS), total dissolved solids (TDS), total and dissolved metals, total and dissolved nutrients (milligrams per litre [mg/L] when measured in water; miligrams per kilogram [mg/kg] when measured in sediment), and/or visual observation of sedimentation. • Additional parameters measured in sediment include particle size (% clay, % gravel, % sand, and % silt)
	Fugitive dustfall	TSS, TDS, total and dissolved metals (mg/L)
	ARD/ML due to runoff and leachate from: • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Total and dissolved metals, major ions (mg/L), hardness ($CaCO_3$), and pH
	Nitrogen loading due to runoff and leachate from project components developed from the use of explosives: • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Total nitrogen, ammonia, nitrate, and nitrite; (mg/L in water; mg/kg in sediment)
Changes to groundwater quality	A change in groundwater flow caused by excavations, ground disturbance, or permafrost degradation (direct effects), may cause a change in the quality of the groundwater in these systems (indirect effect).	Changes in groundwater quality as measured by a change in concentration of parameters (generally mg/L) from pre-construction conditions

16.1.4 Boundaries

The spatial and temporal boundaries of the water and sediment quality effects assessment are described in Sections 16.1.4.1 and 16.1.4.2, respectively.

16.1.4.1 Spatial Boundaries

Potential project-related changes to surface water and sediment quality are assessed in terms of potential residual effects within the following study areas:

- **Project Development Area (PDA):** The area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA):** The area within which measurable project-related effects (direct or indirect) are expected to occur (Figure 16.1). The LAA for surface water and sediment is the area within 1 kilometre (km) of the preliminary alignment route centerline, quarry and borrow sources and associated access roads, and extended westward to include the mainstem of Mackenzie River (Deh Cho) and potential water sources for construction of the Mackenzie Valley Winter Road (MVWR).

  The LAA is divided into a northern section (i.e., Tulita to Prohibition Creek) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the proposed alignment at Tulita to account for the Great Bear River Bridge (not part of the Project).
- **Regional Assessment Area (RAA):** The area that provides context for determining significance of project effects and potential cumulative effects. The surface water and sediment quality RAA is the area within approximately 15 km of the PDA.

Potential project-related changes to groundwater quality are assessed relative to the following areas:

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway ROW, laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA):** The area within which measurable project-related effects (direct or indirect) are expected to occur. The groundwater quantity LAA is the area within a 0.5 km buffer of the preliminary alignment route centerline, quarries and borrow sources and associated access roads. The LAA is divided into a northern section (i.e., Tulita to Prohibition Creek) and a southern section (i.e., Wrigley to Tulita). The northern and southern sections of the LAA are separated by a 10 km break in the Project alignment at the Hamlet of Tulita to account for the Great Bear River Bridge (not part of the Project), as shown in Figure 16.1.

- **Regional Assessment Area (RAA):** The area that provides context for determining significance of project effects and potential cumulative effects. The groundwater quantity RAA is the area within approximately 5 km of the PDA or the mainstem of the Mackenzie River (Deh Cho), whichever is closer (Figure 16.1). The Mackenzie River (Deh Cho) is a regional groundwater flow divide (K'alo Stantec, 2022b) that will limit the influence of project activities on one side of the river to groundwater on the other.

16.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases:

- **Construction phase:** The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, quarries and borrow sources not needed for operations and maintenance will occur during the construction phase.

- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Surface Water Local Assessment Area
- Surface Water Regional Assessment Area
- Groundwater Local Assessment Area
- Groundwater Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Mackenzie River Sub-Basin

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 8/7/2023
TR by CS on 8/7/2023

Client/Project
144903025-0151 REVA
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
16.1

Title
Water and Sediment Quality Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

16.1.5 Residual Effects Characterization

Potential residual effects of the Project on water and sediment quality are characterized in terms of direction, likelihood, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 16.3). Quantitative measures or, where applicable, descriptions of qualitative measures, are provided in Table 16.3.

Table 16.3 Characterization of Residual Effects on Water and Sediment Quality

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse**: A residual effect that moves measurable parameters of water or sediment quality in a negative direction relative to baseline **Neutral:** No measurable long-term trend in water and sediment quality parameters relative to existing conditions
Likelihood	The probability that the residual effect will occur	**Unlikely –** The residual effect is almost certainly not to occur. **Possible –** The residual effect could occur. **Certain –** The residual effect will certainly occur.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Surface Water and Sediment Quality** **No Measurable Change:** No measurable change from pre-construction conditions and/or upstream reference sites **Low:** A measurable change that is anticipated to be within the variability of pre-construction conditions and/or upstream reference sites **Moderate:** A measurable change that is anticipated to be outside the variability of pre-construction conditions (and/or upstream reference sites) and in exceedance of applicable guidelines, legislated requirements, and/or management, but is unlikely to have an adverse effect on ecological or human receptors in the LAA or RAA **High:** A measurable change that is anticipated to be outside the variability of pre-construction conditions (and/or upstream reference sites) and in exceedance of applicable guidelines, legislated requirements, and/or management, and is likely to have an adverse effect on ecological or human receptors in the LAA or RAA **Groundwater Quality** **No Measurable Change:** Concentrations of groundwater quality parameters are consistent within the range of potential inter-annual variation. **Low:** Concentrations of groundwater quality parameters deviate from the potential range of inter-annual variation but do not exceed guideline concentrations.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude (cont'd)		**Moderate:** Concentrations of groundwater quality parameters deviate from the potential range of inter-annual variation and exceed guideline concentrations by up to a factor of two. **High:** Concentrations of groundwater quality parameters deviate from the potential range of inter-annual variation and exceed guideline concentrations by an order of magnitude.
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA. **LAA:** Residual effects extend into the LAA. **RAA:** Residual effects interact with those of other projects in the RAA.
Timing	Considers when the residual effect is expected to occur, where relevant to the VC	**Not Sensitive**: Seasonal aspects are unlikely to affect changes to water or sediment quality. **Sensitive:** Seasonal aspects may affect changes to surface water quality (i.e., from spring thaw to autumn freeze-up, when terrain, soils and permafrost are the most susceptible to ground disturbance).
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	**Short-term**: The effect is restricted to a portion of the construction phase. **Medium-term**: The effect occurs throughout construction (up to 20 years). **Long-term:** The effect occurs beyond construction or throughout operations (more than 20 years).
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** The effect occurs only once. **Multiple irregular event:** The effect occurs at no set schedule. **Multiple regular event:** The effect occurs at regular intervals. **Continuous:** The effect 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.

16.1.6 Significance Definition

A significant residual effect on water quality and/or sediment quality is one that is likely to result in a persistent measurable change in parameters that adversely affect ecological and/or human receptors. The potential for project-related changes in water and/or sediment quality to cause adverse effects on ecological receptors, human health, traditional land use, and community well-being is assessed separately for other VCs: Chapter 9 (human health and community wellness; non-traditional land and resource use), Chapter 10 (caribou and moose), Chapter 11 (cultural use), Chapter 17 (fish and fish habitat), and Chapter 19 (wildlife and wildlife habitat).

For groundwater quality, the significance of potential project effects will be determined based on the characterization of residual effects as outlined in Table 16.3 using the following criteria:

- If the magnitude of the effect is no measurable change or low, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect is confined to the PDA or LAA, the effect is not significant.
- If the magnitude of the effect is moderate and the geographic extent of the effect extends to the RAA, the effect is significant.
- If the magnitude of the effect is high, the significance evaluation of the effect will be based on the characterization of the effect's geographic extent, duration, and reversibility.

Consideration of these attributes for evaluation of whether residual effects are significant or not significant highly relies on professional judgement.

The preceding definition of significance applies to groundwater quality as a resource. Indirect effects from a change in groundwater quality on other VCs are not evaluated in this chapter.

16.2 Existing Conditions for Water and Sediment Quality

Existing conditions for surface water and sediment quality are presented in the surface water and sediment quality technical data report ([TDR]; Appendix 16A; K'alo-Stantec, 2022a). Existing conditions for groundwater quality are presented in the hydrogeology TDR (Appendix 15B; K'alo-Stantec, 2022b).

16.2.1 Methods

A literature review was completed to understand the extent of available surface water and sediment quality data along the project alignment and within the RAA and LAA. Background information on surface water quality for the Sahtu and Dehcho regions was obtained from the following sources:

- The GNWT Community-Based Monitoring Program (GNWT, 2020, pers. comm.)
- The GNWT Water Quality Monitoring Network Evaluation report (Summit Environmental Ltd., 2014)

- Environment and Climate Change Canada (ECCC), Northern Water Quality Monitoring Network (ECCC, 2022b)
- Mackenzie Gas Project Environmental Impact Statement (EIS), Biophysical Baseline Report for Water Quality (EIS Volume 3, Section 6; IORVL, 2004)
- Data from Water Resources, Indigenous and Northern Affairs Canada (INAC) for the Mackenzie Valley Pipeline (GNWT, 2021, pers. comm.)
- Rempel and Gill (2011): Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data
- Golder (2015): Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge
- Tulita Renewable Resources Council Traditional Land and Resource Use Study for Tulita District Mackenzie Highway Project 2022 (TRRC, 2022)

Prospective road source material was screened for ARD/ML potential in October 2020 (K'alo-Stantec, 2021). In total, 11 granular sources where clast lithology indicated the possibility of ARD/ML potential were sampled (9 of these 11 sites are identified as primary material sources). In addition, quarry sites Dhu1 and Dhu2 were tested for ARD/ML potential (K'alo-Stantec, 2021).

The hydrogeology TDR (Appendix 15B; K'alo-Stantec, 2022b) presents the groundwater system existing conditions and provides a conceptual model of local and regional groundwater flow systems to use in the evaluation of potential project effects. A summary of the conceptual model is provided in Section 16.2.3.

16.2.2 Overview of Surface Water and Sediment Quality Existing Conditions

The Project is in the Mackenzie-Great Bear Sub-Basin of the Mackenzie Valley Basin (MRBB, 2021). This Sub-Basin spans more than a third of the Northwest Territories (NWT) and extends from Fort Simpson (Łíídlı Kųę), in the south to the Makenzie River delta in the north, and from the Nunavut border in the east to the Yukon border in the west (MRBB, 2021).

Although watercourses within the Mackenzie-Great Bear Sub-Basin are generally of good quality, some localized effects on water quality have been observed nearby anthropogenic influences such as wastewater discharges (MRBB, 2003, 2021). In addition, Indigenous people have reported increasing water temperatures and turbidity compared to past years. However, the scientific data generally do not show widespread anthropogenic effects on water quality or on fish health (MRBB, 2021). The NWRRC study participants raised concerns regarding the quality of water in Fort Good and reported that the water along the shoreline appears to have an oily sheen (NWRRC, 2023). While Fort Good Hope is not located in the LAA or RAA, NWRRC study participants shared concerns about previous development in the LAA and RAA, specifically oil drilling that occurred in Bluefish Creek, which study participants have attributed to be the cause of water quality decline around Bluefish Creek leading down to the area of Fort Good Hope (NWRRC, 2023).

Natural water quality of the Mackenzie-Great Bear Sub-Basin, including water flowing into the RAA, is generally influenced by water flowing through the Precambrian Shield of the Mackenzie Mountains, as well as mountains surrounding the Liard River, which drains into the Mackenzie River (Deh Cho) (Golder, 2015). This flowing water causes streambank erosion, which mobilizes metals and nutrient-rich sediment. Consequently, the Mackenzie River (Deh Cho) is known for naturally elevated suspended sediment and turbidity compared to other rivers in the arctic. Natural concentrations of turbidity in the Mackenzie River (Deh Cho) are highest during the spring snow melt and are often in exceedance of Canadian Water Quality Guidelines for recreation and aesthetics (MRBB, 2003).

Through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies, a list of drinking water resources relative to the Project that have been identified that are of interest to Indigenous Governments, Indigenous Organizations, and other affected parties (Dessau, 2012 [PR#13]; Golder, 2015; TRRC, 2022). Several locations overlap the LAA and RAA, as described in Table 16.4.

Table 16.4 Drinking Water Resources Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[1]	Identified By: (if applicable)
Springs which feed the large streams from Norman Wells to the Great Bear River; including Prohibition Creek	✓	✓	Sahtu Dene and Métis
Springs which feed the large streams from Norman Wells to the Great Bear River; including Vermillion Creek	✓	✓	Sahtu Dene and Métis; NWRRC
Springs which feed the large streams from Norman Wells to the Great Bear River; including Nota Creek	✓	✓	Sahtu Dene and Métis; NWRRC
Canyon Creek	-	✓	NWRRC
Bluefish Creek	-	✓	NWRRC
Great Bear River (as it intersects with the LAA and RAA)	✓	✓	TRRC; NWRRC
Big Smith Creek	-	✓	Sahtu Dene and Métis
Bear Rock (Petıniʔah) (spring)	✓	-	Sahtu Dene and Métis

Note:
[1] Occurs within the RAA outside the LAA and PDA
Sources: Golder, 2015; NWRRC, 2023; TRRC, 2022

Participants of the NWRRC study also reported that the water level at Canyon Creek is too low to use as a drinking water source, however Canyon Creek used to be a good source of drinking water.

The surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a) describes the extent to which existing conditions surface water and sediment quality data have been previously collected within the LAA and RAA. Additional site-specific baseline surface water and sediment quality data were not collected for this DAR because management plans and mitigation measures will be implemented to address the potential project-specific effect pathways described in Section 16.1.3. In addition, site-specific water quality data will be collected as part of construction and compliance monitoring to build upon existing regional surface water and sediment quality data and to facilitate adaptive management (Section 16.8). Results of the preliminary ARD/ML assessment indicate that ARD/ML potential of existing material sources is low and is not expected to adversely affect water quality of the receiving watercourses (K'alo-Stantec, 2021).

16.2.3 Conceptual Hydrogeological Model

Groundwater flow systems are generally conceptualized as nested regional, intermediate, and local scale systems (Toth, 1963). Regional groundwater flow systems develop from large-scale topographic, physiographic, and geologic features (such as the Central Mackenzie Valley [CMV], larger than the RAA). Local groundwater flow systems develop from smaller-scale variation of topography and geologic features and local flow (i.e., within the PDA and/or LAA) is often dominated by one component of the regional flow system (Freeze and Cherry, 1979). The predominant features of the conceptual groundwater model of the CMV and the PDA, as it traverses the Mackenzie Plain from Wrigley to Norman Wells, include the following (K'alo-Stantec, 2022b):

- The PDA is largely within the discharge zone of regional groundwater flow-paths that extend from recharge areas beyond the RAA within the Franklin and McConnell Mountain Ranges.
- Surficial geology within the RAA is predominately low permeability glaciolacustrine (43.0%) and till (21.3%) with smaller fractions of moderate to high permeability alluvial (15.3%), colluvium 9.4%), and glaciofluvial (5.9%) sediments and other (5.1%) materials.
- Surficial geology within the LAA includes low permeability till (23.3%) and glaciolacustrine (20.6%) materials, moderate to high permeability organic (15.3%), glaciofluvial (14.1%), colluvium (11.0%), eolian (6.1%), and fluvial (4.9%) materials, and (4.2%) other materials.
- Surficial geology along the PDA includes low permeability glaciolactustrine (25.8%) and till (21.3%) materials, moderate to high permeability glaciofluvial (19.5%), organic (12.7%), eolian (7.6%), fluvial (6.4%), and colluvium (5.8%) materials, and (0.9%) other materials.
- Low permeability glaciolacustrine and till deposits, if present, will act as a barrier to local and regional groundwater discharge and artesian (above ground surface) pressure conditions have the potential to develop in underlying stratigraphy.

- Permafrost, where it exists, is expected to be a barrier to groundwater flow and will separate the groundwater flow system into shallow, seasonal, supra-permafrost flow within the active layer and deeper, perennial sub-permafrost flow components. The degree to which this separation exists is expected to increase north along the PDA as the presence of permafrost increases from sporadic discontinuous (10-35% of land area) near Wrigley, through intermediate discontinuous (35% to 65% of land area), to extensive discontinuous (65% to 90% of land area) permafrost near Norman Wells.
- Where extensive discontinuous permafrost is present, interaction between supra-permafrost and sub-permafrost groundwater flow systems may be limited to taliks, regions of thawed strata that allow fluid flow. Taliks within the CMV may be concentrated along regional fault trace and fracture systems where regional flow gradients prevent permafrost from becoming established, and beneath large lakes and streams. Regional groundwater discharge likely occurs predominately through these perennial conduits.
- Permafrost, where it exists, will limit the volume of local groundwater recharge (i.e., occurring within the RAA, LAA, and/or PDA) that reaches the sub-permafrost groundwater system. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost.
- Permafrost, where it exists, limits groundwater flow within the RAA to the shallow supra-permafrost flow component. The limitation will be greater along northern portions of the PDA than southern portions due to the increased presence of permafrost. Groundwater flow limited to the supra-permafrost component limits overall groundwater storage and results in rapid groundwater discharge to surface following spring melt or precipitation events.
- Borrow source excavations target glaciofluvial and fluvial materials for construction fill that also tend to be high permeability and well drained. These characteristics limit the formation of ground ice and may reduce the compartmentalizing effect of permafrost where present in these materials.

16.3 Project Interactions with Water and Sediment Quality

Table 16.5 identifies project activities that have the potential to interact with surface water, groundwater, and sediment in the construction and operations and maintenance phases of the Project. Interactions that have the potential to result in effects on surface water and sediment quality within the LAA or RAA are indicated by a check mark. These interactions are discussed in detail in Section 16.4, in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for activities not expected to interact with surface water, groundwater, and/or sediment quality is provided following the table.

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are not considered in this chapter and are described in Chapter 25 (accidents and malfunctions).

The identification of project activities and their potential interactions with water and sediment was based on engagement with interested parties, knowledge of road construction projects in the NWT, professional judgment of technical specialists involved in the assessment, and a review of existing conditions. The selection of interactions is also informed by the potential effects and effects pathways for each VC as described in Section 16.1.3.

Table 16.5 Project-Environment Interactions with Water and Sediment Quality

Physical Activities	Timing	Environmental Effects		
		Change to Water Quality	Change to Sediment Quality	Changes to Groundwater Quality
Construction Phase				
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer	–	–	-
Establishment and operation of camps	Year-round	✓	✓	-
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓
Material hauling and stockpiling along the ROW	Year-round	✓	✓	-
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓
Culvert installations	Summer or winter	✓	✓	-
Road base placement, compaction, and surfacing	Summer	✓	✓	-
Water withdrawal for construction activities	Year-round	-	-	-
Closure and reclamation of MVWR and temporary borrow sources quarries, camps, and workspaces	Summer	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	–	–	-
Operations and Maintenance Phase				
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓
Material hauling and stockpiling	Summer	✓	✓	-
Operation of, and activities at, maintenance yards	Year-round	–	–	-

Physical Activities	Timing	Environmental Effects		
		Change to Water Quality	Change to Sediment Quality	Changes to Groundwater Quality
Water withdrawal for dust control	Summer	–	–	-
Employment and contracted goods and services[1]	Year-round	–	–	-
Presence and use of the highway	Year-round	✓	✓	✓
Highway and access road maintenance, including snow clearing, repair, grading, dust control	Year-round	✓	✓	-
Vegetation control	Summer	–	–	-
Bridge and culvert maintenance	As needed	✓	✓	-

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, “Employment and contracted goods and services” have been introduced as an additional component under each Project phase.

Project activities are linked to a potential change in groundwater quality through an indirect pathway whereby project activities affect groundwater flow and, subsequently, indirectly affect groundwater quality.

16.3.1 Project Interaction Exclusions

The following Project components and activities are not expected to interact with water or sediment quality during the construction or operations and maintenance phases:

- Equipment mobilization/demobilization and resupply, as these activities are not expected to interact with water or sediment quality during either phase of the Project unless there is an accidental event, as existing authorized infrastructure and services will be used. Accidental events (e.g., accidental fuel spills) are assessed separately in Chapter 25 (accidents and malfunctions).
- The establishment and operation of camps is not expected to interact with groundwater quality since the effect pathway, ground disturbance, will have already occurred during site preparation (site preparation of ROW, access, and workspaces), and there will be no discharge of wastes to surface waters.

- Employment and contracted goods and services, as these activities will not directly result in changes to water or sediment quality during either phase.
- Water withdrawal for construction and for dust control, as this activity is not expected to directly result in measurable changes to water or sediment quality. Water withdrawal will be completed from candidate sources identified in Chapter 5 (Project Description), and extraction volumes will be limited to amounts that will not affect the ecological function of the waterbody.
- Operation of, and activities at, maintenance camps, as these activities are not expected to interact with water or sediment quality during either phase of the Project unless there is an accidental event (e.g., accidental fuel spills). Accidental events (e.g., accidental fuel spills) are assessed separately in Chapter 25 (accidents and malfunctions) and in the Spill Contingency Plan (see Volume 5).
- Emissions and waste management, as project-related wastes (including camp domestic waste, sewage, greywater, plastics, and hazardous and inert wastes) will be disposed at approved municipal facilities and are therefore not assessed herein. The management of project-related waste is described in the Waste Management Plan (WMP; see Volume 5). Dust emissions are considered under each project activity and light and noise emissions do not interact with surface water or sediment quality.
- Vegetation control is not anticipated to interact with water or sediment quality. Brushing will generally occur approximately every 3 years and will involve using a mower to cut back saplings and shrubs to maintain sight distances for public safety. Riparian vegetation will be maintained whenever possible, and brush will not be disposed of in or near waterbodies.

16.4 Assessment of Residual Effects on Water and Sediment Quality

Based on project interactions with the environment identified in Table 16.5, the Project may result in changes to water and sediment quality. These potential effects are considered to be primarily associated with the construction phase of the Project, but potential effects related to operations and maintenance are also considered herein. The potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on water quality are summarized in Table 16.6, and details are provided in Section 16.4.2.1 Effect Pathways and Section 16.4.2.2 Mitigation. Residual effects are characterized in Section 16.4.2.3 following implementation of mitigation measures.

Table 16.6 Potential Effects and Mitigation Measures for Water and Sediment Quality

Potential Effect	Effect Pathway	Mitigation Measures
Change in surface water and/or sediment quality	Erosion and sedimentation due to the following land disturbances: • Clearing of vegetation in the project footprint (construction) • Instream works at water crossings (e.g., culvert installation during construction and culvert maintenance during operations and maintenance) • Alteration of permafrost (construction)	Mitigation measures to prevent or reduce potential effects associated with erosion and sedimentation per: • ESCP (see Volume 5) • PPP (see Volume 5)
	Dustfall due to: • Construction activity • Vehicle use during operations and maintenance	Mitigation measures to prevent or reduce potential effects associated with dustfall as per: • ESCP (Volume 5)
	ARD/ML due to runoff and leachate during construction and operations and maintenance: • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Mitigation measures to prevent or reduce potential effects associated with ARD/ML are described in Section 16.4.2.2 and are included in the following management plans: • QDPs [1] • ESCP (see Volume 5)
	Nitrogen loading due to runoff and leachate from project components developed from the use of explosives (construction only): • Quarries • Rock cuts • Stockpiles • Embankment/Road Base materials	Mitigation measures to prevent or reduce potential effects associated with blasting-related nitrogen loading are described in Section 16.4.2.2 and will be included in the following management plans: • Explosives Management Plan (ExMP) [1] • QDPs [2] • ESCP (see Volume 5)
Change in Groundwater Quality	A change in groundwater flow, such as the increased connection between supra-permafrost and sub-permafrost groundwater flow systems (indirect effect) caused by permafrost degradation (direct effect) may cause a change in the quality of the groundwater in these systems (indirect effect).	Mitigations to reduce disturbance to soils and permafrost and groundwater flows will mitigate changes to groundwater quality. These include mitigation measures in the: • PPP • ESCP • QDPs[1]

Notes:

[1] An Explosives Management Plan will be developed during project permitting.

[2] Quarry Development Plans will be developed during the quarry permitting application process and will be specific to each quarry/borrow source. A draft QDP framework is included in Volume 5.

16.4.1 Analytical Assessment Techniques

The potential for residual effects was assessed following implementation of mitigation measures. Effects were also assessed based on the following:

- The integration of data from other VCs in this DAR (e.g., Water Quantity; Fish and Fish Habitat; Terrain, Soils, and Permafrost)
- The level of sensitivity of surface water and sediment to potential effects
- A review of surface water effects assessments for similar all-season highway projects in the Northwest Territories (e.g., Tłı̨chǫ Highway [MVRB, 2018], Prairie Creek All Season Road [CZC, 2015], and Inuvik to Tuktoyaktuk Highway [Hamlet of Tuktoyaktuk et al., 2011] DAR and Effects Assessments)

This assessment of residual effects followed a qualitative approach that relies on professional judgement to evaluate potential project-related changes to water and sediment quality. The hydrogeological conceptual model (see Section 15.2.4) was a fundamental tool used to assess the effect of project activities upon groundwater.

16.4.2 Changes to Surface Water and/or Sediment Quality

16.4.2.1 Effects Pathways

Project-related changes to surface water and sediment quality may result from increased suspended sediment loading into the aquatic environment due to land disturbances, such as the removal of vegetation during clearing, stripping of borrow/quarry sources, excavation of road cuts, instream works at water crossings (e.g., culvert installations), alteration of permafrost, and dustfall.

Changes to surface water and sediment quality may also occur if project components (e.g., quarries, granular borrow sources, road cuts, rock material stockpiles, embankment and road base materials) have the potential for ARD/ML. Runoff and leachate from these materials have the potential to enter watercourses and affect surface water and sediment quality.

Elders, land users and community members in the Sahtu Region previously expressed concern about potential project effects on human health through water and air quality, and consequently the health of the region’s wildlife, fish, and vegetation (Golder, 2015). Sahtu Region residents have expressed concerns about potential project effects on water quality and quantity in the Sahtu Region including contamination, which could be far reaching due to the speed at which surface and groundwater flows. Residents raised concerns about potential project effects on patterns of surface water flow and potential groundwater changes, as well as increased sediment in surface water from vegetation clearing along waterbodies, including effects of blasting, runoff and thawing permafrost, erosion, flooding and scouring. Additionally, Sahtu residents discussed potential project effects from reduced land subsistence, which can also affect groundwater and surface water (Dessau, 2012 [PR#13]; Golder, 2015).

Tulita Renewable Resources Council study participants raised concerns about potential project effects to open-water sources from vehicle breakdown, specifically near Bear Rock (Petınıʔah), which have potential to cause contamination, or effect the flow of water in Great Bear River (TRRC, 2022).

The Project will likely use ammonium nitrate/fuel oil (ANFO) explosives for the development of quarries and road cuts. The undetonated nitrogen component of the explosives, ammonium nitrate (AN), is highly water-soluble. Runoff and leachate from quarries and quarry materials may result in releases of nitrogen to the aquatic environment, which can be detected as nitrate, nitrite, and ammonia.

16.4.2.2 Mitigation

Mitigation measures to prevent or reduce changes in water and sediment quality are summarized by effect pathway.

16.4.2.2.1 Mitigation of Erosion and Sedimentation

16.4.2.2.1.1 Removal of Vegetation and/or Topsoil

The removal of vegetation and topsoil during ROW clearing and preparation of quarry and borrow sources can increase bank instability, expose soils, increase erosion potential, and mobilize sediments into watercourses via bank failure or runoff from exposed surfaces. The potential for erosion and sedimentation due to the removal of vegetation and topsoil is well understood, and various well established and standard approaches will be used in the design and construction of the Project to limit or eliminate risks associated with this effect pathway.

Mitigation measures to prevent or reduce erosion and sediment loading into the aquatic environment due to the removal of vegetation and topsoil include implementation of standards and BMPs described in the ESCP, guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- Northern Land Use Guidelines: Pits and Quarries (GNWT, 2015b)
- The GNWT, Department of Transportation - Erosion and Sediment Control Manual (GNWT, 2013a)
- Measures to Protect Fish and Fish Habitat (DFO, 2022a)

The Project includes the development of an ESCP (Volume 5) and a PPP (Volume 5), which provide reference to BMPs to be used for erosion and sedimentation control. Key mitigation measures to prevent or reduce erosion and sediment loading into the aquatic environment due to the removal of vegetation and topsoil include the following:

- Riparian vegetation will be maintained whenever possible.

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
- Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction.
- Clearing will be limited to areas required for construction and safe operations.
- Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
- Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost.
- Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads.
- Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW, where possible.
- Clearing will not be conducted during high rainfall or runoff events.
- Clearing will be completed by hand, where required, to prevent damage to the ground, such as rutting, compaction and erosion.
- Organic topsoil will be left in place to retain a protective layer during the construction of the road to limit permafrost degradation and protect the soils from erosive factors of water.
- Tree roots will be grubbed only in areas required for construction or stripping.
- Runoff control will be implemented to avoid entry to waterbodies, including installing drainage per design specifications, diverting water from entering watercourse, and controlling of flow velocity.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- Grading of stream banks at approaches shall be limited, where possible.
- BMPs for erosion control will be implemented according to the ESCP.
- Erosion and sedimentation control measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measure.
- Cleared snow will be directed away from watercourses and drainages.
- Runoff control will be implemented to avoid entry to waterbodies, including: installing drainage per design specifications; diverting water from entering watercourse; and controlling of flow velocity.
- Erosion and sedimentation control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013a) and will be in place prior to construction activities and before the spring melt/freshet.

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the ESCP (Volume 5), potential effects due to erosion and sedimentation related to vegetation and topsoil clearing are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management (Section 16.8).

16.4.2.2.1.2 Instream Works at Water Crossings

Instream works at water crossings (e.g., culvert installations) can result in the release of fine sediments directly from excavation in and around the stream and indirectly from run-off from exposed soils. The potential for erosion and sedimentation from instream works is well understood, and various effective, well established, and standard approaches will be used in the design and construction of the Project to reduce risks associated with this effect pathway.

The design and implementation of standards, BMPs, and mitigation measures associated with instream works will be guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- The GNWT, Department of Transportation - Erosion and Sediment Control Manual (GNWT, 2013a)
- Measures to Protect Fish and Fish Habitat (DFO, 2022a)
- Code of Practice: Culvert Maintenance (DFO, 2022b)

As described, the Project will include the development of an ESCP. Mitigation measures that will prevent or reduce erosion and sediment loading into the aquatic environment due to instream water crossings include the following:

- All temporary crossings will follow Fisheries and Oceans Canada's (DFO's) codes of practice for temporary fords and/or ice bridges and snow fills (DFO, 2022c).
- A project-specific ESCP will be developed and implemented.
- Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
- Effective erosion and sediment control measures (such as silt fencing) will be installed before starting work in and around watercourses to prevent sediment from entering the water body. Culverts will be designed and installed to maintain flows and fish passage (GNWT, 2015a).

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the ESCP, potential effects due to erosion and sedimentation related to instream works at water crossings are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management (Section 16.8).

16.4.2.2.1.3 Alteration of Permafrost

Based on available regional permafrost mapping, the Project spans extensive discontinuous permafrost (predominantly near Norman Wells), intermediate discontinuous permafrost (e.g., Mackenzie Plain area), and sporadic discontinuous permafrost (area surrounding Wrigley) zones (soils, terrain and permafrost TDR, Appendix 14A; K'alo-Stantec, 2023). To the extent feasible, disturbance of permafrost areas will be avoided because could cause thawing and ground subsidence, potentially leading to soil erosion and sedimentation into watercourses (GWNT, 2015a). Appropriate construction techniques will be required to prevent significant thawing of soils in areas along the project corridor where permafrost is located (GNWT, 2013a).

The potential for erosion and sedimentation from the degradation of permafrost is well understood, and various established approaches will be used in the design and construction of the Project to reduce risks associated with the development of the highway in areas of permafrost.

The design and implementation of mitigation measures and BMPs to prevent or reduce erosion and sedimentation associated with the degradation of permafrost will be guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- The GNWT Department of Transportation - Erosion and Sediment Control Manual (GNWT, 2013a)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions (TAC, 2010)

The Project includes the development of a PPP and ESCP (Volume 5). Mitigation measures and BMPs that will prevent or reduce permafrost degradation and sedimentation include the following:

- A minimum of 10 centimetres (cm) of packed snow or ice will be used on winter access roads.
- Construction equipment will be operated on designated winter roads or constructed embankment only.
- Clearing of new areas will be completed when the ground is frozen to limit disturbance to soils and permafrost.
- Clearing will not be conducted during high rainfall or runoff events.
- Clearing will be completed by hand, where required to prevent damage to the ground.
- Placement of embankment will occur primarily during winter (December 15 to April 1), during frozen conditions. If work is to be completed under non-frozen conditions, equipment will be equipped with mushroom shoes.
- Use of equipment on highly saturated soil will be avoided, where possible.
- The Project will follow mitigation measures in the PPP to reduce ponding, erosion, and damage to permafrost.

- Borrow source floors will be sloped to reduce ponding of water.
- Excavations will be contoured prior to closure to reduce steep slopes.
- Project design will avoid ice-rich areas, where possible.
- Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW, where possible.
- If surface organic material must be removed for construction, it will be stockpiled and re-applied, where possible.
- Geotextile and embankment placement will be completed in the winter to limit disturbance to soils and permafrost.
- Travel of vehicles will be confined to existing infrastructure roads and trails as much as possible to avoid disturbing vegetated areas.
- If ice-rich permafrost is identified during excavation activities, suitable measures will be taken to protect permafrost and ground ice encountered during material extraction activities.
- Ice-rich soils or materials that are susceptible to physical erosion encountered during excavation will be covered to reduce permafrost degradation.
- Excavations and developed borrow sources will be visually monitored throughout the summer and fall to confirm there is no physical erosion resulting from the degradation of permafrost.
- Construction equipment will travel on designated winter roads or constructed embankment only.
- Undisturbed areas will be avoided until they are scheduled for clearing/stripping to limit unnecessary soil degradation and compaction.
- The embankment will be constructed predominantly using a “fill approach” with minimal disruption to the subgrade rather than a “cut and fill” approach; however, road cuts will be needed where grades at a steep valley approach can be reduced by cutting into the hill slope.
- Steep grades where subsidence may occur as a result of permafrost thaw will be avoided, where possible.
- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- Erosion and drainage patterns will be observed and documented per the ESCP.
- Runoff control methods will be used to protect permafrost soils, including diverting water entering the site, modifying slope surfaces, reducing slope gradients, controlling flow velocity, providing adequate or increased drainage, and diverting flows away from exposed soil areas for mitigating permafrost degradation.
- Culvert design will include requirements for bedding materials and geotextile to protect surrounding permafrost from thaw. Rip rap will be incorporated into culvert design to avoid erosion around each culvert.

- Modification to the location or number of drainage culverts will be determined in consultation with the Engineer, as based on observed site conditions.
- Grading of stream banks at approaches shall be limited, where possible.
- Accumulated snow may be dispersed (e.g., snow drifts flattened and/or plowed) to reduce potential long-term effects on permafrost. In areas where snow drifting becomes a reoccurring issue, strategies such as snow fencing will be considered to keep snow drifts off the road surface and away from drainage ditches.
- Disturbance of the active layer during construction and maintenance activities will be limited.

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the PPP and ESCP (Volume 5), potential effects due to erosion and sedimentation related to alteration of permafrost are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management (Section 16.8).

16.4.2.2.2 Mitigation of Dustfall

Dustfall associated with road construction and operation can result in the deposition of fine sediments in watercourses. The potential for dustfall to influence water and sediment quality from transportation infrastructure projects is well understood, and several well established and standard approaches will be used in the construction and operation of the Project to reduce effects associated with dustfall. The design and implementation of mitigation measures and BMPs associated with dustfall will be guided by (but not limited to) Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a).

In addition to erosion and sedimentation controls outlined in Section 16.4.2 and the ESCP (Volume 5) that will help control dustfall related to the clearing of vegetation and topsoil, mitigation measures specific to dustfall control include the following:

- A dust control program using water will be implemented during construction and operations.
- Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies. Dust suppression will follow the GNWT Guideline for Dust Suppression.
- Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces.
- Where possible, windrowed material will be mulched and spread over cleared areas within the project footprint to protect the soil and permafrost.

- Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials to reduce the amount of dustfall.
- The contractor will be encouraged to use passenger vehicles (e.g., van or bus) to move crews.

With the implementation of these mitigation measures and BMPs, and the procedures outlined in the ESCP (Volume 5), potential effects due to dustfall are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Water and sediment quality monitoring will be conducted as required to confirm effectiveness of the mitigation measures and to facilitate adaptive management.

16.4.2.2.3 Mitigation of Acid Rock Drainage and Metal Leaching (ARD/ML)

Changes to surface water and sediment quality may occur if project components (e.g., quarries, granular borrow sources, stockpiles, road base materials) have the potential for ARD/ML. Runoff and leachate from these components have the potential to enter watercourses and affect surface water and sediment quality.

The design and implementation of mitigation measures and BMPs associated with the development and use of borrow source and quarry materials for the Project will be guided by (but not limited to) the following resources:

- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- Northern Land Use Guidelines: Pits and Quarries (GNWT, 2015b)
- Mine Environmental Neutral Drainage (MEND) Prediction Manual (Price, 2009)

To prevent or reduce the potential for project-related ARD/ML, only material with low ARD and ML potential will be used for the Project. Generally, rock material sources proposed are anticipated to have low ARD potential due to their location within geological units dominated by carbonate and dolomitic rocks.

Sources to be used for the Project with neutralization potential ratio (NPR) between 1.0 and 3.0 that cannot reasonably be avoided will be further evaluated to identify if potential acid generation can be mitigated through measures such as site-specific planning, designated use of material, and water management. Consequently, only materials with low ARD/ML potential will be used for the development of the Project. Therefore, ARD/ML is not anticipated to be a potential source of project-related changes to water and sediment quality.

As described in the surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a), 11 prospective material sources were screened for ARD/ML potential (not a full ARD/ML assessment) and indicate that ARD/ML potential is likely to be low and is not expected to adversely affect water quality of the receiving watercourses (K'alo-Stantec, 2021). Therefore, potential effects on surface water and sediment quality associated with ARD/ML are anticipated to be negligible.

16.4.2.2.4 Mitigation of Nitrogen Loading Due to Use of Explosives

The use of ANFO explosives is anticipated for the development of quarries and highway materials. The undetonated nitrogen component of the explosives, AN, is highly water-soluble. The use of ANFO explosives may result in releases of nitrogen (which can be detected as nitrate, nitrite, and ammonia) from quarries and quarry materials to the aquatic environment.

Blasting-related nitrogen compounds can enter waterbodies through spillage (during the loading of blastholes or during transportation), by the movement of water through the blasthole, by the erosion of explosives from flowing water through the blasthole, and by leaching of undetonated explosive from the blast rubble and quarry materials.

- An ExMP will be developed and will include control measures to prevent or reduce the mobilization of nitrogen compounds to the aquatic environment.
- Storage of explosives will be controlled and runoff from storage areas will be contained.
- To the extent possible, blasting activities will be completed during winter months to avoid freshet runoff.
- Blast holes will be kept free of water, where possible, to avoid the incomplete combustion of ANFO.
- Explosives will be sealed and kept dry to prevent the incomplete combustion of ANFO.
- The handling and transport of explosives will be carried out by the supplier and blasting contractor under a licence to conduct such work and according to the requirements of applicable regulations including the *Explosives Act*, *Transport of Dangerous Goods Act*, and National Fire Code of Canada.

With the implementation of these mitigation measures and BMPs, as well as adherence to a project-specific ExMP, potential effects due to the use of explosives are anticipated to be negligible and not result in adverse or long-term changes to water and sediment quality. Therefore, blasting activities are not anticipated to result in adverse or long-term changes to water and sediment quality.

16.4.2.3 Residual Effects

In consideration of the scope and scale of project-related activities, effect pathways (Section 16.1.3), and mitigation measures (Section 16.4.2.2) relevant to surface water and sediment quality, project-related residual effects are not anticipated to result in adverse effects on aquatic life, wildlife, or drinking water quality for human consumption. The characterization of residual effects on surface water and sediment quality is further summarized.

The Project is anticipated to move measurable parameters in a neutral direction. This is because no measurable long-term trend in surface water and sediment quality parameters is anticipated relative to existing conditions.

With the implementation of well-established mitigation measures and management practices to reduce or eliminate effects associated with erosion and sedimentation, ARD/ML, and blasting, project activities are predicted to result in low-magnitude changes to surface water and sediment quality that generally remain within the variability of existing conditions.

Residual effects are not anticipated to extend beyond the LAA. Water that drains into the mainstem of the Mackenzie River (Deh Cho) from much smaller watercourses that intersect the PDA will undergo substantial mixing before being transported downstream in the Mackenzie River (Deh Cho) and beyond the LAA.

The timing of residual effects is anticipated to be influenced by seasonal changes. This is because erosion and sedimentation that could influence surface water and sediment quality (e.g., from the clearing of vegetation and topsoil, instream works, and dustfall) are anticipated to be negligible in the winter when surficial terrain and waterbodies are frozen and covered in snow.

The duration of residual effects is characterized as medium-term and limited to the construction phase of the Project. This is because the effect pathways relevant to potential changes in surface water and sediment quality are directly associated with the development of the Project (including the development of material sources) and will generally not persist into operations and maintenance. Exceptions during the operations and maintenance phase include culvert and bridge maintenance and the creation of fugitive dust by summer highway users. However, culvert and bridge maintenance (which will include relevant mitigations outlined Section 16.4.2.2) and fugitive dust (which will include the regular use of water for dust control) are not anticipated to result in measurable changes to surface water or sediment quality during the operations and maintenance of the highway.

The frequency of residual effects during the construction phase is anticipated to include multiple irregular events that occur at no set schedule. This is because construction activities that have the potential to influence surface water and sediment quality will occur at different times and places within the PDA as the development of the Project progresses.

Residual effects are anticipated to be reversible because changes in surface water and sediment quality will be influenced by construction activities that are finite. Land disturbances associated with the construction of the Project are well understood and will be managed to eliminate or reduce the potential for long-term effects that extend beyond the construction phase using best practices, mitigation measures, and site-specific reclamation programs (e.g., the facilitation of vegetation regrowth where necessary to prevent erosion).

16.4.3 Changes to Groundwater Quality

16.4.3.1 Effects Pathways

The effect pathways for changes to groundwater quality are associated with excavation, ground disturbance and permafrost degradation.

16.4.3.1.1 Excavation

Excavations, if they advance below the groundwater table in permafrost-free areas, will result in the flow of groundwater into the excavation that must be removed (pumped out). As a result, the excavation will become a local sink for groundwater flow and groundwater levels near the excavation will decline in a cone of depression centered on the excavation. Wetlands, streams, or lakes hydraulically connected to the groundwater system within the cone of depression area may begin to infiltrate to ground. The chemistry of surface water is generally different from the chemistry of groundwater, and infiltration (groundwater recharge) of surface water to the underlying groundwater system may change the chemistry of that system.

Important changes in groundwater chemistry from the introduction of surface water could include organic material and/or bacterial or viral organisms that are generally not present in groundwater. These additions would affect the quality of the groundwater use for potential groundwater users near the excavations.

16.4.3.1.2 Ground Disturbance

Ground disturbance activities such as site preparation of the ROW, access roads, and workspaces (Table 16.5) may alter the characteristics of the ground surface such that the rate that precipitation or melt water infiltrates to the groundwater system (recharge) changes. Meteoric water (i.e., snowmelt and precipitation) is generally lower in total dissolved solids and other chemical constituents than groundwater. As a result, increased recharge may dilute the concentrations of aqueous parameters present in groundwater.

16.4.3.1.3 Permafrost Degradation

Project activities that may affect groundwater through permafrost degradation may occur along the entire PDA, but effects are more likely to occur where permafrost is classified as extensive continuous (65% to 90% of the land area; i.e., primarily in the northern half of the PDA [K'alo-Stantec, 2023b]).

Excavations, ground disturbance, and the presence of the highway are effects pathways where there is the potential to cause degradation of permafrost, a change in groundwater flow, and an associated change in groundwater quality. Permafrost degradation may increase the hydraulic connection between supra- and-sub-permafrost components of the groundwater flow system (see Chapter 15, water quantity). This may cause a change in water quality in the downgradient component and a change in the water quality of downgradient surface water environments.

16.4.3.2 Mitigation

Design-based mitigation to reduce or eliminate adverse effects on groundwater quality are summarized in Table 16.6, organized according to the effect pathway each mitigation targets (i.e., excavation, ground disturbance, and permafrost degradation).

Additional detail on mitigation to limit the removal of vegetation and/or topsoil for road construction (i.e., ground disturbance) is provided in Chapter 18 (vegetation and wetlands).

Additional detail on mitigations to limit the degradation of permafrost are provided in Chapter 14 (terrain, soils, and permafrost).

16.4.3.3 Residual Effect

With the mitigation measures summarized in Table 16.6, the Project is likely to result in a change in groundwater quality (i.e., a residual effect) if groundwater is affected by excavation, ground disturbance, or permafrost degradation.

Potential residual effects on groundwater quality caused by unintended releases during an accident or malfunction are addressed in additional detail in Chapter 25 (accidents and malfunctions). As a result, these residual effects are not addressed further in the groundwater and quality assessment.

16.4.3.3.1 Excavation

Residual effects on groundwater quality caused by excavations are expected to be no measurable change to low in magnitude based on the following rationale:

- A change in groundwater quality from groundwater level drawdown caused by an excavation implies infiltration from a water source with different chemistry (e.g., a stream or lake).
- Infiltration from lakes or streams within a cone of depression will only occur in sufficient amount to change groundwater quality from a subset of these features; those with a strong hydraulic connection to the underlying groundwater system. Some lakes and streams will have only a weak hydraulic connection to the underlying groundwater system.
- There are no identified groundwater users within the PDA, LAA, or RAA that would be affected by the addition of organic matter and/or bacterial or viral organisms (hydrogeology TDR, Appendix 15B; K'alo-Stantec, 2022b).

Residual effects associated with excavations are not expected to be sensitive to timing since borrow source, quarry, and road cut excavations will operate year-round and result in permanent changes in topography. As a result, the likelihood, sensitivity, duration, frequency, and reversibility of associated residual effects are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

16.4.3.3.2 Ground Disturbance

Residual effects on groundwater quality caused by ground disturbance are expected to be no measurable change to low in magnitude and limited to the PDA.

Ground disturbance that can be remediated (e.g., temporary camp locations) are expected to be possible, not sensitive, medium-term (e.g., during the construction phase), continuous, and reversible. Effects related to ground disturbance caused by permanent changes, such as the presence of the highway, are expected to be possible, not sensitive, long-term, continuous, and irreversible.

16.4.3.3.3 Permafrost Degradation

Residual effects on groundwater quality caused by permafrost degradation are subject to the same characterizations as those of the groundwater quantity effect pathway (Section 15.4.4). As a result, the magnitude of the groundwater quality change associated with permafrost degradation for the Project is anticipated to be no measurable change to moderate, and the geographic extent is expected to be limited to the PDA or LAA. The likelihood, sensitivity, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible.

16.4.4 Summary of Residual Effects

Residual effects resulting from the Project on changes to surface water and sediment quality will occur during the construction of the Project. These changes to surface water and sediment quality are predicted to be neutral in direction (i.e., no measurable long-term trend in surface water and sediment quality parameters relative to existing conditions) and low in magnitude; not extend beyond the LAA; and be medium-term, limited to the construction phase, and not persist into operations.

Effects will be influenced by seasonal changes in ice and snow cover. Effects will include multiple irregular events associated with construction activities and are likely reversible due to the finite duration of the construction phase of the Project (Table 16.7).

Table 16.7 Residual Effects on Water and Sediment Quality

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Changes to Surface Water and Sediment Quality	C/O	N	P	L	LAA	S	MT	IR	R
Changes to Groundwater Quality	C/O	A	P	NMC[1], L[2], M[3]	PDA[1,3] LAA[2]	NS	LT	C	I

KEY

*See Table 16.3 for detailed definitions

Project Phase:
C: Construction
O: Operations and Maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
S: Sensitive
NS: Not Sensitive

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

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

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Applies to the ground disturbance effects pathway (Section 16.4.3.1)
2 Applies to the excavation effects pathway (Section 16.4.3.1)
3 Applies to the permafrost degradation effect pathway (Section 16.4.3.1)

Residual effects resulting from the Project on groundwater quality after mitigation is implemented will occur and are predicted to be adverse in direction. The magnitude and geographic extent of residual effects depend on the pathway mechanism that causes the effect (Section 16.4.3) as follows:

- Residual effects on groundwater quality from excavations are expected to have magnitudes that range from no measurable change to low and are geographically limited to the LAA (Table 16.7, Section 16.4.3).
- Residual effects on water and sediment quality from ground disturbance are expected to be no measurable change to low in magnitude, short-term and reversible (where remediation occurs) or long-term and irreversible (where remediation won't occur), and geographically limited to the PDA (Table 16.7, Section 16.4.3).
- Residual effects on water and sediment quality from permafrost degradation are expected to be no measurable change to moderate in magnitude, continuous and irreversible, and geographically limited to the LAA (Table 16.7, Section 16.4.3).

Residual effects on water and sediment quality are summarized in Table 16.7. With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirements related to watershed management and drinking water, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for protection of water and sediment quality will respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K'ąąlǫ Tué (Willow Lake Wetlands) SMZ, and Deh Cho (Mackenzie River) SMZ as areas with important ecological habitats. Mitigation measures to protect water quality take into account the Project's location within Tulita's community drinking water source catchment.

16.5 Assessment of Cumulative Effects on Water and Sediment Quality

16.5.1 Residual Effects Likely to Interact Cumulatively

Existing environmental conditions reflect cumulative effects on the environment from past and present projects and physical activities. Past and present projects and physical activities have influenced the existing conditions for surface water and sediment quality (Section 16.2). The assessment of cumulative effects focuses on the same residual effect as previously assessed (i.e., a change in surface water and sediment quality).

Table 16.8 identifies other past, present, and reasonably foreseeable projects and physical activities within the RAA with effects that have the potential to interact cumulatively with residual effects on water and sediment quality from the Project.

Where adverse residual effects from the Project act cumulatively with those from other past, present, and reasonably foreseeable projects and physical activities, a cumulative effects assessment is undertaken to determine their significance.

As described in Section 16.4.4, residual effects on this VC are not anticipated to extend beyond the LAA. Therefore, other projects within the RAA that are not anticipated to extend potential effects on the LAA are excluded as potential sources of cumulative effects. Excluded projects are as follows:

- Geotechnical activities are excluded from potential cumulative effects on surface water and sediment quality because the only two identified projects of this type within the RAA are relatively small in scale and related to the development of a visitor centre (Parks Canada) and a health centre (GNWT Department of Infrastructure [INF]) in Tulita. According to the Land Use Permits issued by the Sahtu Land and Water Board, land disturbances related to these projects are limited to the development of groundwater monitoring wells and, in the case of the visitor centre, minor compaction of grass. In consideration of the scope, environmental footprint, and mitigation measures associated with these geotechnical investigations, cumulative effects on surface water and sediment in the project LAA are not anticipated.
- Mining and exploration activities are excluded from potential cumulative effects because the only foreseeable mining-related project within the RAA is a proposed diamond drilling and exploration operation (Devonian Metals Ltd.) at the existing Wrigley Zinc property, approximately 12 to 13 km upstream of the southern extent of the LAA. According to a November 2020 Land Use Permit Application with the MVLWB, activities of this project will be limited to geophysical, geotechnical, and geological surveying. These activities are not expected to result in measurable changes to downstream surface water or sediment quality in the project LAA. In consideration of the scope, environmental footprint, and mitigation measures associated with this exploration activity, cumulative effects on surface water and sediment in the project LAA are not anticipated.

Table 16.8 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effect	
	Changes to Surface Water and Sediment Quality	**Changes to Groundwater Quality**
Past and Present Physical Activities and Resource Use (Base Case)		
Geotechnical	–	–
Oil, Gas & Seismic*		
Access roads, staging areas and seismic lines only (drilling locations are not within the RAA)	✓	–
Infrastructure		
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effect	
	Changes to Surface Water and Sediment Quality	**Changes to Groundwater Quality**
Canyon Creek All Season Access Road	✓	✓
Norman Wells Pipeline	✓	✓
Mackenzie Valley Fibre Link	✓	✓
Mackenzie Highway #1 Operations and Maintenance	✓	–
Prohibition Creek Access Road	✓	✓
Quarries and Borrow Sources		
HRN Quarry	✓	✓
Mining & Exploration	–	–
Municipal Operations, including water, waste, power, and community development		
Wrigley Municipal Activities	✓	✓
Tulita Municipal Activities	✓	✓
Norman Wells Municipal Activities	✓	✓
Project-Related Physical Activities (Project Case)		
Mackenzie Valley Highway Project	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)		
Quarries		
Dhu-1 Quarry	✓	✓
Infrastructure		
Great Bear River Bridge	✓	✓
Oil and Gas		
Enbridge Maintenance Camp	✓	–

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as: production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

16.5.2 Changes to Surface Water and Sediment Quality

16.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on surface water and sediment quality arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project (Sections 16.4.2 and 16.4.3). These effect pathways include potential erosion and sedimentation resulting from projects and activities involving land disturbances, such as the removal of vegetation and/or topsoil, instream works, alteration of permafrost, and dustfall. Other projects involving the development of quarries with explosives also have the potential to interact cumulatively with the Project.

A detailed list of projects and activities within the RAA that have the potential to interact cumulatively with the Project is provided in Section 4.6.1, Table 4.2.

16.5.2.2 Mitigation for Cumulative Effects

Mitigation measures to reduce or eliminate potential cumulative effects on surface water and sediment quality are the same as those presented in Table 16.6 and Sections 16.4.2 and 16.4.3.

16.5.2.3 Cumulative Effects

Other past, present, or foreseeable projects and activities in the RAA have the potential to result in changes to surface water and sediment quality via the same effects pathways described in Sections 16.4.2 and 16.4.3. These effect pathways may interact cumulatively with project-related changes to surface water and sediment quality.

In consideration of the scope, scale, and proximity of other past, present, or foreseeable projects and activities in the RAA, cumulative effects on surface water and sediment quality are anticipated to move measurable parameters in a direction that is neutral. This is because cumulative effects are anticipated to result in no measurable long-term trend in surface water and quality.

With the implementation of well-established mitigation measures and management practices to reduce or eliminate effects associated with erosion and sedimentation, ARD/ML, and blasting, cumulative effects are predicted to have no measurable change relative to project-related residual effects. Therefore, cumulative effects on surface water and sediment quality are characterized the same as residual effects (i.e., low magnitude).

Cumulative effects, by definition, can only occur at the same time and place as project-related residual effects. Therefore, the geographic extent (LAA), timing (seasonal), duration (medium-term), and frequency (multiple irregular events) of cumulative effects are the same as previously characterized for residual effects (Section 16.4.4).

Cumulative effects are anticipated to be reversible because changes in surface water and sediment quality due to project-related residual effects will be influenced by construction activities that are finite. Project-related effect pathways relevant to surface water and sediment quality are directly associated with the development of the Project and will not persist into operation. Land disturbances associated with the construction of the Project are well understood and will be managed to eliminate or reduce the potential for long-term effects that extend beyond the construction phase using best practices, mitigation measures, and site-specific reclamation programs (e.g., the facilitation of vegetation regrowth where necessary to prevent erosion).

16.5.3 Changes to Groundwater Quality

16.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on groundwater quality arising from past, present, and reasonably foreseeable future projects and physical activities include the same effects pathways as those resulting from the Project (Section 16.4.2.1). These include excavation, ground disturbance, and permafrost degradation. The pathway mechanisms through which cumulative effects on groundwater quality occur are the same mechanisms as described in Table 16.2 and Section 16.1.3.

16.5.3.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects on groundwater quality from excavation, ground disturbance, and permafrost degradation pathways include those presented in Table 16.6.

No additional mitigation measures are recommended to reduce or eliminate cumulative effects on groundwater quality beyond those measures presented in Section 16.4.2.2 and Table 16.6. It is assumed that other projects and activities would apply similar mitigation measures to those presented in Table 16.6.

16.5.3.3 Cumulative Effects

Residual effects from the Project to groundwater quality are not anticipated to interact with the effects of other projects in the RAA and therefore are not expected to contribute to cumulative effects within the RAA.

Municipal operations include effluent discharge to surface water, which is a potential effects pathway to groundwater quality. However, if these projects operate within guidelines under the applicable approvals required for their operation, it is anticipated that the residual effects on a change in groundwater quality will be no measurable change to low magnitude change.

The residual effects of other past or present projects (Table 16.8) on baseline groundwater quality conditions with the Project LAA are difficult to determine. Existing groundwater quality data (groundwater chemistry) were lacking at a level of detail required to characterize baseline conditions beyond general statements on regional and local groundwater chemistry (Section 16.2.3).

Reasonably foreseeable projects and developments include the Dhu-1 Quarry, the Great Bear River Bridge, and the Prohibition Creek Access Road. The projects are not expected to act cumulatively to affect groundwater flow, which is the pathway through which these projects may cumulatively affect groundwater quality (Section 16.1.3). Therefore, these projects are not expected to cumulatively affect groundwater quality.

The magnitude of cumulative effects is expected to range from no measurable change to moderate within the LAA, consistent with the assessment completed for residual effects. Likelihood, sensitivity, timing, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

16.5.4 Summary of Cumulative Effects

Cumulative effects on surface water and sediment quality are characterized as 'neutral' in direction and low magnitude. The geographic extent (LAA), timing (seasonal), duration (medium-term), and frequency (multiple irregular events) of cumulative effects are the same as previously characterized for residual effects (Sections 16.4.2 and 16.4.3). Cumulative effects are anticipated to be reversible.

Cumulative effects on groundwater quality within the LAA from the Project and past, present, and reasonably foreseeable future projects and activities are predicted to be adverse in direction and range from no measurable change to low in magnitude. Cumulative effects will persist for the long term due to the long operational period and permanent changes to the environment imposed by many of these projects. For many of these project and activities, cumulative effects will likely be irreversible.

Table 16.9 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Changes to Surface Water and Sediment quality	N	U	NMC	LAA	S	MT	IR	R
Contribution from the Project to the residual cumulative effect	The Project is not anticipated to contribute to measurable cumulative effects to surface water and sediment quality in the RAA.							
Changes to Groundwater Quality	A	P	NMC[1], L[2], M[3]	PDA[1,3], LAA[2]	NS	LT	C	I
Contribution from the Project to the residual cumulative effect	The Project is not anticipate to contribute to measurable cumulative effects to changes to groundwater quality in the RAA.							

KEY

*See Table 16.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Timing
S: Sensitive
NS: Not Sensitive

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

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

Reversibility:
R: Reversible
I: Irreversible

Notes:

1 Applies to the ground disturbance effects pathway (Section 16.4.3.1)
2 Applies to the excavation effects pathway (Section 16.4.3.1)
3 Applies to the permafrost degradation effect pathway (Section 16.4.3.1)

16.6 Determination of Significance

16.6.1 Significance of Residual Effects

Residual effects of the Project include low magnitude, reversible changes to surface water and sediment quality that are geographically limited to the LAA (Table 16.7).

Based on these characterizations, as well as the significance definition in Section 16.1.6, the residual effects of the Project on surface water and sediment quality are predicted to be not significant.

Based on the characterizations of residual effects outlined in Table 16.7 and summarized in Section 16.4.4, and the significance definition in Section 16.1.6, residual effects of the Project on groundwater quality are predicted to be not significant.

16.6.2 Significance of Cumulative Effects

Cumulative residual effects of the Project include low magnitude, reversible changes to water and sediment quality and groundwater quality that are geographically limited to the LAA (Table 16.9).

Based on these characterizations, as well as the significance definition in Section 16.1.6, these cumulative residual effects on water and sediment quality are predicted to be not significant.

Cumulative residual effects on groundwater quality range from no measurable change to moderate effects geographically limited to the LAA. Likelihood, sensitivity, timing, duration, frequency, and reversibility of cumulative residual effects on groundwater quality are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively. Based on these characterizations, as well as the significance definition in Section 16.1.6, cumulative effects on groundwater quality are predicted to be not significant.

16.6.3 Project Contribution to Cumulative Effects

Within the LAA, contribution from the Project to the cumulative residual effect cannot be quantified because quantified magnitudes of change in water and sediment quality due to the Project and other projects are not known. However, such a quantified relative contribution within the LAA will not be relevant if the magnitude of residual effects is low.

Outside the LAA (within the RAA), the Project does not contribute to cumulative residual effects.

The contribution of residual effects of the Project to cumulative effects on groundwater quality within the LAA are expected to range from no measurable change to moderate in magnitude, consistent with the assessment of residual effects (Section 15.4.4). Likelihood, sensitivity, timing, duration, frequency, and reversibility are expected to be possible, not sensitive, long-term, continuous, and irreversible, respectively.

The contribution of residual effects of the Project to cumulative effects within the RAA are predicted to be no measurable change since residual effects of the Project are anticipated to be limited to the LAA.

16.7 Prediction Confidence

For surface water and sediment quality, with the successful implementation of mitigation measures, the prediction confidence is rated 'high.'

Confidence in the prediction of project-related effects relies heavily on the mitigation measures described in Sections 16.4.2 and 16.4.3. These mitigations are established, well understood, and comprise best management standards and practices. However, without the effective implementation of suitable mitigation measures to reduce or eliminate changes to surface water and sediment quality due to erosion and sedimentation, fugitive dust, ARD/ML, and explosives-related nitrogen loading, this assessment would result in higher-magnitude effects and low prediction confidence.

For groundwater quality, confidence in the assessment of potential effects is increased by considering that the Project does not require excavations that extend far below the groundwater table and will not discharge effluent to ground or the surface water environment. As a result, many common pathways to significant residual changes in groundwater quality are not present.

Confidence in the assessment of potential effects on groundwater quality is reduced based on the lack of existing conditions groundwater quality data from which to characterize potential residual effects. Additionally, the long, linear disturbance nature of the project results in the PDA crossing a variety of conceptual groundwater flow systems, the variability of which limits the potential to describe or define these systems in detail.

In summary, the prediction confidence in assessing potential project effects on groundwater quality is low to moderate based on this discussion and on professional judgement.

16.7.1 Assumptions

Results of this effects assessment are dependent on effective implementation of mitigation measures described in Sections 16.4.2 and 16.4.3. The characterizations of residual effects (Section 16.4) and cumulative effects (Section 16.5) were developed under the assumption that mitigation measures and BMPs will adhere to the procedures and objectives described by the following guidance:

- The GNWT Department of Transportation – Erosion and Sediment Control Manual (GNWT, 2013a)
- Measures to Protect Fish and Fish Habitat (DFO, 2022a)
- Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions (TAC, 2010)

- Guideline for Dust Suppression (GNWT, 2013b)
- Northern Land Use Guidelines: Roads and Trails (GNWT, 2015a)
- Northern Land Use Guidelines: Pits and Quarries (GNWT, 2015b)
- Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky, 1998)

In addition to the assumption that appropriate and effective mitigation measures will be successfully implemented to reduce (or in some cases prevent) potential adverse effects on surface water and sediment quality, it is assumed that future assessments of ARD/ML potential at each candidate material source will be consistent with preliminary screening results that indicate ARD/ML potential is likely to be low (K'alo-Stantec, 2021). For this reason, it is assumed that surface water and sediment quality of the receiving watercourses will not be adversely affected by run-off in contact with locally sourced rock materials from selected locations within the RAA.

16.7.2 Gaps and Uncertainties

Data gaps for existing conditions were identified in the assessment. These data gaps include information requested in the DAR Terms of Reference (ToR; MVEIRB, 2015 [PR#66]) and are as follows:

- A description of sediment load (suspended and bed load) for each major drainage or major watercourse (ToR Section 5.1.3; MVEIRB, 2015). Historical and recently reported concentrations of TSS were summarized for three locations in the Mackenzie River (Deh Cho) (i.e., Wrigley, Tulita, and Norman Wells) in the surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a). Suspended sediments and/or sediment bed loads were not identified for each watercourse that may be affected by the Project, but no further bridge construction work is planned at major drainages. Sites within the RAA and LAA for which historical TSS data are available are summarized in the surface water and sediment quality TDR (Appendix 16A; K'alo-Stantec, 2022a). Where applicable, pre-construction baseline conditions for sediment load should be established nearer to the time of construction.
- The identification of existing water quality and variations for each area of water use that may be affected by the highway (ToR Section 5.1.3; MVEIRB, 2015). Except for TSS as described, information on the seasonal and/or annual variability of surface water and sediment quality for watercourses that may be affected by project-related activities (i.e., particularly smaller watercourses that intersect the PDA) was limited and not summarized. However, regional water quality has limited value for predicting changes to water quality from construction. Construction monitoring will be used to monitor effectiveness of mitigation measures applicable to water quality at the time when the activity is taking place.

- Detailed information about traditional water-use locations that may be affected by the Project was not identified across the whole LAA. Protection of water quality in the Mackenzie Valley, and the Tulita drinking water catchment area is of high cultural importance. Some watercourses in the LAA are traditionally used as sources of sustenance, including drinking water and for harvesting of fish. Additional information on specific water uses and locations, if available, will be incorporated in the design of site-specific monitoring programs that reflect the intended use of a watercourse.
- Existing groundwater quality data (i.e., groundwater chemistry) were not available to characterize baseline conditions (gap) such that neither quantitative nor qualitative definitions of residual effects characterizations (Table 16.3) for groundwater quality could be confidently developed (uncertainty).

As explained in Sections 16.4.2 and 16.4.3, mitigation measures will be implemented to reduce effects on surface water and sediment quality from erosion and sedimentation, ARD/ML, and explosives-related nitrogen loading. As a result, collection of additional site-specific water and sediment quality data to characterize existing conditions is not anticipated for the DAR. Additional water quality data, however, will be required for pre-construction and compliance monitoring and to facilitate adaptive management (Section 16.8).

Uncertainties of this assessment include those associated with the assumptions (Section 16.7.1) and data gaps as described. Briefly, these uncertainties include the following:

- Mitigation measures to reduce (or in some cases prevent) measurable changes in surface water and sediment quality are established best practices and generally effective. Although the listed mitigations are anticipated to reduce or eliminate the extent of measurable changes to water and sediment quality, they do not guarantee no measurable changes (i.e., no effects).
- The ARD/ML potential of locally sourced rock materials. Preliminary screening results indicate low ARD/ML potential (K'alo-Stantec, 2021); however, additional samples will be collected and analyzed for ARD/ML potential during the ongoing selection and characterization of potential material sources.
- Existing surface water quality (including seasonal and long-term variability) and sediment quality within watercourses that intersect the PDA and which may be affected by the Project
- Existing water uses and locations in watercourses within the RAA
- The degree to which permafrost degradation will contribute to changes in surface water and sediment quality due to erosion and sedimentation
- The degree to which ongoing operation of the Project will contribute to changes in surface water and sediment quality in the future

16.8 Follow-up and Monitoring

Surface water quality and, if needed, sediment quality data will be collected as part of construction and compliance monitoring programs at water course crossings and in water bodies adjacent to borrow sources and quarries.

As described in Section 23.4, monitoring sites will include nearfield locations downstream of watercourse crossings, and in water bodies adjacent to borrow sources and quarries. Monitoring will include inspection of construction practices, mitigation measures employed and the functionality of those mitigation measures. Monitoring will also include certain water quality parameters during instream works. Due to a lack of baseline water and sediment quality monitoring in some watercourses potentially affected by the Project, suitable upstream reference sites will be sampled to help characterize pre-construction reference conditions, where needed to help identify potential project-related effects.

In-situ physical parameters (e.g., turbidity, pH, dissolved oxygen, and temperature) in surface water will be routinely monitored during construction at upstream and downstream sites. If project-related effects associated with physical parameters are observed at locations identified to be important for drinking water and fish harvesting, additional parameters (e.g., TSS, total and dissolved metals, nutrients) relevant to specific water uses and guidelines will be monitored in water and sediment.

In specific cases where historical water/sediment quality data may be appropriate to investigate potential project-related effects, the available surface water and sediment quality data identified for sites within the RAA and LAA (Appendix 16A; K'alo-Stantec, 2022a) may be used to support future project-specific monitoring programs.

Ongoing engagement with Indigenous Governments, Indigenous Organizations and other affected parties will also help inform the design of future monitoring programs to account for specific water uses and water use locations within the RAA and LAA.

To confirm the preliminary conclusions of the ARD/ML survey (K'alo-Stantec, 2021), additional samples of potential quarry material and other material to be disturbed (such as road cuts) will be collected and analyzed for ARD/ML potential during the selection and characterization of potential material sources and evaluation of road cuts.

Management plans will be developed to assess and mitigate potential residual effects of excavation on groundwater quality for each borrow source and quarry site as required by the GNWT (2015b). These plans will provide an adaptive management framework that outlines required actions should groundwater withdrawal and subsequent discharge begin to affect groundwater quality or other VCs.

Information pertaining to compliance and effects monitoring is provided in Chapter 23 (compliance and effects monitoring). Briefly, the goal of compliance and effects monitoring is to verify compliance with conditions of regulatory authorizations and other legal requirements such as conditions of land use permits, water licences and quarry permits, environmental criteria (e.g., water quality, air emissions), and codes of practice. In addition, compliance and effects monitoring also confirm the predictions made in the environmental assessment, confirm mitigation measures are working as intended to reduce effects, and inform changes that may be required to mitigations or monitoring as part of an adaptive management approach.

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17.0 ASSESSMENT OF POTENTIAL EFFECTS ON FISH AND FISH HABITAT

Fish and Fish Habitat was selected as a valued component (VC) because of its importance in supporting aquatic life, wildlife, human health, and community well-being. Changes in fish and fish habitat may adversely affect the productivity and sustainability of fisheries, which in turn may affect local community fisheries. Fish and fish habitat in the Sahtu and Dehcho regions is of high cultural importance to Indigenous Governments, Indigenous Organizations and other affected parties. Larger watercourses are traditionally used for harvesting fish, while smaller watercourses may provide prey and nutrients to fisheries.

The Mackenzie Valley Highway Project (the Project) has the potential to affect fish and fish habitat. Waterbodies that may be affected are those that are crossed by the Project and near to the Project. Project-specific components that could interact with fish and fish habitat include construction of new watercourse crossings (culverts), riparian clearing, construction camps, quarries, water withdrawal, and highway operation and maintenance activities. This assessment does not include effects of existing crossing structures, such as bridges, except for potential maintenance of these crossings during highway operation.

The assessment of potential effects on fish and fish habitat concludes that with the application of mitigation measures, residual effects resulting from the Project on fish and fish habitat will be adverse. Residual effects and cumulative effects due to changes in habitat are not expected to negatively affect the productivity and sustainability of fish populations crossed by the Project and near to the Project, and therefore are predicted to be not significant. Applying a precautionary approach to address uncertainty, the assessment has identified the potential for increased fishing pressure to adversely affect large-bodied fish populations leading to a potential significant effect.

17.1 Scope of Assessment

17.1.1 Regulatory and Policy Setting

The assessment of potential effects on fish and fish habitat is guided by the project Terms of Reference (ToR; Mackenzie Valley Environmental Impact Review Board [MVEIRB], 2015 [Public Registry {PR}#66]), federal legislation, and the Sahtu Land Use Plan (SLUP).

17.1.1.1 *Fisheries Act*

The *Fisheries Act* provides for the protection of fish and their habitat (including benthic invertebrates). The *Fisheries Act* prohibits causing harmful alteration, disruption, or destruction (HADD) of fish habitat (section 35), death of fish by means other than fishing (section 34.4[1]), and the introduction of a deleterious substance (section 36). The Act also includes provision for flow and passage (section 34.3) and a framework for regulatory decision-making (section 34.1).

The *Fisheries Act* requires that projects avoid causing HADD of fish and fish habitat, unless authorized by the Minister of Fisheries and Oceans Canada (DFO). Projects with the potential to obstruct fish passage, modify flow, or result in entrapment of fish may also qualify as causing HADD to fish. Where a non-compliance of the *Fisheries Act* cannot be avoided or mitigated, an Authorization under paragraph 35(2)(b) of the *Fisheries Act* is required. The Fisheries Protection Program, maintained by DFO and its collaborative partners, is responsible for the review of projects to determine if a non-compliance of the *Fisheries Act* is likely to occur.

17.1.1.2 *Species at Risk Act*

The federal *Species at Risk Act* (SARA) provides protection for species at risk (SAR) in Canada. The legislation provides a framework to facilitate recovery of species listed as threatened, endangered, or extirpated, and to prevent species listed as special concern from becoming threatened or endangered. Species at risk and their habitats are protected under SARA, which prohibits: (1) the killing, harming, or harassing of endangered or threatened SAR (sections 32 and 36); and (2) the destruction of critical habitat of an endangered or threatened SAR (sections 58, 60, and 61).

17.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the SLUP applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of fish and fish habitat in CR#7:

> *"1) Land use activities must be designed using the most current information for identified species of interest and species at risk as obtained from the Government of the Northwest Territories Department of Environment and Climate Change Canada (GNWT-ECC), Environment and Climate Change Canada's Canadian Wildlife Service, DFO, Parks Canada Agency, the Sahtú Renewable Resources Board (SRRB) and the local Renewable Resources Councils (RRC) .*
>
> *2) Impacts to wildlife, their habitat and migration patterns, and important community harvesting areas must be prevented or mitigated to the extent possible."*
>
> *"b) In addition, DFO has established in-water construction timing windows for the protection of fish and fish habitat. These are updated from time to time and are available at* https://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/index-eng.html*. During these periods, no in-water work or shoreline work is allowed except under site- or project-specific review and with the implementation of protective measures."* (SLUPB, 2023)

Conformity requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge.".* Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) Special Management Zone (SMZ) (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

17.1.1.4 Other Relevant Guidance

Federal and territorial guidance documents most pertinent to fish and fish habitat are:

- DFO (2013): Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada
- DFO (2010): Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut
- DFO Codes of Practice as applicable at the time activities are undertaken (available at: Codes of practice (dfo-mpo.gc.ca))

17.1.2 Influence of Engagement

The GNWT has engaged with Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapters 2 (Consultation and Engagement), 3 (Traditional Knowledge), and 11 (culture and traditional land use) of this Developer's Assessment Report (DAR). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to fish and fish habitat. This feedback has been considered and summarized in Table 17.1 and has been integrated into the assessment of potential effects on fish and fish habitat that follows.

Table 17.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils identified fish species of cultural importance near the Project.	Auld and Kershaw, 2005; IMG-Golder Corporation, 2006; Norman Wells Renewable Resource Council (NWRRC), 2023; SRRB, 2021b; SLUPB, 2022	The GNWT has reviewed and considered the species of importance and important habitats identified by Indigenous Governments, Indigenous Organizations, and other affected parties. The GNWT has considered this information in the selection of water sources to be considered for the Project. For example, owing to concerns raised, Trout Lake near Bear Rock (Petınıʔah) has been removed as a water source.	For information about fish species of cultural importance and important fish habitat, see Section 17.2.2 (Table 17.4 and Table 17.6). See also Section 11.3.3.7 for additional information about important harvesting areas and harvested species.
Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils identified important fish habitat, and fishing locations near the Project.	5658 NWT Ltd. and GNWT, 2011 (PR#16); Dessau, 2012 (PR#13); EBA, 2006; Golder, 2015; IMG-Golder Corporation, 2006; NWRRC, 2023; Tulita Renewable Resources Council (TRRC), 2019; TRRC, 2022; SLUPB, 2013		
Community engagement participants reported that all of the creeks being crossed by the current Mackenzie Valley Winter Road are fish-bearing. They shared that the fish in the creeks are small.	August 2021 Engagement; November to December 2022 Engagement; November 2022 to February 2023 Engagement	The GNWT has identified mitigation measures to reduce the effects of the Project on fish and fish habitat. A Fish and Fish Habitat Protection Plan (FFHPP) will be developed and implemented. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT is open to and interested in discussions with community members on how best to integrate community-based monitoring into project mitigation.	For mitigation measures to reduce effects of the Project on fish and fish habitat, see Table 17.8 See also: Section 17.4.2 (Change in Fish Habitat) Section 17.4.3 (Change in Fish Health) Section 17.4.4 (Change in Water Quality) Section 17.5 (Residual Effects) Section 17.6 (Assessment of Cumulative Effects on Fish and Fish Habitat) Volume 5 for management plans.
Elders and land users in the Sahtu Region expressed concern about potential project effects on the Wrigley (Pehdzéh Kį N'deh) area,[1] which may affect the health of the region's fish. Specific concerns included project effects on fish habitat; project effects on spawning and fish abundance due to direct effects from development and industry; and indirect effects as a result of climate change.	SRRB, 2021; Golder, 2015		

Comment	Source	GNWT Response	Where Addressed
Community engagement participants reported that erosion and sedimentation are changing the water, which is affecting fish, including fish migration; participants reported that Arctic grayling are declining because there is a lack of silt fencing. Effects from climate change (temperature change) and seismic activity affecting fish and fish habitat were also identified as concerns.	November to December 2022 Engagement	A project-specific Erosion and Sedimentation Control Plan (ESCP) will be developed and implemented. Seismic activity is not part of the Project and there are no past, present or reasonably foreseeable seismic activities that will interact with the residual effects of the Project. There is noted uncertainty in the assessment of effects on fish and fish habitat as discussed in Section 17.8.2	Section 17.4.4.1 (Change in Water Quality: Increased Sedimentation) Section 17.6 (Assessment of Cumulative Effects on Fish and Fish Habitat Table 17.10) Section 17.8.2 (Gaps and Uncertainties)
Community engagement participants expressed concern that vibration from large truck loads crossing creeks may affect fish migration at culverts. Participants reported that small fish have been injured because of the bolts used in the culverts.	April to July 2022 Engagement; November to December 2022 Engagement	Vibrations from vehicles crossing watercourses may cause a short-term (seconds) startle response due to low anticipated volumes of vehicle traffic during the project operation no residual effect on fish health is anticipated including fish migration. Culverts will be designed and constructed to maintain water flow and fish passage. Culverts will be periodically inspected to determine if they are functioning as per design (e.g., allow fish passage) and for evidence of erosion and sedimentation. If a barrier to fish passage or erosion and sedimentation issues are observed corrective actions would be implemented to correct the problem.	Section 17.4.2 (Change in Fish Habitat) Section 17.4.3 (Change in Fish Health)

Note:

[1] Pehdzéh Kį N'deh area was not identified or disclosed in the report

17.1.3 Potential Effects, Pathways and Measurable Parameters

The Project may cause changes to fish and fish habitat and may also result in changes in the health of fish. Fish habitat, as defined in Section 2(1) of the *Fisheries Act*, means all waters frequented by fish and any other areas upon which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply, and migration areas. Fish health for the purpose of this assessment means the physical condition of a fish which contributes to its growth and reproduction. Potential effects on fish and fish habitat are measurable changes, such as area of altered or lost habitat, barriers to fish passage, or increases in sediment that exceed guidelines (e.g., Canadian Council of Ministers of the Environment [CCME] Guidelines for the Protection of Aquatic Life).

Changes to fish and fish habitat may occur through the placement of culverts and rip rap in watercourses to be crossed by the Project and changes to riparian areas. Fish habitat can be affected through barriers to fish passage which may prevent fish accessing habitat to perform life history functions such as spawning and rearing, and increased fishing pressure due to increased access during operations and maintenance of the Project. Changes to water quality affecting fish health can occur due to erosion and sedimentation during construction or operation of the Project, or through accidental spills releasing deleterious substances into the water column (see Chapter 25, accidents and malfunctions).

Few studies on the effects of noise on fish from vehicle traffic have been conducted and mainly in areas near urban centers with high volumes of vehicular traffic over sustained periods of time, such as rush hours (Holt and Johnston 2015; Crovo et al. 2015). Vehicle traffic during operation of the Project is anticipated to be low at approximately 50 vehicles per day (see Section 5.2.2). Effects of noise on fish during operation of the Project from vehicular noise are anticipated to be limited to startle responses lasting seconds, after which fish would resume their normal behaviour, and would not impede fish migration. The effect on fish from noise behaviour is not assessed further.

Table 17.2 summarizes the potential effects of the Project on fish and fish habitat, the pathways in which the effects may occur, and measurable parameters used to monitor and assess the magnitude, geographic extent, and duration of effects.

Table 17.2 Potential Effects, Effects Pathways and Measurable Parameters for Fish and Fish Habitat

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in fish habitat	• Direct loss or alteration of habitat from vegetation clearing and trimming of riparian area along the highway right-of-way (ROW). • Direct loss or alteration of fish habitat from the placement of structures (e.g., culverts, rip rap) below the ordinary high water mark (OHWM). • Barriers to fish passage due to poor culvert placement or increased stream velocity may prevent fish from accessing preferred habitat. • Winter water withdrawal from lakes can reduce available overwintering habitat and/or cause reductions in littoral zone. • Winter water withdrawal from watercourses can reduce available overwintering habitat or impede fish passage.	• Area (hectares [ha]) of riparian habitat lost or altered. • Area (ha) of fish habitat below the OHWM altered or lost. • Flow velocity (metres per second [m/s]) in culvert to meet fish passage requirements for fish species present following Di Rocco and Gervais (2023) • Water withdrawn compared to available under-ice lake volume (cubic metres [m^3]). • Winter water withdrawal from watercourses will be based on instantaneous flow (m^3/s) and mean annual discharge (MAD)(m^3/s) compared to DFO's Framework to Support Flow Requirements to Support Fisheries in Canada (DFO, 2013b).
Change in fish health	• Water withdrawal during isolation, road construction, or for camp use can cause entrainment or impingement of fish on pump screen. • Water withdrawal for camp use and dust suppression from streams with low flow or withdrawal above 10% instantaneous flow or when below 30% mean annual discharge (MAD) may affect fish health or lead to stranding. • Winter water withdrawal can result in oxygen depletion affecting fish health. • Increased access to fishing. • Injury or death of fish due to the use of explosives near water. • Increased sediment load in a watercourse. • Use of quarry materials for embankments or rip rap that can lead to acid rock drainage (ARD) or metal leaching (ML) affecting fish health.	• Size of fish screens compared to Interim Code of Practice for End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (DFO, 2020). • Instantaneous flow (m^3/s) and MAD (m^3/s) compared to DFO's Framework to Support Flow Requirements to Support Fisheries in Canada (DFO, 2013b). • Water withdrawn compared to available under-ice lake volume (m^3). • Flow velocity (m/s) in culverts to meet fish passage requirements for fish species present. • Visual inspection of culverts to verify they meet design specifications. • Number (count) of fish entrained or impinged. • Number (count) of fishers using road to access fishing locations (voluntary).

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in fish health (cont'd)	• Residue on quarry material from the use of ammonium nitrate explosives in quarry operations may affect fish health due to negative changes in water quality. • Increased sediment in the water column due to highway construction, operations, and maintenance (e.g., dust, erosion, instream works).	• Qualitative evaluation of change in fishing pressure. • Instantaneous pressure change (kilopascals [kPa]) and, if spawning or incubation period, then also particle velocity (millimetres per second [mm/s]). • Turbidity using Nephelometric Turbidity Units (NTU) or total suspended solids (TSS) measured levels in accordance with CCME guidelines. • Measurement of water chemistry parameters, if needed, against CCME guidelines.

17.1.4 Boundaries

17.1.4.1 Spatial Boundaries

Three study areas are described as follows:

- **Project Development Area (PDA)**: The area of direct project disturbance within which physical works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 metres (m) wide highway ROW, and quarry/borrow sites with access roads on a 30 m ROW.
- **Local Assessment Area (LAA)**: Defined as the area 300 m downstream and 100 m upstream of each crossing structure proposed to be constructed as part of the Project. The crossing structure reference point is defined as the current highway route, as defined as the centerline of the alignment routing corridor (see Section 5.2.3). The LAA is where measurable project-related effects (direct or indirect) are expected to occur (Figure 17.1).
- **Regional Assessment Area (RAA)**: Defined by the area within approximately 15 kilometres (km) of the PDA. The RAA includes the Mackenzie River (Deh Cho), and associated tributaries and drainages. A 15 km buffer was selected to provide regional context for determining significance of Project-specific effects and potential cumulative effects to be assessed (Figure 17.1).

- Assessed Proposed Watercourse Crossing
- Proposed Mackenzie Valley Highway Project
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,600,000

N

Kalo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 8/3/2023
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Mackenzie Valley Highway Project

Figure No.
17.1

Title
Fish and Fish Habitat Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Imagery: Maxar
World Hillshade: Esri, USGS. Imagery date: 2021

17.1.4.2 Temporal Boundaries

Temporal boundaries used in the assessment reflect the specific project phases and activities:

- **Construction phase:** The Project is estimated to take approximately 10 years to construct, over a timeframe of up to 20 years. The schedule is conceptual and assumes the alignment will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley to the Dehcho/Sahtu border (102 km); Tulita, south to the Dehcho/Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (PCAR) (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.

17.1.5 Residual Effects Characterization

Potential residual effects of the Project on fish and fish habitat are characterized in terms of direction, magnitude, geographic extent, timing, duration, frequency, and reversibility (as defined in Table 17.3). Quantitative measures or, where applicable, descriptions of qualitative measures, are provided in Table 17.3.

Table 17.3 Characterization of Residual Effects on Fish and Fish Habitat

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse:** A residual effect that moves measurable parameters of fish and fish habitat in a negative direction relative to baseline **Neutral:** No net change in measurable parameters for the fish and fish habitat relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely:** The residual effect is almost certainly not to occur **Possible**: The residual effect could occur **Certain**: The residual effect will certainly occur

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude	The amount of change in measurable parameters or fish and fish habitat relative to existing conditions	**No Measurable Change:** No measurable change in the fish and fish habitat can be noted **Low:** A measurable change to fish habitat but would not affect the productivity or sustainability of fish populations **Moderate:** Measurable change to fish habitat and may have a short-term effect on productivity (< 1 year) but not affect long-term sustainability of fish populations **High:** Measurable change to fish habitat that could affect the long-term productivity and sustainability of fish populations
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA **LAA:** Residual effects extend into the LAA **RAA:** Residual effects interact with those of other projects in the RAA
Timing[1]	Considers when the residual effect is expected to occur, where relevant to fish and fish habitat	**No sensitivity:** Effect does not occur during sensitive life stage (e.g., fish spawning) or timing does not affect the VC **Moderate sensitivity:** Effect may occur during a lower sensitivity period of a critical life stage, such as pre- or post-spawning run **High sensitivity:** Effect occurs during a critical life stage (e.g., fish spawning and incubation)
Duration	The time required until the measurable parameter or fish and fish habitat returns to its existing condition, or the residual effect can no longer be measured	**Short-term:** The residual effect is restricted to the period of construction **Medium-term:** The residual effect extends through to the completion of reclamation activities **Long-term:** The residual effect will continue through operations and maintenance phase
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** Occurs once, not anticipated to be repeated **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 fish and fish habitat 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

Note:

[1] In terms of Timing, the critical life stages include episodes (such as spawning, rearing, migration, overwintering, and feeding). Timing is also relevant to Indigenous activities, such as harvesting of fish.

17.1.6 Significance Definition

The potential effects of the Project are deemed significant if the productivity and sustainability of fish populations crossed by the Project and near to the Project are negatively affected. This may result if:

- Habitat alteration or destruction of fish habitat cannot be mitigated, avoided, or offset.
- Death of fish may result in loss of productivity or sustainability of a fish population.
- Blockage of fish passage may result in loss of productivity and sustainability of a fish population (for example, if fish cannot access spawning or overwintering areas).

Determination of whether effects are significant will be based on the determination of the effectiveness of avoidance and mitigation measures applied to project activities. Fish population abundance data is not available, and there were no observations indicating fish captured were in poor health for the watercourses along the project highway alignment. However, productivity of fish populations is directly linked to the health of fish habitat where productivity refers to the ability for a fish to complete its life cycle. The health of fish habitat can therefore be used as surrogate for measuring whether productivity of a fishery may be affected. Significance of effects will be determined based on the understanding of the effectiveness of avoidance and mitigation measures to break pathways of effects on fish and fish habitat. If productivity of a fishery is maintained and recruitment is unaffected, sustainability of the fishery should also be maintained.

17.2 Existing Conditions for Fish and Fish Habitat

17.2.1 Methods

A fish and fish habitat technical data report (K'alo-Stantec, 2022; Appendix 17A) was completed to address data gaps from the ToR (MVEIRB, 2015 [PR#66]). Data was obtained through a literature review of currently available information and previous field assessments along the Project alignment (5658 NWT Ltd. and GNWT 2011; Dessau 2012). The literature review incorporated review of relevant fisheries literature, Traditional Knowledge, and TLRU information. Fish and fish habitat surveys of watercourses proposed to be crossed by the Project were conducted in the fall of 2020 and 2021. Detailed information on field methodology is provided in K'alo-Stantec (2022) in Appendix 17A.

17.2.2 Overview

Fishing is an important cultural and social activity in the Sahtu Region (SLUPB, 2023; Auld and Kershaw, 2005) as well as in the Dehcho Region (Dessau, 2012 [PR#13]). The Mackenzie River (Deh Cho) is an important area for fish harvesting but lakes are also fished (Sahtu Heritage Places and Sites Working Group, 2000; Dehcho Land Use Planning Committee [DLUPC], 2006). Other rivers and watercourses reported as important for fish harvesting include Great Bear River (TRRC, 2022; NWRRC, 2023), Blackwater River (Auld and Kershaw 2005), Birch Creek, Oscar Creek, Bluefish Creek, and Sucker Creek (NWRRC, 2023).

Through the Project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies, participants identified 20 fishing locations and areas of interest to fish and fish habitat relative to the Project within the PDA, LAA, and RAA, as described in Table 17.4.

Table 17.4 Fish Harvesting Locations Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[2]	Identified By:
Pehdzéh Kį N'deh area[1]	✓*	✓	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis
Sahtu Region	✓*	✓	Sahtu Dene and Métis
Great Bear River near Tulita (fishing area)	✓	-	TRRC
Great Bear River (as it intersects with the LAA and RAA) (fishing)	✓	✓	Communities in the Sahtu Region (SRRB); Elders in the K'ásho Got'įnę and Tulít'a regions; TRRC; NWRRC
Ochre River (fish spawning site)	✓*	-	Pehdzéh Kį First Nation; Dehcho First Nations
Blackwater River (fish spawning site; fishing)	✓*	-	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis
Hodgson Creek (Near Wrigley)	✓*	-	Pehdzéh Kį First Nation
Mackenzie River (Deh Cho) around Norman Wells[3]	✓	✓	Sahtu Dene and Métis
Mackenzie River around Tulita[4] (fishing sites)	✓	✓	Sahtu Dene and Métis
Mackenzie River (Deh Cho)(south of Wrigley) (fishing sites)	-	✓	Pehdzéh Kį First Nation; Dehcho First Nations
DehdéleĮǫ Tué (Sucker Lake/ Three Day Lake)	-	✓	Sahtu Dene and Métis
Bluefish Creek (fishing and spawning site)	-	✓	NWRRC
Oscar Creek (fishing site)	-	✓	NWRRC
Sucker Creek (fishing site)	-	✓	NWRRC
Birch Creek (fishing site)	-	✓	NWRRC
Windy Island	✓	✓	Sahtu Dene and Métis
Little Bear River	-	✓	Sahtu Dene and Métis
Redstone River	✓	✓	Community engagement
Lakes surrounding the Tulita area (fish spawning)[5]	✓	✓	TRRC

Location	Within LAA	Within RAA[2]	Identified By:
Trout Lake (fishing site)	✓*	✓	NWRRC
Canyon Creek	-	✓	NWRRC
Christmas Creek	-	-	Community engagement
Tate Lake	-	-	Community engagement
Jackfish Lake	-	✓	Community engagement

Notes:

[1] Pehdzéh Kį N'deh area as described in DLUPC, 2006

[2] Occurs within the RAA outside the LAA and PDA

[3] Specific locations were not identified in the report – location identified as Norman Wells

[4] Specific locations were not identified in the report – location identified as Tulita

[5] Specific locations were not identified in the report – location identified as Tulita

* May occur within PDA

Sources: 5658 NWT Ltd. and GNWT, 2011 (PR#16); Auld and Kershaw, 2005; Dessau, 2012 (PR#13); EBA, 2006; Golder, 2015; IMG-Golder Corporation, 2006; NWRRC, 2023; TRRC, 2019; TRRC, 2022; SLUPB, 2013; DLUPC, 2006; project-specific Engagement program (2021-2023)

The harvesting of whitefish species are important in the Sahtu (Auld and Kershaw, 2005) and Dehcho (Dessau, 2012 [PR#13]) regions, although other fish species are also harvested in the RAA such as Arctic grayling (*Thymallus arcticus*), walleye (*Sander vitreus*), Northern pike (*Esox lucius*), trout (*Salvelinus spp.*), suckers (*Catostomus spp.*), and salmon (*Oncorhynchus spp.*) (TRRC, 2022; NWRRC, 2023).

Available TLRU information also indicated that fish are an important resource for harvesting and there are important spawning areas within the LAA (TRRC, 2022; Section 3.2.1 in Appendix 17A). Spawning areas within the RAA identified during community engagements include Ochre River and Blackwater River (DLUPC, 2006), and Canyon Creek and Bluefish Creek (NWRRC, 2023).

A total of 92 crossings have been identified along the project alignment (Figure 17.1 and Appendix 5A) to be crossed using culverts. Crossings include watercourses, intermittent drainages, and wetlands. Fish captures have been reported at 5 watercourses, while 59 watercourses had the potential to at least support fish on a seasonal basis. Another 22 watercourses were determined to be unlikely to provide fish habitat due to no defined channels and lack of presence or only isolated ponding of water. It is unknown whether four of the watercourses provide fish habitat as they were not assessed (K'alo-Stantec, 2022, Appendix 17A).

A total of 33 fish species had been documented within the RAA (K'alo-Stantec, 2022, Appendix 17A). Of these 33 species, only 19 have been reported in watercourses crossed by the Project (Table 17.5). Large-bodied fish (e.g., Arctic grayling, northern pike, burbot, whitefish species) have only been reported (K'alo-Stantec, 2022, Appendix 17A) in four of the watercourses to be crossed by the Project:

- Four Mile Creek
- Twelve Mile Creek
- Prohibition Creek
- Unnamed Watercourse at kilometre marker (KM) 774.1 (Identified as KM 774.04 in K'alo-Stantec, 2022).

Prohibition Creek had the highest diversity of fish species (i.e., 13 species) and was the only watercourse to contain whitefish species. Except for the listed four watercourses, all other watercourses where fish have been reported contain six or less species, with most having only forage species present (K'alo-Stantec, 2022, Appendix 17A).

Table 17.5 Fish Species Reported in Watercourses Crossed by the Project

Common Name	Scientific Name
Arctic grayling (blue fish) [1]	*Thymallus arcticus*
Broad whitefish [1]	*Coregonus nasus*
Mountain whitefish [1]	*Prosopium williamsoni*
Round whitefish [1]	*Prosopium cylindraceum*
Cisco [1]	*Coregonus sp.*
Northern pike [1]	*Esox lucius*
Burbot (loche) [1]	*Lota lota*
Longnose sucker [1]	*Catostomus catostomus*
Brook stickleback	*Cluea inconstans*
Finescale dace	*Chrosomus neogaeus*
Pearl dace	*Margariscus margarita*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Fathead minnow	*Pimephales promelas*
Trout-perch	*Percopsis omiscomaycus*
Lake chub	*Couesius plumbeus*
Spoonhead sculpin	*Cottus ricei*
Slimy sculpin	*Cottus cognatus*

Notes:
"1" = fish commonly harvested
Data Sources: IORVL, 2004; K'alo-Stantec, 2022

A number of fish species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils have been identified in Table 17.6 following a review of publicly available literature (Appendix 11A) and shared through the project-specific engagement program and project-specific TLRU studies.

Table 17.6 Culturally Important Fish Species Identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties

Common Name	Latin Name	Identified By
Arctic char[1]	*Salvelinus alpinus*	SRRB
Artic grayling (bluefish)	*Thymallus arcticus (Pallas)*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Broad whitefish	*Coregonus nasus (Pallas)*	Pehdzéh Kį First Nation; Dehcho First Nations; SRRB; NWRRC
Burbot (loche)	*Lota lota*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Bull trout	*Salvelinus malma*	SRRB
Chum salmon (dog-face salmon)	*Oncorhynchus keta (Walbaum)*	Pehdzéh Kį First Nation; Dehcho First Nations; SRRB; NWRRC
Dolly Varden	*Salvelinus confluentus*	SRRB
Coney (Inconnu)	*Stenodus leuichthys (Güldenstadt)*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Jackfish/northern pike	*Esox lucius (Linnaeus)*	Pehdzeh First Nations; Dehcho First Nations; SRRB
Lake cisco	*Coregonus artedii (Lesueur)*	Pehdzéh Kį First Nation; Dehcho First Nations; SRRB
Sculpin	*Cottus sp.*	Community engagement
Lake trout	*Salvelinus namaycush*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB
Lake whitefish (crooked back)	*Coregonus clupeaformis (Mitchill)*	Pehdzéh Kį First Nation; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC
Longnose sucker	*Catostomus catostomus (forster)*	Pehdzéh Kį First Nations; Dehcho First Nations; SRRB
Mountain whitefish	*Prosopium williamsoni*	Pehdzéh Kį First Nations; Dehcho First Nations
Pickerel/walleye	*Stizostedion vitreum (Mitchill)*	Pehdzéh Kį First Nations; Dehcho First Nations; Sahtu Dene and Métis; SRRB; NWRRC

Common Name	Latin Name	Identified By
Round whitefish	*Prosopium cylindraceum (Pallas)*	Pehdzéh Kį First Nations; Dehcho First Nations
Trout-perch	*Percopsis omiscomaycus (Walbaum)*	Pehdzéh Kį First Nations; Dehcho First Nations
White sucker	*Catostomus commersoni (Lacépède)*	Pehdzéh Kį First Nations; Dehcho First Nations

Note:

[1] Arctic char are not present in the Mackenzie River (Deh Cho) system

Sources: Auld and Kershaw, 2005; IMG-Golder Corporation, 2006; NWRRC, 2023; SRRB, 2021b; SLUPB, 2022; DLUPC, 2006; project-specific engagement program (2021-2023)

Two fish species within the RAA, bull trout (*Salvelinus confluentus*; Western Arctic population) and Dolly Varden (*Salvelinus malma*), are considered populations of Special Concern under SARA (Government of Canada [GOC], 2022). Both species are listed as "sensitive" in the Northwest Territories (Working Group on General Status of NWT Species, 2021). Sensitive species are not at risk of extinction or extirpation but may require special protection to prevent them from becoming at risk. These species are ranked as medium priority for further consideration (Working Group on General Status of NWT Species, 2021). Arctic grayling (*Thymallus arcticus)*, inconnu (*Stenodus leucichthys*), and Arctic cisco (*Coregonus autumnalis*) have historical presence in the RAA and are listed as "sensitive" (Working Group on General Status of NWT Species, 2021). Species listed as "special concern" or "sensitive" have no additional regulatory requirements associated with them under territorial or federal legislation. These four species of management concern are unlikely to be present or to use fish habitats within the Project's LAA:

- Dolly Varden are unlikely to occur within tributaries of the Mackenzie River (Deh Cho) within the project RAA. The southern range of the northern population of Dolly Varden is the Gayna River, which is located downstream of Norman Wells and beyond the RAA. Dolly Varden have been reported in previous studies conducted within the RAA; however, these fish were likely misidentified bull trout (Reist et al., 2002).
- Bull trout in the eastern tributaries of the Mackenzie River (Deh Cho), such as those along the project alignment, are likely individuals from tributaries on the west side of the Mackenzie River (Deh Cho) migrating to potential feeding or overwintering areas (Mochnacz et al., 2013). Bull trout prefer to spawn in small, steep gradient streams with gravel substrate (Mochnacz et al., 2013). Bull trout have been reported in a tributary to the Redknife River and the Great Bear River (Mochnacz et al., 2013), however the small size of most watercourses (drainage areas of less than 10 km) along the Project alignment and poor overwintering potential suggests bull trout would not occur in most of these watercourses.

- Inconnu and Arctic cisco prefer large river systems and are not known to migrate up small tributaries of the Mackenzie River (Deh Cho), such as those that would be crossed by the Project. Inconnu are found throughout the Mackenzie River (Deh Cho) and Great Slave Lake (Stephenson et al., 2005; Scott and Crossman, 1998) while Arctic cisco have been reported as far south as the Liard River (Sawatzky et al., 2007). Larval Arctic cisco are swept downstream to the Mackenzie River (Deh Cho) delta and along the Beaufort Sea coast to nursery areas before returning to the Mackenzie River (Deh Cho) and its larger tributaries, such as the Great Bear River, to spawn (Evans et al., 2002).
- Arctic grayling is present in some larger watercourses to be crossed by the Project. Spawning occurs over gravel and cobble bottoms in the spring as ice-cover begins to break up, (Scott and Crossman 1998). Young-of-the year remain in their natal streams for up to 15 months (Ford et al. 1995). Adults may move into larger river or lakes to overwinter (Scott and Crossman 1998).

Watercourses crossed by the Project in both the Sahtu and Dehcho regions are mainly small unnamed watercourses with small drainage areas, typically less than 10 square kilometers (Tetra Tech, 2021, 2022). Water depths of watercourses in the Sahtu Region were typically less than 0.5 m while those in the Dehcho Region were typically less than 1 m. In both regions, water depths over 1 m were either associated with wetland areas or beaver impoundments. The shallow depth of these watercourses suggests they would freeze to the bottom during winter and therefore would not provide overwintering habitat.

Based on a desktop review of existing information and field assessments, 37 of the 41 potential watercourse and wetland crossings within the Sahtu Region were either confirmed fish habitat or have fish habitat potential. Most of the watercourses which have fish habitat potential likely only support forage fish species. The exceptions are Twelve Mile Creek, Four Mile Creek, and Prohibition Creek. Twelve Mile Creek and Four Mile Creek are known to provide suitable habitat for Arctic grayling (*Thymallus arcticus*), northern pike (*Esox Lucius*), and burbot (*Lota lota*). Prohibition Creek provides habitat for Arctic grayling, northern pike, and several whitefish species (*Coregonus sp.*) (K'alo-Stantec, 2022; Appendix 17A).

In the Dehcho Region, desktop assessments of 49 watercourses or wetlands were conducted, and supplementary field assessments were conducted in September 2020. Field assessments focused on 25 locations where there was no existing bridge crossing. Of the 49 watercourses and wetlands:

- Seventeen were unlikely to provide fish habitat due to a lack of connectivity or flow.
- Four watercourses could not be assessed at the time due to freeze-up occurring and it is unknown if they provide fish habitat.
- Twenty-six watercourses afford fish habitat or have fish habitat potential. An unnamed watercourse at KM 774 is known to support Arctic grayling; however, most of the watercourses with fish habitat potential likely only support forage fish species.

Site-specific habitat descriptions of watercourses to be crossed by the Project found in the technical data report (K'alo-Stantec, 2022; Appendix 17A).

There are no fish advisories for human consumption within the RAA related to contaminants (GNWT, 2022).

It is not uncommon for wild fish species to have parasites; however, high parasite infestation may affect fish health (Iwanowicz 2011). There are no reports of abnormal levels of parasites in fish within the RAA. Common parasites found in freshwater fish in the Northwest Territories are listed by Stewart and Bernier (1999).

Other than in waters overlying Sahtu Lands where Sahtu Dene and Métis have exclusive rights to fish commercially, there are no exclusive rights to fish granted to land claim beneficiaries within the RAA. Guiding and outfitting opportunities are found within the RAA for large-bodied fish species (e.g., Arctic grayling, northern pike); however, watercourses crossed by the Project are small and unlikely to support large-bodied fish or only juveniles of large-bodied fish, and therefore do not afford good guiding or outfitting opportunities. Recreational fishing likely occurs primarily in the Mackenzie River (Deh Cho) or larger systems along the project alignment, such as the Blackwater River. Most watercourses along the project alignment are too small to provide fishing opportunities.

The RAA is located within Zone 2 for the identification of the Northwest Territories restricted activity timing windows for the protection of fish and fish habitat (DFO, 2013a). Restricted activity timing windows are determined based on species presence and spawning habitat potential within waterbodies. The following restricted activity timing windows apply to watercourses crossed by the Project:

- **April 1 to July 15:** Most watercourses crossed by the Project provide habitat potential for spring- and summer-spawning fish.
- **December 1 to July 15:** Twelve Mile Creek and Four Mile Creek (Sahtu Region) support spring-spawning species and burbot, which spawn in winter.
- **August 15 to July 15:** Prohibition Creek supports spring-, summer-, and fall-spawning fish species.

17.3 Project Interactions with Fish and Fish Habitat

For each potential effect, Table 17.7 identifies the physical activities and components of the Project that can interact with fish and fish habitat. Interactions that can result in effects on fish and fish habitat within the LAA or RAA are indicated by a check mark. These interactions are discussed in detail in Section 17.4 in the context of effects pathways, standard and project-specific mitigation, and residual effects. A justification for activities not expected to interact with fish and fish habitat is provided following the table.

Project schedules and activities for the construction phase and the operations and maintenance phase are described in detail in Sections 5.4 and 5.5, respectively. Project-related accidents and malfunctions are not considered Project interactions and are described in Chapter 25.

Table 17.7 Project-Environment Interactions with Fish and Fish Habitat

Physical Activities	Timing	Environmental Effects	
		Change in Fish Habitat	Change in Fish Health
Construction Phase			
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	-	✓
Establishment and operation of camps	Year-round	-	✓
Site preparation of ROW, access, and workspaces	Winter	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	-	✓
Material haul	Year-round	-	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓
Culvert installations	Summer or winter	✓	✓
Road base placement, compaction, and surfacing	Summer	-	✓
Water withdrawal to support construction activities	Year-round	-	✓
Closure and reclamation of Mackenzie Valley Winter Road (MVWR) and temporary borrow sources/quarries, camps, and workspaces	Summer	-	✓
Employment and contracted goods and services[1]	Year-round	-	✓
Operations and Maintenance Phase			
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	-	✓
Material haul and stockpiling	Summer	-	✓
Operation of and activities at maintenance yards	Year-round	-	✓
Water withdrawal for dust control	Summer	-	✓
Employment and contracted goods and services[1]	Year-round	-	✓
Presence and public use of the highway	Year-round	✓	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	✓	✓
Vegetation control	Summer	✓	✓
Bridge and culvert maintenance	As needed	✓	✓

Notes:

✓ = Potential interaction

– = No interaction

[1] Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

The potential interactions between project activities and the environment were considered for the construction phase and the operations and maintenance phase of the Project. The identification of project activities and their potential interactions was based on engagement with Indigenous Governments, Indigenous Organizations, and other affected parties, the professional judgment of technical specialists involved in the assessment, and a review of existing conditions. The selection of interactions is also informed by the potential effects and effects pathways for fish and fish habitat as described in Section 17.1.3.

17.4 Assessment of Residual Effects on Fish and Fish Habitat

Based on project interactions with the environment identified in Table 17.7, the Project may affect the fish and fish habitat. Potential effects, effect pathways (Table 17.2), and mitigation measures that will reduce or eliminate the effects on fish and fish habitat are identified in Table 17.8. Potential residual effects and associated analytical assessment techniques are described in subsequent subsections.

Table 17.8 Potential Effects and Mitigation Measures for Fish and Fish Habitat

Effect Name	Effect Pathway	Mitigation Measures
Change in Fish Habitat	• Loss or alteration of riparian area	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
		• Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).
		• A buffer strip of undisturbed vegetation of at least 30 m wide will be maintained between the highway ROW and other areas to be cleared.
		• Riparian vegetation will be maintained whenever possible.
	• Loss or alteration of fish habitat below the ordinary high water mark (OHWM)	• All temporary crossings will follow DFO's Code of Practice for Temporary Fords (DFO, 2022a) and/or Ice Bridges and Snow Fills (DFO, 2022b).
		• Temporary crossings will be constructed perpendicular to the watercourse.
		• Snow fill temporary crossings will be constructed of clean snow fill.
		• Snow fill crossings will be v-notched prior to the spring melt/freshet before April 1 each year.
		• Temporary bridges, if required, will not be placed below the OHWM.
		• Culvert maintenance will follow the DFO Code of Practice for Culvert Maintenance (DFO, 2022c).
		• Instream work will be limited, to the extent possible.
		• Rip rap will be free of silt and other debris.

Effect Name	Effect Pathway	Mitigation Measures
Change in Fish Habitat (cont'd)		• Rip rap repair and culvert construction will be timed to avoid restricted activity periods for fish as applicable to the watercourse. Rip rap will be free of silt and other debris.
		• Grading of stream banks at approaches shall be limited, where possible. Rip rap repair and culvert construction will be timed to avoid restricted activity periods for fish as applicable to the watercourse.
		• The objective of site closure will be to approximate pre-development conditions to the extent possible. Grading of stream banks at approaches shall be limited, where possible.
		• Temporary isolation will occur for the placement of rip rap and culverts and will follow the Interim Code of Practice: Temporary Cofferdams and Diversion Channels (Interim) (DFO, 2020a).
		• Beaver dam removal will be done in accordance with the Code of Practice: Beaver Dam Breaching and Removal (DFO, 2022d) and conditions of the GNWT General Wildlife Permit.
	• Barriers to fish passage	• Culverts will be designed and constructed to maintain water flow and fish passage.
		• Ice in culverts will be thawed by steaming, where needed to maintain flow.
		• Flow velocity (metres per second [m/s]) in culvert will meet fish passage requirements for fish species present based on Di Rocco and Gervais (2023).
		• Water flow and fish passage will be maintained during construction.
Change in Fish Health	• Water withdrawal	• Winter water withdrawal will be within the limits of water licences and in accordance with the DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013a) and other appliable guidance (e.g., DFO 2013b).
		• Water withdrawal will be in accordance with DFO's Interim Code of Practice: End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (Interim) (DFO, 2020b).
	• Increased fishing pressure due to improved access	• Pullouts will not be located near watercourses with sport fish.
		• Project personnel will be prohibited from hunting and fishing while housed in work camps for the Project.
	• Use of explosives near waterbodies	• Only material with low ARD/ML potential will be used for the Project.
		• An Explosives Management Plan (ExMP) will be developed and implemented. Blasting will not occur within 100 m of fish-bearing waterbodies such that instantaneous pressure will be less than 50 kPa where fish may be present and particle velocity will be less than 13 mm/s near a spawning bed where eggs or larval fish may be present.

Effect Name	Effect Pathway	Mitigation Measures
Change in Fish Health (cont'd)	• Inadequate culvert design creating high water velocities and turbulence in culvert, resulting in injury to fish	• Flow velocity (metres per second [m/s]) in culvert will meet fish passage requirements based on Di Rocco and Gervais (2023) for fish species present.
Change in Water Quality	• Increased sedimentation	• In-water construction activities will be conducted during no or low flow periods where possible and with erosion control mitigation in place. Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.
		• Ponded water will be directed away from existing waterbodies.
		• Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
		• Excavated spoil material will be disposed of at least 30 m from the watercourse. Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
		• Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
	• Accidental spills	• Fuel handling and refueling will be in accordance with an Operating Procedure to be included in the SCP Standard Operating Procedures. Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container.
		• A Spill Contingency Plan (SCP) will be developed and implemented.
		• Areas and containers used to store project wastes will be constructed, operated, and maintained in a manner to prevent waste from discharging to the surrounding environment. Fuel handling and refueling will be in accordance with an Operating Procedure to be included in the SCP Standard Operating Procedures.
		• Maintenance yards will have a liner of concrete installed under areas of vehicle storage and maintenance. Areas and containers used to store project wastes will be constructed, operated, and maintained in a manner to prevent waste from discharging to the surrounding environment.

Effect Name	Effect Pathway	Mitigation Measures
Change in Water Quality (cont'd)		• Vehicles parked for more than 2 hours will use drip trays. Maintenance yards will have a liner of concrete installed under areas of vehicle storage and maintenance.
		• Machinery will arrive on-site and will be maintained in a clean condition and free of invasive species and noxious weeds. Vehicles parked for more than 2 hours will use drip trays.
		• Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high -water mark and in a manner to prevent any deleterious substances from entering the water. Machinery will arrive on-site and will be maintained in a clean condition and free of invasive species and noxious weeds.
		• Machinery will not be left in any waterbody.

17.4.1 Analytical Assessment Techniques

The general approach to assessing potential effects on fish and fish habitat follows the sequence and methods outlined in Chapter 4 (assessment methods). A conservative approach is used to address uncertainty, which increases confidence in the final determination of significance.

Watercourses where no fish were captured during field surveys and no prior fish data was available were identified as fish habitat based on habitat potential.

Watercourses were considered unlikely to provide fish habitat if:

- There was no connectivity to another waterbody, based on satellite imagery
- The drainage conveyed seasonal surface water runoff (i.e., snow melt, rain events) but was otherwise dry

The assessment used a habitat-based approach based on potential fish species presence and their life history requirements (e.g., spawning, rearing, migration, overwintering). Fisheries and Oceans Canada's Pathways of Effects (DFO, 2018) were used to identify effects pathways which may occur as a result of project activities. Mitigation measures were identified which either break the effect or reduce the magnitude of the effect. Detailed habitat assessment methodology is provided in K'alo-Stantec (2022). No SARA-listed fish species are reported for watercourses crossed by the Project. Species listed as SARA species within the RAA are all listed as Special Concern and as such have no regulatory requirements associated with them, therefore these species would be assessed like all other fish species occurring in the PDA. Past professional experience from assessments conducted on other linear projects (e.g., Inuvik to Tuktoyaktuk Highway) was also used to inform the significance of effects.

17.4.2 Change in Fish Habitat

Change in fish habitat may result during the construction and operations and maintenance phases of the Project, as shown in Table 17.8. The proposed works has potential to alter instream habitat, riparian vegetation (i.e., cover), and stability of the watercourse bed and banks. The severity of the potential residual effect is determined by physical factors (e.g., channel width, flow characteristics, substrate type), construction timing, fish habitat potential, and fish species that are potentially present at the watercourse level.

17.4.2.1 Loss or Alteration of Riparian Vegetation

Riparian vegetation will be lost or altered at watercourse crossings. Loss of riparian habitat will occur along the width (9 m) of the roadway plus generally 5.5 m on each side to account for embankment slopes, at each watercourse crossing location (at embankment height of 1.8 m and 3:1 sideslope. Alteration of riparian habitat will be through the trimming of vegetation close to the ground along the 60 m ROW width. Where the project ROW follows the existing MVWR alignment, an approximately 20 m wide ROW has already been altered through regular vegetation control; therefore, an additional 40 m of alteration of riparian habitat will occur for these sections of the Project. Based on the current alignment route, the project route deviates from the existing MVWR alignment at four watercourse crossings; therefore, up to 31 m of riparian vegetation will be lost at these locations (60 m minus the 29 m of riparian habitat to be lost directly at the crossing location). Lost riparian vegetation extends 30 m outward from the watercourse banks. Maintenance of the ROW by trimming vegetation will be conducted periodically during highway operations.

Loss of riparian vegetation can lead to flow alterations, increased sedimentation, and reduced invertebrate abundance (Denbeste and McCart, 1984; Johansen et al., 2005). Overhanging riparian vegetation is important as it moderates water temperature through shading (Johansen et al., 2005; Sokolowski and Pratt, 2007). As riparian area within the ROW, except for the actual roadway, will only be trimmed, trimmed vegetation will still provide riparian functionality and benefits to fish habitat.

Vegetation clearing, which may occur in the riparian area, will only be to maintain that area affected during construction. No additional effects are anticipated from this activity.

The implementation of mitigation (Table 17.8) and best management practices will reduce the magnitude of anticipated residual effects.

17.4.2.2 Loss or Alteration of Fish Habitat Below the OHWM

During construction, the Project will result in loss of fish habitat through the permanent infilling around culvert installations. The loss of fish habitat will be limited to the footprint of the infilling around each of the culvert installations and remaining habitat within each watercourse will remain available to fish populations. The placement of riprap on the banks of the watercourses will result in the loss and alteration of fish habitat. In addition, there will be alteration of fish habitat as a result of the installation of culvert aprons on the upstream and downstream ends of culverts. Rip rap used for bank stabilization and culvert will be free of or have low ARD/ML material. The placement of riprap will permanently alter fish habitat in the area surrounding each crossing location within the footprint of the bank stabilization and apron, changing the existing substrate and bank material composition. The permanently altered fish habitat will still be accessible to fish.

Culvert and bridge maintenance are not anticipated to further the loss or alteration of habitat (i.e., no increase in loss or alteration footprint from construction). If alteration or loss of habitat is anticipated due to maintenance activities, the works would be subject to territorial and federal approvals and would be submitted for review under a separate cover. The application of mitigation measures (Table 17.8) and best management practices will reduce, but are not anticipated to eliminate, residual effects.

17.4.2.3 Barriers to Fish Passage

Barriers to fish passage can occur through improper installation of culverts. Improper installation of culverts can result in perched culverts or increases in stream velocity, which can prevent fish passage and restrict access to important habitat areas (e.g., spawning habitat). Site-specific culvert design will take into account topography, road geometry, substrate material fish passage, and fish habitat. Best management practices for the installation of culverts have been established to reduce the potential for perched culverts. Culverts will be designed for fish passage based on swimming performance analyses by Di Rocco and Gervais (2023) for the fish species which may be present at any given crossing and season, with the lowest swimming performance ability to meet DFO fish passage requirements. Culvert designs will be reviewed and approved by DFO during the permitting process. Additional information on culvert design can be found in Chapter 5, Section 5.4.7.1.

Accumulation of debris in culverts may affect fish passage through a culvert; however, culvert maintenance can have a net positive effect on fish passage through the removal of debris.

With the implementation of best management practices and mitigation (Table 17.8), no residual effect is anticipated. Barriers to fish passage is not considered further in this assessment.

17.4.3 Change in Fish Health

The interpretation of change in fish health for this assessment refers to health of fish at an individual level and population level and can include injury and death of fish.

17.4.3.1 Water Withdrawal

Water withdrawal may occur through dewatering for isolation during construction (if the watercourses are flowing at the time of culvert installation), camp use, construction of travel lanes, compaction where water is used, and dust control. Potential for injury or death of fish may occur as a result of impingement against pump intakes or entrainment. Water withdrawal from waterbodies can lower water levels, which may limit fish habitat—especially overwintering habitat. Lower water levels can further limit overwintering habitat through reduced dissolved oxygen levels, which affects fish health (Cott et al., 2008a, 2008b). Fish health may also be affected through water withdrawal activities, which can limit migration of fish and may prevent fish from accessing preferred habitat.

The potential effects from water withdrawal can be effectively mitigated. Pump intakes used for water withdrawal for instream isolations and project water requirements will follow DFO Interim Code of Practice for End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (DFO, 2020b). Water withdrawals in waterbodies during winter will follow the DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut (DFO, 2010a) and water withdrawal from streams will meet low risk criteria (DFO, 2013b). A fish salvage of the isolated workspace will be completed prior to instream works. All applicable regulatory permits and authorizations will be obtained before the start of fish salvage and instream activities. Fish salvaged from isolated workspace prior to instream works and moved to an area of equivalent or greater habitat potential by a qualified fisheries biologist.

Residual effects on fish because of fish salvages will be of short duration (hours) and limited to stress. With the implementation of mitigation (Table 17.8), residual effects are anticipated to be negligible for this effect pathway and therefore are not considered further in this assessment.

17.4.3.2 Increased Fishing Pressure

During operation of the Project, there will be increased access to fish-bearing waters during the open water season. Increased access during the open water season may lead to increased fishing pressure, resulting in reduced stock levels. This effect would only occur at larger watercourses that support large-bodied fish; in particular, watercourses crossed by existing bridges. Arctic grayling is the most common large-bodied fish found in watercourses crossed by the Project and the most likely to be affected by an increase in fishing pressure. In the Fort McMurray area of Alberta, increased access and overfishing were considered the main cause of declining populations of Arctic grayling in the area (Valastin and Sullivan, 1997; Schwalb et al., 2015). The example in the Fort McMurray area may be extreme as highway volume is considerably higher in this area than what is projected by the Project (approximately 50 vehicles/day) and therefore has the potential for higher fishing pressure than would be expected as a result of the Project. Most watercourses along the Project only support forage fish, which are not typically targeted by fishing activities and would not be subject to increased fishing pressure. Other fish species of community concern, such as whitefish and trout, are largely absent from watercourses crossed by the Project, although they may be found at the mouth of these watercourses at the Mackenzie River (Deh Cho) and increased fishing pressure for these species is unlikely.

Increased fishing pressure within the Mackenzie River (Deh Cho) and larger lakes in the RAA would be limited. Access to the Mackenzie River (Deh Cho) would primarily be from communities connected to the Project, as there are limited opportunities to access the Mackenzie River (Deh Cho) from watercourses crossed by the Project. Most watercourses crossed by the Project are not navigable and therefore could not be accessed by boat. Access to lakes within the RAA would be limited to all-terrain vehicles or snow machines. As there is no direct access to lakes via the Project in summer and limited areas in which to park a vehicle and trailer, increased fishing pressure on lakes that might affect fish populations is not anticipated. Access during the winter period has been available in the past from the MVWR, and access to additional lakes may become available during the construction phase, as suitable lakes are expected to be used as water sources. Potential increased fishing pressure on the Mackenzie River (Deh Cho) and lakes within the RAA is not anticipated to affect fish populations in these waterbodies.

17.4.3.3 Use of Explosives Near Waterbodies

Explosives will be used during quarry operations both during the construction and operations and maintenance of the Project. Explosives may also be used at up to 14 rock cut locations along the highway; however, rock cut locations are yet to be determined. All quarries to be used in the construction and operation of the Project are 1 km or greater from a waterbody, thereby reducing the potential for effects on fish and fish habitat. Overpressures of 100 kPa or more, or peak particle velocities of 13 mm/s or more during spawning or fish incubation periods, can lead to injury or death of fish (DFO, 2010b). Overpressure will be limited to no more than 50 kPa, as current guidelines of 100 kPa may not be protective of early life stages of fish (Godard et al., 2008), and peak particle velocity guidelines of less than 13 mm/s will be met. The potential effects on fish health from the use of quarry materials is discussed under changes in water quality (Section 17.4.4.2). Overpressure and peak particle velocity can be managed through the implementation of mitigation measures (Table 17.8) and best management practices; therefore, no residual effect is anticipated for this effect pathway and is not considered further in this assessment.

17.4.3.4 Inadequate Culvert Design

Inadequate culvert design can lead to high water velocities in culverts creating turbulence within the culvert. High levels of water turbulence can result in fish making contact with the culvert, causing injury to the fish. Culvert design for fish passage based on swimming performance analyses by Di Rocco and Gervais (2023) for fish species which may be present at any given crossing with the lowest swimming performance ability should reduce the potential for levels of in-culvert turbulence, which could lead to injury to fish; therefore, no residual effect is anticipated for this effect pathway and is not considered further in this assessment.

17.4.4 Change in Water Quality

Water quality can be affected through erosion and sedimentation during construction (e.g., vegetation removal, grading, excavation, and change in flow where instream works occur) and operations and maintenance of the Project (e.g., vegetation management), or through accidental spills into watercourses. The effects of spills are assessed in Chapter 25 and are not assessed further here.

17.4.4.1 Increased Sedimentation

Increases in sediment in watercourses can damage gills, which affects fish health, or smother fish eggs, which results in death to fish. Reduced visibility in the water column due to increased suspended sediment can also reduce fish feeding success, thereby potentially affecting fish health. Construction at watercourses will be conducted in the dry. Where flowing water is present, temporary instream isolations will be used to allow work to be conducted in the dry. Isolation limits the potential for sediment entering the water column during construction activities, such as excavation of the beds and banks for the placement of culverts and rip rap. Isolation methods may produce short duration sediment pulses when installing and removing isolation structures, resulting in potential changes to surface water quality due to increased concentrations of total suspended sediment; however, this effect is expected to be short-term (1 to 10 hours) with a rapid return to background levels (Reid and Anderson, 2000; Reid et al., 2002) and expected to be limited to the LAA. In addition, these pulses of sediment can typically be mitigated using erosion and sediment controls described in Table 17.8. Rip rap underlain by geotextile material placed at water crossing locations is designed to prevent erosion that could result in sediment entering a watercourse.

Temporary vehicle crossings can also lead to the introduction of sediment to a watercourse. Mitigation measures related to temporary vehicle crossings are described in Table 17.8, the ESCP (Volume 5), and applicable measures in DFO's Code of Practices for Temporary Stream Crossings (DFO, 2022a, 2022b), which will be followed to mitigate sedimentation of watercourses.

Construction of the Project and use of the highway by the public once constructed can cause dust to become airborne and some of this material to become deposited within a watercourse. This dust may result in increased sedimentation within watercourses. Dust control measures will be implemented during construction and operation of the Project.

The management of sedimentation is undertaken through the implementation of mitigation measures (Table 17.8) and best management practices detailed in the ESCP (Volume 5), which are expected to be effective at mitigating changes to water quality as applicable to fish health and fish habitat such that the effect would be neutral and typically only measurable for several minutes; therefore, residual effects are anticipated to be negligible. This potential effect is not assessed further here.

Additional information on water quality can be found in Chapter 16.

17.4.4.2 Use of Quarry Materials

The use of quarry material may have ARD potential or contain ammonia/nitrate residue from the use of explosives, which can reduce water quality and, in turn, affect fish health.

With the application of mitigation measures (Table 17.8) and best management practices, changes in water quality due to the use of quarry materials can be avoided; therefore, no residual effects are anticipated. This effect pathway is not considered further in this assessment.

17.4.4.3 Mitigation

Standard industry best practice and avoidance measures, along with specific mitigation (Table 17.8), will be implemented during construction and operations and maintenance of the Project to reduce effects on fish and fish habitat. Additional mitigation may be required through the issuance of licences and permits through the regulatory process. Key mitigation measures used to avoid or reduce potential effects on fish and fish habitat include:

- Culverts will be designed and constructed to maintain water flow and fish passage.
- Culvert maintenance will follow the DFO Code of Practice: Culvert Maintenance (DFO, 2022c).
- Instream work will be limited to the extent possible.
- Temporary isolation will occur for the placement of rip rap and culverts (if flowing water is encountered) and will follow the interim DFO Code of Practice: Temporary Cofferdams and Diversion Channels (DFO, 2020a).
- Water flow and fish passage will be maintained during construction, including during any instream isolations.
- Beaver dam removal will be done in accordance with the DFO Code of Practice: Beaver Dam Breaching and Removal (DFO, 2022d) and conditions of the GNWT General Wildlife Permit.
- Water withdrawal will be in accordance with DFO Measures to Protect Fish and Fish Habitat (DFO 2022e) and the interim Code of Practice: End-of-pipe Fish Protection Screens for Small Water Intakes in Freshwater (DFO, 2020b).
- Water withdrawal will be within the limits of water licences and in accordance with the DFO Measures to Protect Fish and Fish Habitat (e.g., DFO, 2010, 2013a) and other applicable guidance (e.g., DFO 2013b).
- Sediment control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
- Material stockpiles will be kept a minimum of 30 m from a watercourse or waterbody with the appropriate erosion control mitigation in place to prevent sediment from entering a watercourse or waterbody.
- Riparian vegetation will be maintained whenever possible.
- Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the high water mark and in a manner to prevent any deleterious substances from entering the water.

17.5 Residual Effects

Residual effects after the application of mitigation will occur through the loss and alteration of both riparian area and fish habitat below the OHWM. A residual effect on fish population health may occur if there is an increase in fishing pressure due to the operation of the Project.

17.5.1 Change in Fish Habitat

As described in Section 17.4.2, residual effects on fish habitat will occur through the loss and alteration of riparian habitat and fish habitat below the OHWM as a result of construction for the placement of culverts at crossings and ROW vegetation trimming.

17.5.1.1 Loss or Alteration of Riparian Area

Riparian habitat will be permanently lost along the 9 m width of the left and right banks to construct the roadbed at each crossing. The riparian areas at crossings that follow the MVWR alignment have previously been trimmed within its 30 m ROW. The Project's ROW will be 60 m and therefore an additional length of 30 m of riparian vegetation on each bank of the crossing will be trimmed. Alignment changes have been made which affect four crossings where riparian habitat was not previously altered. At these locations, the full 60 m ROW will be trimmed minus the 9 m width of the roadbed where riparian habitat will be lost (i.e., 51 m). Altered riparian habitat along the ROW at watercourse crossings due to trimming will retain ground vegetation in these areas and afford some riparian functionality, which benefits fish habitat.

The area of loss and alteration of riparian habitat includes the length of area affected extended to 30 m from the OHWM for each watercourse bank. The loss and alteration of riparian area at each crossing location is as follows:

- Loss of riparian habitat is 540 square metres (m^2)
- Altered riparian habitat for alignment on MVWR alignment is 1,800 m^2
- Altered riparian habitat for alignment that deviates from MVWR alignment is 3,060 m^2

Loss of riparian habitat where the roadbed is constructed will not result in increased sedimentation because the banks will be protected by rip rap to prevent erosion and sedimentation. For watercourses with unstable banks, rip rap will prevent sedimentation at these locations. In the ROW where riparian habitat will be altered, vegetation will be cropped but root masses will remain intact. This can help reduce erosion and sedimentation into adjacent watercourses.

Where riparian vegetation is altered, the banks of the watercourse will not be disturbed. These factors will reduce or negate potential sedimentation due to the alteration of riparian habitat while maintaining a level of riparian functionality. The removal of vegetation has the potential to affect water temperature and water flows; however, this is typically associated with larger clearings that occur through large-scale operations (e.g., past forestry practices) which may affect kilometres of riparian area along a watercourse. The loss of riparian vegetation as a result of the Project will be limited to the width of the highway roadbed at watercourse crossings.

A review of the potential effects of winter pipeline construction, which is similar in scale to a highway crossing, on fish and fish habitat in Hodgson Creek, found no effect on stream discharge, velocity, temperature, dissolved oxygen, or water chemistry (McKinnon and Hnytka, 1988). Changes in invertebrate supply are anticipated to be negligible due to vegetation being cropped and maintained in the ROW areas, and the small scale of riparian loss at the roadway. Following a review of literature, Cott et al. (2015) reported that where riparian vegetation removal can be localized and reduced, the resultant effects from a single linear development are likely negligible to the overall functioning of a stream if best management practices are followed. Installed culverts and rip rap will add some cover for small fish (e.g., forage fish) to negate part of the loss of overhead cover through riparian trimming.

The loss and alteration of riparian habitat will occur in the construction phase and periodic alteration of riparian habitat due to trimming during the operation and maintenance phase of the Project. The likelihood of the effects is certain and the direction is adverse. The effect is continuous, limited to the PDA, of low magnitude, and irreversible.

17.5.1.2 Loss or Alteration of Fish Habitat Below the OHWM

Loss of habitat is expected to occur from the infilling associated with culvert installation at watercourses and through the tie-in of rip rap in the stream bed for erosion and sediment control. The infilling of the sides of culverts is necessary to construct the roadbed of the highway. The effects due to the placement of rip rap can be mitigated through limiting the height of the rip rap protection, where feasible, and sizing of the rip rap used in culvert design (Fischenich, 2003). The area of habitat loss at each watercourse will be small in relation to the overall watercourse and similar habitat is widely available elsewhere in the watercourse. No limiting habitat features (e.g., spawning areas) will be lost that may result in reduced fish populations.

Alteration of habitat will occur at each watercourse crossing through rip rap placement to prevent bank erosion and for the aprons at both ends of the culvert. The alteration of habitat through rip rap can be beneficial for aquatic fauna. Coarse substrate the size of rip rap are limited or absent from watercourses crossed by the Project, and addition of rip rap can add complexity to the aquatic environment in these systems. Spaces between rip rap stones can provide velocity refuge and cover for aquatic invertebrates and small fishes (Fischenich, 2003).

Construction activities and resulting changes to fish habitat are not expected to disrupt sensitive life stages of fish. Limiting habitat features like spawning habitat for large-bodied fish would not be affected and spawning habitat for forage fish is largely available in the watercourses crossed by the Project. When construction occurs during the winter period, watercourses are expected to be frozen to the bottom with no fish presence. Construction activities that may occur during open water periods will be short-term. Similar habitat is available in each watercourse and will remain accessible to fish during the open water construction period.

Watercourses along the project highway alignment are largely undisturbed. The loss and alteration of fish habitat below the OHWM will occur through construction and continue during the operations and maintenance phase of the Project. The likelihood of an effect is certain with the direction of the effect adverse and limited to the PDA, but of low magnitude with the implementation of mitigation. The effect is long-term, continuous, and irreversible.

17.5.2 Change in Fish Health

A residual effect on fish health may occur if fishing pressure increases during construction and operation of the Project due to increased access at large-bodied fish-bearing waters. Most watercourses crossed by the Project do not provide fishing opportunities due to their small size and fish species found in these systems are predominantly forage fish. Increased fishing pressure is expected to occur during the open water seasons of operations and maintenance. The increase in fishing pressure could result in reduced fish stocks through overfishing, although likely limited to only Arctic grayling at major watercourse crossings (e.g., Ochre River, Blackwater River) and possibly those watercourses that are closer to communities. Fishing pressure at watercourses may be reduced by restricting construction workers from fishing during construction, avoiding constructing pullouts near watercourses containing large-bodied fish, and through educating users to the highway on maintaining healthy fish stocks.

Change in fish health populations due to increased fishing pressure may occur during the open water season of operations and maintenance of the Project. The likelihood of an effect is possible with the direction of the effect adverse and occurring within the LAA in systems containing large-bodied fish. The magnitude of the effect can range from moderate to high depending on fishing pressure at individual watercourses. The magnitude of the effect would be higher if fishing pressure increased during important migratory periods, such as spawning migrations. The frequency of the fishing pressure is anticipated to be irregular. The effect is reversible with the implementation of fishery management practices.

17.5.3 Summary of Residual Effects

Residual effects from the Project are anticipated for changes in fish habitat and potential changes to fish health as it pertains to the health of fish populations, which may result from increased fishing pressure at watercourses crossed by the Project. Residual effects characterization is provided in Table 17.9.

Table 17.9 Residual Effects on Fish and Fish Habitat

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Fish Habitat	C	A	CE	L	PDA	NS	LT	S	I
Change in Fish Habitat	O	A	CE	L	PDA	NS	LT	C	I
Change in Fish Health	C	A	P	L	LAA	NS	ST	IR	R
Change in Fish Health	O	A	P	L-H	LAA	MS	LT	IR	R

KEY

* See Table 17.3 for detailed definitions

Project Phase:
C: Construction
O: Operations and Maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

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

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

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

Reversibility:
R: Reversible
I: Irreversible

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirement related to fish and fish habitat for identified species of interest and species at risk, and consideration of engagement input and incorporation of Traditional Knowledge. Where in-water construction timing windows for the protection of fish and fish habitat cannot be met, site-specific measures for protection of fish will be implemented, including those identified in the Draft FFHPP (Volume 5).

The design of the Project and mitigation measures for protection of fish and fish habitat will respect the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ (which could be used for winter water withdrawal only), Norman Range SMZ, K’ąąlǫ Tué (Willow Lake Wetlands) SMZ and the Deh Cho (Mackenzie River) SMZ.

17.6 Assessment of Cumulative Effects on Fish and Fish Habitat

This sub-section assesses the potential cumulative effects arising from the Project. A cumulative effect occurs if, following mitigation, fish and fish habitat is affected, for the same effect, by both the Project and other projects and physical activities.

17.6.1 Residual Effects Likely to Interact Cumulatively

The Project has the potential to interact cumulatively with other linear projects which have watercourses draining into the Mackenzie River (Deh Cho). Those projects which have the potential to contribute to cumulative effects are identified in Table 17.10.

Table 17.10 Projects with the Potential to Contribute to Cumulative Effects in the RAA

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects: Change in Fish Habitat	Environmental Effects: Change in Fish Health
Past and Present Physical Activities and Resource Use (Base Case)		
Geotechnical	-	-
Oil, Gas & Seismic*	-	-
Infrastructure		
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	-
Canyon Creek All Season Access Road	✓	✓
Norman Wells Pipeline	✓	-
Mackenzie Valley Fibre Link	✓	-
Prohibition Creek Access Road	✓	✓
Quarries and Borrow Sources	-	-
Mining & Exploration	-	-
Municipal Operations, including water, waste, power, and community development		
Wrigley Municipal Activities	-	-
Tulita Municipal Activities	-	-
Norman Wells Municipal Activities	-	-
Project-Related Physical Activities (Project Case)		
Mackenzie Valley Highway Project	✓	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Environmental Effects: Change in Fish Habitat	Environmental Effects: Change in Fish Health
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)		
Quarries		
Dhu-1 Quarry	✓	-
Infrastructure		
Great Bear River Bridge	✓	✓
Oil and Gas	-	-

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

17.6.2 Change in Fish Habitat

Other projects that have the potential to contribute to cumulative effects with the Project are linear projects which have crossings at watercourses draining into the Mackenzie River (Deh Cho). Projects such as the Great Bear River Bridge and Canyon Creek and Prohibition Creek access roads have localized residual effects on fish habitat, such as loss or alteration of fish habitat below the OHWM through culverts and rip rap, and loss and alteration of riparian area in their respective ROW. The MVWR can interact cumulatively at only four watercourse crossings where the Project's alignment has been altered, otherwise the Project overlays the MVWR alignment for the majority of its length. Once the Project is operational, the MVWR will no longer operate.

The Norman Wells Pipeline project has watercourse crossings that are buried; however, alterations of riparian areas are maintained through periodic trimming of the vegetation within its ROW. The Mackenzie Valley Fibre Link is also buried. Its ROW lies within the project ROW except where the project alignment has been altered, affecting crossings at four watercourses. Riparian alteration will be maintained through periodic trimming of the vegetation.

Cumulative changes to fish habitat from projects that include water withdrawal are not considered, since the Projects' contribution is considered negligible (Section 17.5.2).

17.6.2.1 Cumulative Effects Pathways

Effects from the loss or alteration of riparian areas may affect water temperature, nutrient inputs into watercourses, and invertebrate populations. For watercourses that are crossed by the Project, the Norman Wells Pipeline, and the fibre line, these effects could interact cumulatively on a single watercourse. For other projects that may interact cumulatively with the Project, the cumulative effect would be the potential loss of invertebrate prey items and nutrients into the Mackenzie River (Deh Cho). There would be no water temperature effects on the large volume of water flowing in the Mackenzie River (Deh Cho) due to the relatively small-scale riparian loss or alteration at each watercourse crossing, which would result in a localized effect on water temperature.

The infilling on the sides of culverts and installation of piers for the proposed Great Bear River Bridge will result in a loss of fish habitat. The placement of rip rap on the banks of the ROW adjacent to installed culverts and rip rap aprons on the ends of culverts will also result in alteration of fish habitat. The alteration of fish habitat can alter the functionality of that habitat either beneficially or detrimentally. As these works occur on separate individual watercourses, the pathway for cumulative effects will relate to the interchange of species and food supply between the Mackenzie River (Deh Cho) and these other systems.

There is no loss of fish habitat below the OHWM for crossings related to the Norman Wells Pipeline and fibre line projects. Alteration of fish habitat below the OHWM for both these projects has largely recovered to their natural state, except at some crossings where rip rap was used to prevent bank erosion at the crossing site.

17.6.2.2 Mitigation for Cumulative Effects

There are no new mitigation measures for cumulative effects. Projects previously constructed followed standard mitigation and best practices used for watercourse crossings. Projects which may occur in the foreseeable future would also follow standard mitigation and best management practices similar to the Project.

17.6.2.3 Cumulative Effects

The projects identified in Table 17.10 and the Project will result in residual effects through the loss and alteration of fish habitat.

The types of effect from the Project, the Canyon Creek and Prohibition Creek access roads, and the Great Bear River Bridge projects are identical, as watercourse crossings, with a few minor exceptions, are on separate individual watercourses. Therefore, cumulative effects would not occur at individual watercourses crossed by these projects. As these watercourses drain into the Mackenzie River (Deh Cho), the potential for cumulative effects would be on the fisheries of the Mackenzie River (Deh Cho), primarily in potential loss of prey (fish and invertebrates) entering the Mackenzie River (Deh Cho). Due to the higher number of watercourses crossed by the Project compared to the other road projects, the contribution of potential cumulative effects are higher from the Project.

17.6.3 Change in Fish Health

Cumulative effects for change in fish health relates to a change in fish population due to increased fishing pressure leading to overfishing of species such as Arctic grayling. Potential cumulative effects with the Project can be anticipated from the Canyon Creek and Prohibition Creek access roads, and the Great Bear River Bridge (Table 17.10) which create potential for increased fishing pressure leading to overfishing and reduced fish stocks. The potential cumulative effects of these individual road projects during the construction phase are replaced by the effects of the Project during the operations phase, as the highway segments connect.

17.6.3.1 Cumulative Effects Pathways

Transportation corridors provide increased access to areas not previously available to many people. This increased access can lead to increased fishing pressure, which can result in overfishing and reduced fish stocks. Increased fishing pressure would be limited to those watercourses which bear large-bodied fish species, such as Arctic grayling, and is likely to be greater at locations closer to communities. Populations of fish in smaller tributaries to the Mackenzie River (Deh Cho), such as those found along the Prohibition Creek and Canyon Creek access roads and the potential Prohibition Creek access road, may be more susceptible to overfishing due to their likely small population size. The Project will connect and make use of these access roads during construction thereby potentially increasing traffic along these roads, resulting in the potential for increased fishing pressure.

Fish stocks which use tributaries to the Mackenzie River (Deh Cho) crossed by these road transportation corridors may also use Mackenzie River (Deh Cho) for part of their life history functions. For example, Arctic grayling may use a tributary of the Mackenzie River (Deh Cho) for spawning and rearing but migrate back into the Mackenzie River (Deh Cho) or to other larger systems to overwinter. Overfishing in the tributaries crossed by these projects and the Project may reduce fish stocks in other areas, where harvested.

17.6.3.2 Mitigation for Cumulative Effects

The mitigation measure for overfishing is to avoid construction of pullouts or parking availability at these fish-bearing watercourses, which will limit access to large-bodied fish. Fishery management measures may be able to be put in place, such as through the Northwest Territories Sport Fishing Regulations, which could restrict fishing during spawning periods by non-Indigenous persons or the placement of catch limits on species which may be subject to overfishing (e.g., Arctic grayling). These measures would need to be developed and approved by regulators responsible for fisheries management, the SRRB, and other resource managers.

17.6.3.3 Cumulative Effects

Limiting access to parking at large-bodied fish-bearing watercourses may reduce the potential for overfishing; however, it may not completely eliminate full access and the potential for overfishing. As a precautionary approach it is assumed some fish stocks may become stressed due to overfishing.

17.6.4 Summary of Cumulative Effects

The residual effects of change in fish habitat from both the loss and alteration of riparian areas and areas below the OHWM are not expected to affect productivity of these individual systems. The loss and alteration of fish habitat at any one watercourse will be less than one percent of available habitat. As productivity of these systems is not anticipated to be affected, their contribution to the Mackenzie River (Deh Cho) in terms of nutrients and prey organisms should not be affected. If a *Fisheries Act* authorization is required for one of the projects in the foreseeable future (e.g., Great Bear River Bridge, where an authorization is required), offsetting will be required to match or exceed lost or altered fish habitat. The characteristics of the residual cumulative effects for change in fish habitat are provided in Table 17.11. The effect is certain and direction adverse within the RAA. The duration is long-term and continuous. Although the effect is irreversible, the magnitude of the effect is low.

Increased access for fishing opportunities due to the Project and its connection with other transportation corridors in the RAA can be expected to result in increased fishing pressure of some fish populations (e.g., Arctic grayling). This increased fishing pressure, especially on smaller systems, can result in stress on fish populations. The application of mitigation will reduce the cumulative effects but not necessarily negate them. The characteristics of the residual cumulative effects for change in fish health are provided in Table 17.11.

The effect is possible and direction adverse within the RAA. The duration is long-term, but the frequency is irregular (e.g., when people fish). The effect can be reversible with fisheries management initiatives. The magnitude is anticipated to be medium to high depending on the fishing pressure that occurs associated with these projects.

Table 17.11 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Fish Habitat	A	CE	L	RAA	NS	LT	C	IR
Contribution from the Project to the residual cumulative effect	The Project is the largest contributor to this residual cumulative effect due to the number of watercourse crossings associated with it compared to those projects it may interact with cumulatively.							
Residual Cumulative Change in Fish Health	A	P	M-H	RAA	HS	LT	IR	R
Contribution from the Project to the residual cumulative effect	The Project is the largest contributor to this residual effect. The Project will connect the other transportation corridor projects together, increasing the potential for overfishing in the RAA.							

KEY

*See Table 17.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

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

N/A: Not applicable

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

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

Reversibility:
R: Reversible
I: Irreversible

17.7 Determination of Significance

17.7.1 Significance of Residual Effects

The change in fish habitat due to the loss or alteration of fish habitat below the OHWM and in the riparian area will occur at each crossing site along the project highway alignment where there is no existing crossing (e.g., bridge). The loss and alteration of fish habitat below the OHWM is a result of placement of culverts and rip rap at each crossing site and the infilling around the culvert sides for construction of the roadbed. The loss of riparian area will occur with the construction of the roadbed at the crossing. Alteration of riparian habitat is through trimming of vegetation along the ROW at each crossing site. Trimming of the vegetation leaves vegetation intact but lowers the height of the vegetation. These changes occur over relatively small areas, less than 1% of available habitat at each crossing location in largely undisturbed systems. With the application of accepted best management practices and mitigation, the magnitude of effect at each crossing site is low, although the effects are adverse in direction. The changes to fish habitat are not anticipated to result in the loss of productivity of fisheries in these watercourses and therefore the effect is considered not significant.

The change in fish health of fish populations could occur with increased fishing pressure during operation of the highway, which can lead to increased access to watercourses containing large-bodied fish. This increased access can lead to fishing opportunities for users of the highway, which could result in overfishing of some populations of large-bodied fish, in particular Arctic grayling. This increase in fishing pressure would only be anticipated to occur during the open water season of project operation but could coincide with important migratory movements of some large-bodied fish. Concern was raised at community meetings of the potential of overfishing due to increased access to fishable watercourses during project operation. Mitigation against overfishing is limited and may include not constructing pullouts near watercourses which have large-bodied fish to reduce fishing access to these watercourses.

Population numbers of large-bodied fish along the project highway alignment is unknown and therefore the level of increased fishing pressure that a population can withstand and still be sustainable is unknown. The degree of increased fishing pressure which may occur along the Project alignment is also unknown, but as a precautionary approach to acknowledge the uncertainty, increased fishing pressure resulting in overfishing has the potential to adversely affect large-bodied fish populations and therefore has the potential to be a significant effect. The GNWT will work with SRRB and other resource managers to address uncertainty regarding the effects of increased access created by the Project on harvested resources in the assessment areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization.

In conclusion, a significant effect would only be for the change in fish population health if overfishing were to occur during construction and operations and maintenance of the Project.

17.7.2 Significance of Cumulative Effects

The change in fish habitat due to the loss and alteration of riparian habitat and fish habitat below the OHWM is not significant. Mitigation and best management practices employed during the construction of watercourse crossings are known to be effective at breaking or reducing effects on habitat. It is anticipated that there will be no loss of aquatic productivity at the crossings by the Project or other projects it interacts with cumulatively and therefore no loss of productivity within the RAA.

The change in fish health of fish populations has the potential to be significant if increased access to large-bodied fish bearing waters leads to overfishing. Not all crossings of large-bodied fish bearing waters may provide suitable fishing opportunities due to fish habitat limitations or access challenges (e.g., high banks). The implementation of management strategies to prevent overfishing can also reduce the potential for overfishing. There is uncertainty if increased access to large-bodied fish bearing watercourses will lead to overfishing but, as a conservative approach, it is assumed the potential exists.

17.7.3 Project Contribution to Cumulative Effects

The Project is the largest contributor to both change in fish habitat and change of fish health of fish populations of the cumulative projects. The Project has the largest number of crossings compared to those projects which may interact cumulatively. The Project connects other transportation-related projects to each other, increasing its contribution to a change in fish health populations.

17.8 Prediction Confidence

The predicted confidence for residual effects and residual cumulative effects for fish and fish habitat is high for the change in fish habitat effect. This prediction for changes to fish habitat is based on the accuracy of the project design information, fish and fish habitat data, and the known effectiveness for mitigation and best management practices to be used during the Project. Mitigation was identified that would break or reduce the various pathways of effects which will result from the Project. Proposed construction design for watercourse crossings has been successfully used before in the Northwest Territories (e.g., Inuvik to Tuktoyaktuk Highway) and elsewhere in Canada with no significant effects on fish and fish habitat.

The confidence level for change in fish health populations due to increased fishing pressure is low. The low confidence level is a result of the uncertainty of whether watercourses known to contain large-bodied fish provide suitable fishing opportunities along the project highway alignment; the lack of data on stock size of large-bodied fish; and if fishing pressure increased, the extent of that increase and its effects on fish populations. Prediction confidence can be increased through additional engagement with Indigenous Governments, Indigenous Organizations and other affected parties on the potential for fishing opportunities at relevant crossings and through monitoring of recreational fisheries along the project alignment.

17.8.1 Assumptions

This assessment was based on the following assumptions:

- There will be no changes in the highway alignment
- All new crossings will only require culverts
- All identified mitigation will be applied correctly

17.8.2 Gaps and Uncertainties

Data gaps related to fish and fish habitat for the Project include:

- Not all project crossings have been field assessed for fish and fish habitat.
- Population estimates for fish found along the project alignment are unknown.

The following are uncertainties as they relate to the assessment of the Project:

- Potential for changes to the alignment during the design of the Project
- Uncertainty whether watercourses where no fish were captured are fish-bearing
- Whether watercourses with large-bodied fish crossed by the Project would provide favourable fishing opportunities
- Changes in population or SAR status of fish species which occur in the RAA prior to construction of the highway and over the life of the Project due to factors external to the Project (e.g., climate change) may affect the assessment of effects
- Changes or additions of new DFO codes of practice may affect the types of mitigation measures to be applied to the Project.

17.9 Follow-up and Monitoring

The objectives of fish and fish habitat monitoring may include:

- Verify compliance with terms and conditions of authorizations and commitments
- Verify effectiveness of mitigation measures
- Verify effects predictions

A Fish and Fish Habitat Protection Plan is included in Volume 5. Monitoring of fish and fish habitat as identified in this plan integrates the requirements of the water quality and water quantity monitoring programs, as water quality and quantity are key aspects of fish and fish habitat. Visual observations and monitoring undertaken as part of the ESCP will also be used to fulfil the objectives. Monitoring as part of the ESCP will also include turbidity monitoring during instream works (see draft ESCP in Volume 5).

During operations, monitoring will include routine periodic inspection of culverts to determine if they are functioning as per design (e.g., allow fish passage) and for evidence of erosion and sedimentation. If a barrier to fish passage or erosion and sedimentation issues are observed, corrective actions would be implemented to address the problem.

The GNWT will work with SRRB and other resource managers such as DFO to address uncertainty regarding the potential effects of increased access created by the Project on the sustainability of large-bodied fish populations in the assessment areas. This would include monitoring of harvest that can be used to identify the need for management actions to be taken by the appropriate resource management organization. The need for such a program will be evaluated in cooperation with regulators and resource management agencies including the GNWT, DFO and agencies such as the SRRB. Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into a project-specific fish and fish habitat monitoring plan.

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18.0 ASSESSMENT OF POTENTIAL EFFECTS ON VEGETATION AND WETLANDS

Vegetation and wetlands were selected as a Valued Component (VC) as they support ecosystem functions such as nutrient and water cycling, habitat, and carbon accumulation, and provide socio-economic and cultural value to Indigenous Governments, Indigenous Organizations, and other affected parties. The Mackenzie Valley Highway Project (the Project) has the potential to affect vegetation and wetlands during the construction and operations and maintenance phases of the Project through pathways such as land clearing, alteration of surface and sub-surface water flow paths, and disturbance of the underlying soils.

Changes to vegetation and wetlands from the Project may also affect fish and fish habitat (see Chapter 17), caribou and moose (see Chapter 10), wildlife and wildlife habitat (see Chapter 19), birds and bird habitat (see Chapter 20), and culture and traditional land use, including harvesting (see Chapter 11). Changes may occur due to loss or alteration of naturally vegetated areas. Vegetation is identified as a Subject of Note in the Terms of Reference (ToR) issued by the Mackenzie Valley Environmental Impact Review Board (MVEIRB, 2015 [Public Registry {PR}#66]). Assessment of vegetation and wetlands as a VC facilitates the assessment of other VCs, including terrain, soils, and permafrost; air quality; water and sediment quality; and water quantity.

The assessment of potential effects on vegetation and wetlands concludes that with the application of mitigation measures, residual effects resulting from the Project on vegetation and wetlands will be adverse. Residual effects and cumulative effects will not threaten the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or threaten the long-term viability of local or regional wetland function and therefore will be not significant.

18.1 Scope of Assessment

18.1.1 Regulatory and Policy Setting

The assessment of potential effects on vegetation and wetlands is guided by the ToR (MVEIRB, 2015) and the following federal and territorial legislation and guidance.

18.1.1.1 Federal

18.1.1.1.1 *Species at Risk Act*

The *Species at Risk Act* (SARA) is federal law that aims to prevent endangered or threatened species from becoming extinct or extirpated and manages species of special concern to help prevent them from becoming endangered or threatened. The status of species is assessed and designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which then recommends a designation for legal protection by being officially listed under SARA. Both plant and animal species can be listed under SARA. There are five vascular plant species and one moss species protected under SARA in the Northwest Territories (NWT); however, none of these species has a range which overlaps with the Project (Government of Canada. 2019).

Under SARA, the individual, the residence, and the habitat of listed species are protected on all federal lands, and on other lands where an order under SARA has been issued for an individual species where it has been determined that the provincial, territorial, or other government is not effectively protecting the species and its habitat through its laws.

18.1.1.1.2 *Fisheries Act*

The *Fisheries Act* provides for the protection of fish and their habitat (including benthic invertebrates). The *Fisheries Act* prohibits causing harmful alteration, disruption, or destruction (HADD) of fish habitat (section 35 of the *Fisheries Act*), death of fish by means other than fishing (section 34.4[1]), and the introduction of a deleterious substance (section 36). The Act also includes provision for flow and passage (section 34.3) and a framework for regulatory decision-making (section 34.1).

The *Fisheries Act* requires that projects avoid causing HADD of fish and fish habitat, unless authorized by the Minister of Fisheries and Oceans Canada (DFO). Projects with the potential to obstruct fish passage, modify flow, or result in entrapment of fish may also qualify as causing HADD to fish. Where a non-compliance of the *Fisheries Act* cannot be avoided or mitigated, an Authorization under paragraph 35(2)(b) of the *Fisheries Act* is required. The Fisheries Protection Program, maintained by DFO and its collaborative partners, is responsible for the review of projects to determine if a non-compliance of the *Fisheries Act* is likely to occur.

18.1.1.1.3 Federal Policy on Wetland Conservation

The Federal Policy on Wetland Conservation (Government of Canada, 1991) commits all federal departments to the goal of no net loss of wetland functions that:

- Are on federal lands and waters; or,
- Are in areas affected by the implementation of federal programs and activities where the continuing loss or degradation of wetlands or their functions have reached critical levels; or,
- May affect wetlands that are ecologically or socio-economically important to a region in NWT (includes wetland areas that are used as hunting, trapping, and fishing resources).

Wetland functions that coincide with areas of federal regulatory jurisdiction, such as habitat for species listed under SARA and migratory birds considered under the *Migratory Bird Convention Act*, are of particular concern to federal regulatory agencies and wetland compensation may be required if an effect on SARA listed species, fish, or migratory birds is predicted.

While the federal policy applies directly to projects occurring on federal land and waters, or those that receive federal funds, it also provides guidance on national priorities for wetland conservation. Although no wetlands of international importance are likely to be affected by the Project (Ramsar Convention Secretariat, 2019), this policy is used as guidance to maintain consistency with national priorities for wetland conservation. The federal wetland policy has not been updated since 1991.

18.1.1.2 Territorial

18.1.1.2.1 Species At Risk in Northwest Territories

The *Species at Risk (NWT) Act* identifies and protects plant and animal species at risk (SAR) in NWT. The Act protects occurrences and habitat of designated SAR and their habitats to avoid further decline and to promote recovery. There is one plant species, hairy braya (*Braya pilosa*), listed as At Risk under the *Species at Risk (NWT) Act*.

Species of conservation concern (SOCC) are those plant species listed by the Working Group on General Status of NWT Species (2016) as May Be at Risk or Sensitive. Species with a rank of May be at Risk are the highest priority for more detailed assessment by the NWT Species at Risk Committee. Species ranked Sensitive are not at high risk of extinction or extirpation but require some special attention or protection to prevent them from becoming more at risk. Species in both of these categories are not protected under the *Species at Risk (NWT) Act*.

18.1.1.2.2 *Wildlife Act*

The *Wildlife Act* of the NWT provides general provisions for regulating the prevention of wildlife and plants declared to be pests, including the import, control, and destruction of these species (under subsection 100[1]).

18.1.1.2.3 *Forest Management Act*

The *Forest Management Act* concerns the management and use of forests in Northwest Territories. It contains provisions on its administration and on the functions and powers of forest officers, forest management agreements, permits and licences, enforcement, offences and penalties, and on the resolution of disputes.

18.1.1.2.4 *Forest Protection Act*

The *Forest Protection Act* was created by the Government of the Northwest Territories (GNWT) to set provisions to secure the protection of forests in Northwest Territories. It covers the extinguishment of fires, clearance, fires to clear land, fires in engines, the administration of the Act by forest officers, enforcement, and offences and penalties.

18.1.1.2.5 *Waters Act*

The *Waters Act* and its Waters Regulations regulate the direct and indirect use of waters and disposal of wastes and physical alterations to inland waterbodies.

18.1.1.3 Sahtu Land Use Plan

Specific to the areas to which the Sahtu Land Use Plan (SLUP) applies, the Project must meet the 13 general conformity requirements (CR) of the SLUP (Sahtú Land Use Planning Board [SLUPB], 2023). The SLUP's conformity requirements include consideration of species introduced in CR#8 and sensitive species and features in CR#9, which are reproduced below as they relate to vegetation and wetlands:

> CR#8: *"Land use activities must not result in the intentional introduction of non-native plant and animal species, or of domestic animal species."*
>
> CR#9: *"1) Any land use activity requiring a land use permit or water license must be designed using the most current available information on the location of rare or may-be-at-risk plants, hot and warm springs, mineral licks, karst topography, amphibian sightings, and ice patches and carried out in a manner that minimizes impacts to these features.*
>
> 2) Specifically, land use activities:
>
> *b) that are situated within the boundary of glacial refugia or within 500 m of known hot or warm springs and have the potential to impact rare or maybe-at-risk plants shall require a plant survey. Any rare or maybe-at-risk plants found in the survey shall be monitored for impacts from the activity."* (SLUPB, 2023)

Conformity Requirement #2 requires that *"The proposed activities must be designed and carried out with due regard for community concerns and incorporate relevant traditional knowledge.".* Additionally, per CR#14, the Project must be designed and carried out in a manner that protects, respects, or takes into account the values of the Conservation Zones (CZ) and Special Management Zones (SMZ) potentially affected by the Project as directed in the SLUP's Zone Descriptions (SLUPB, 2023), including the following:

- Petiniʔah (Bear Rock) CZ (Zone #32)
- Mio Lake CZ (Zone #36)
- Norman Range SMZ (Zone #50)
- K'ąąlǫ Tué (Willow Lake Wetlands) SMZ (Zone #62)
- Deh Cho (Mackenzie River) SMZ (Zone #63)

18.1.2 Influence of Engagement

The GNWT has engaged with affected Indigenous Governments, Indigenous Organizations, and other affected parties. Detailed information regarding these engagement activities is presented in Chapter 2 (Consultation and Engagement), Chapter 3 (Traditional Knowledge), and Chapter 11 (culture and traditional land use). The GNWT has recently initiated Consultation with Indigenous Governments and Indigenous Organizations.

Through the project-specific engagement program delivered between 2010-2012 and 2021-2023, including project-specific traditional land and resource use (TLRU) studies, Indigenous Governments, Indigenous Organizations, and other affected parties shared information, expressed concerns, and provided recommendations related to vegetation, wetlands, and plant harvesting. This feedback has been considered and summarized in Table 18.1 and has been integrated into the assessment of potential effects on vegetation and wetlands that follows.

Table 18.1 Summary of Engagement Feedback

Comment	Source	GNWT Response	Where Addressed
Engaged Indigenous Governments, Indigenous Organizations and other affected parties identified plant harvesting locations near the Project.	Dehcho First Nations, 2011; EBA, 2006; IMG-Golder, 2006; Norman Wells Renewable Resources Council (NWRRC), 2023; SLUPB, 2022; Tulita Renewable Resources Council (TRRC), 2022	The GNWT has identified mitigation measures to reduce or eliminate the effects on vegetation and wetlands. The preliminary highway alignment route deviates from the MVWR in areas of wetlands. Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible. The GNWT Department of Infrastructure (INF) will develop an invasive alien plant species monitoring program in discussion with GNWT Environment and Climate Change (ECC). The GNWT-INF will undertake regular inspection for invasive alien plant occurrences and apply management through mowing to reduce introduction and spread of invasive alien plant species in the ROW and surrounding natural vegetation.	For information about plant species of interest and important habitat and harvesting locations, see Section 18.2.2.4. For mitigation measures to reduce or eliminate effects on vegetation and wetlands, see Table 18.8 See also: Section 5.2.3 (Design Considerations) Section 18.4.2 (Change in Landscape Diversity) Section 18.4.3 (Change in Community Diversity) Section 18.4.4 (Change in Species Diversity) Section 18.4.5 (Change in Wetland Function) Chapter 9 (Socio-economic Impact Assessment: Human Health and Community Wellness) Chapter 11 (culture and traditional land use, including harvesting) Volume 5 for management, monitoring, and protection plans.
Community engagement participants stated that vegetation is growing faster than it used to. Since the Canyon Creek Road was constructed, participants are seeing more lady slipper, which normally grows along cliffs and muskeg, but is now commonly found along the road out in the open.	November to December 2022 Engagement		
Community engagement participants expressed concern about the introduction of invasive species during construction and requested that all equipment be cleaned and sanitized.	November 2022 to February 2023 Engagement		
Community engagement participants recommended that the GNWT allow the vegetation to grow back naturally following construction.	November 2022 to February 2023 Engagement		
Community engagement participants recommended that the route avoid wetlands and swampy areas.	November 2022 to February 2023 Engagement		

Comment	Source	GNWT Response	Where Addressed
Community engagement participants members expressed concern that development may affect human health through water and air quality, and the health of the region's vegetation.	Golder, 2015	(*cont'd from above*) Abandoned sections of MVWR ROW and access roads will be reclaimed to promote re-establishment of vegetation cover. A Spill Contingency Plan (SCP) will be developed and implemented. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties during advancement of project design and planning. The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects on plant species of interest to Indigenous Governments, Indigenous Organizations and other affected parties.	
Pehdzéh Kı̨ First Nation and Dehcho First Nations expressed concerns about potential effects during construction on the land and forest. Reforestation was identified as important to the participants.	Dessau, 2012 (PR#13)		
Sahtu Dene and Métis expressed concerns about potential effects on resident species, including effects of increasing invasive species which can influence potential for wildfires. Changes in vegetation and wetlands and changes resulting from removal of permafrost may result in decreased plants, and plant harvesting locations available to Indigenous harvesters.	SRRB, 2016		
NWRRC TLRU study participants raised concerns about changing temperatures and the cumulative effects of climate change on vegetation during project construction and operation	NWRRC, 2023		

18.1.3 Potential Effects, Pathways and Measurable Parameters

Potential effects on vegetation and wetlands could occur wherever project activities interact with vegetation or wetland resources. The key focus for the Vegetation and Wetlands VC is the sustainability of plant species and plant communities, and the maintenance of wetland functions. Potential effects could occur through the direct loss of plant species and plant communities that support traditional use activities, provide habitat, and support intrinsic ecological values such as biodiversity. Loss of wetland functions resulting from clearing, ground disturbance, or altering natural drainage patterns could also occur.

The potential effects on vegetation and wetlands considered in this Developer's Assessment Report (DAR) include:

- Change in landscape diversity
- Change in community diversity
- Change in species diversity
- Change in wetland functions

Table 18.2 summarizes the potential effects, effects pathways and measurable parameters.

Table 18.2 Potential Effects, Effects Pathways, and Measurable Parameters for Vegetation and Wetlands

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in landscape diversity	• Fragmentation of native plant communities/landcover types arising from clearing	• Patch area of native landcover types (hectares [ha]) • Perimeter (edge) length (metres [m]) to area (ha) ratio of native landcover type patches • Risk of change in landcover plant composition from competition with alien or invasive alien plant species
Change in community diversity	• Direct loss or alteration of native communities/landcover types from clearing and ground disturbance • Removal of merchantable timber • Indirect alteration of native communities/landcover types, including riparian areas, from the introduction or spread of alien and invasive alien plant species and pests, or dust contaminant deposition	• Area (ha) of native upland and wetland communities and spatial distribution • Area (ha) and qualitative description of spatial distribution of forest stand age classes • Change in amount of merchantable timber (cubic metres [m^3]) • Quantitative (ha) and qualitative estimation of native upland and wetland communities affected by dust contaminant deposition

Potential Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in species diversity	• Direct loss of occurrences of plant SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties, such as renewable resources councils from clearing and ground disturbance • Indirect loss or alteration of SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils from the introduction or spread of invasive alien plants, and dust contaminant deposition	• Qualitative estimation of SOCC lost and spatial distribution • Qualitative estimation of changes in abundance of plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils, spatial distribution, and identified collection locations • Qualitative estimation of changes in abundance of plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils, spatial distribution, and identified collection locations
Change in wetland function	• Direct loss of wetland area or alteration of wetland function (i.e., hydrology, structure, plant composition, nutrient cycling, and litter accumulation) from clearing or infilling of wetlands • Indirect alteration of wetland area or function (i.e., hydrology, structure, plant composition, nutrient cycling, and litter accumulation) from changes in surface or groundwater flow patterns	• Area (ha) and spatial distribution of wetland types • Qualitative evaluation of altered surface and shallow groundwater flow patterns

18.1.4 Boundaries

18.1.4.1 Spatial Boundaries

The Project Development Area (PDA), Local Assessment Area (LAA), and Regional Assessment Area (RAA) for the assessment of effects on vegetation and wetlands are shown in Figure 18.1. These spatial boundaries are used to assess project effects, including residual and cumulative effects from the Project on vegetation and wetlands.

- **Project Development Area (PDA):** The area of direct project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps, and quarry/borrow sites with access roads on a 30 m ROW.

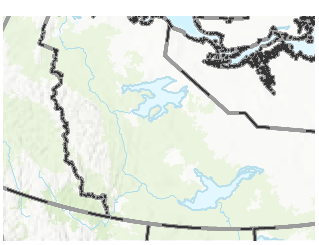
- **Local Assessment Area (LAA)**: The area within which measurable project-related effects (direct or indirect) are expected to occur. The LAA for vegetation and wetlands is a 1 kilometre (km) buffer around the preliminary highway alignment route centerline, quarry and borrow source extents, and associated access roads. The size of the LAA is based on measurable extent of project-related effects (direct or indirect) to vegetation and wetlands, while also considering recommended setback distances for certain wildlife and wildlife habitat features consistent with guidance provided by Environment and Climate Change Canada (ECCC) [Dufour, 2020, pers. comm.].
- **Regional Assessment Area (RAA)**: The area that provides context for determining significance of project effects and potential cumulative effects. The RAA for vegetation and wetlands aligns with that for wildlife and wildlife habitat and is the area within approximately 15 km of the PDA. A 15 km buffer was selected to provide context for determining significance of project-specific effects and potential cumulative effects and is consistent with other highway projects in the NWT (e.g., Inuvik to Tuktoyaktuk Highway [Kiggiak-EBA, 2011]).

18.1.4.2 Temporal Boundaries

The temporal boundaries for the Project consist of the following phases, which are described in more detail in Chapter 5:

- **Construction phase:** The Project will take approximately 10 years to construct over a timeframe of up to 20 years. The conceptual schedule assumes the highway will be constructed in three consecutive segments, beginning in approximately 2026: Wrigley north to the Dehcho–Sahtu border (102 km); Tulita south to the Dehcho–Sahtu border (134 km); and Tulita north to the Prohibition Creek Access Road (45 km). The conceptual schedule assumes the Project would be fully constructed and provide all-season connection to Norman Wells sometime between 2041 and 2046.
- **Operations and maintenance phase:** The operations and maintenance phase will commence in a staged manner once construction of each segment has been completed. The operations and maintenance phase is considered indeterminate as the highway is intended to be permanent infrastructure.

A closure and reclamation phase is not applicable to the Project. Closure and reclamation of temporary workspaces, and borrow sources and quarries used only for construction are included within the construction phase.



18.1.5 Residual Effects Characterization

Table 18.3 presents definitions for the characterization of residual effects on vegetation and wetlands. Residual effects are those that remain after mitigation measures have been implemented.

Table 18.3 Characterization of Residual Effects on Vegetation and Wetlands

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Adverse:** A residual effect that moves measurable parameters of vegetation and wetlands in a negative direction relative to baseline **Neutral:** No net change in measurable parameters for vegetation and wetlands relative to baseline
Likelihood	The probability that the residual effect will occur	**Unlikely –** The residual effect is almost certain not to occur **Possible –** The residual effect could occur **Certain –** The residual effect will certainly occur
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**: No measurable change in vegetation or wetlands **Low**: A measurable change in distribution and abundance of vegetation and wetlands, but no loss within the LAA of any of: • Large intact native vegetation patches • Upland or wetland landcover types • Occurrences of plant SOCC • Plants of importance to Indigenous Governments, Indigenous Organizations, and other affected parties Or, changes in distribution of existing invasive alien plants, but no new invasive alien plants introduced
		Moderate: Loss within the LAA of any of: • Large intact native vegetation patches • Upland or wetland landcover types • Occurrences of plant SOCC which are the only occurrences of that SOCC in the LAA • Plants of importance to Indigenous Governments, Indigenous Organizations, and other affected parties Or, changes in distribution of invasive alien plants in the LAA, and likely introduction of new invasive alien plants

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Magnitude (cont'd)		**High**: Loss within the PDA or LAA of any of: • Large intact native vegetation patches • Upland or wetland landcover types • Occurrences of plant SOCC which are the only occurrences of that SOCC in the RAA • Plants of importance to Indigenous Governments, Indigenous Organizations, and other affected parties Or, changes in distribution of invasive alien plants in the RAA, and likely introduction of new invasive alien plants
Geographic Extent	The geographic area in which a residual effect occurs	**PDA:** Residual effects are restricted to the PDA **LAA:** Residual effects extend into the LAA **RAA:** Residual effects interact with effects of other projects in the RAA
Timing	Considers when the residual effect is expected to occur, where relevant to vegetation and wetlands	**No sensitivity:** Seasonal timing of effect does not affect the vegetation and wetlands. **Moderate sensitivity:** Vegetation and wetlands are moderately sensitive to seasonal timing. **High sensitivity:** Vegetation and wetlands are highly sensitive to seasonal timing.
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	**Short-term:** The residual effect is restricted to a single construction segment **Medium Term**: The residual effect lasts through the construction phase (up to 20 years) **Long-term:** The residual effect extends beyond construction or throughout operation
Frequency	Identifies how often the residual effect occurs and how often during the project or in a specific phase	**Single event:** The residual effect occurs once **Multiple irregular event:** The residual effect occurs at no set schedule **Multiple regular event:** The residual effect occurs at regular intervals **Continuous**: The residual effect 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

18.1.6 Significance Definition

A significant adverse residual effect on vegetation and wetlands is one that, following the application of avoidance and mitigation measures, threatens the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or threatens the long-term viability of local or regional wetland function.

18.2 Existing Conditions for Vegetation and Wetlands

Project activities have the potential to directly or indirectly change the abundance or distribution of vegetation and wetland resources, including: landcover types, native vegetation communities, occurrences of SAR, SOCC, and wetland function. Potential residual effects on vegetation and wetlands (Section 18.4) are assessed relative to the existing conditions of these resources. This section provides an overview of the existing conditions relative to the presence and relative abundance of vegetation and wetlands in the LAA and RAA. More detailed information about existing conditions for vegetation and wetlands within the LAA and RAA is provided in the Vegetation and Wetlands Technical Data Report (TDR; Appendix 18A; K'alo-Stantec, 2022).

18.2.1 Methods

A review of existing data sources and previous studies regarding vegetation and wetland resources was completed within the LAA and RAA to characterize conditions and identify gaps in information. Vegetation communities, wetlands, and occurrences of historical fires were identified from existing provincial and federal spatial data sets. The analysis of baseline conditions and project effects were completed using the spatial data layer of mapped ecosystems overlain with a spatial data layer of existing disturbances and the PDA and LAA. In addition, a review of relevant traditional land and resource use information was completed summarizing data from publicly available sources that provides information on existing conditions and potential project effects as identified by Indigenous Governments, Indigenous Organizations, and other affected parties. For example, recent traditional land and resource use information has highlighted the importance of plants within the LAA (TRRC, 2022; Section 3.1.2.2 in Appendix 18A [K'alo-Stantec, 2022]). In the Northwest Territories, invasive alien plants are those species referred to in GNWT Invasive Alien Species webpage (GNWT, 2023).

Details on the methods used for ecosystem mapping, rare plant, and alien and invasive alien species are described in the Vegetation and Wetlands TDR (Appendix 18A; K'alo-Stantec, 2022).

18.2.2 Overview

The Project is situated in the Mackenzie Valley region of the NWT between the current terminus of the existing all-season highway in Wrigley (Highway #1, kilometre marker [KM] 690) and Prohibition Creek, approximately 28 km south of Norman Wells (Figure 18.1). The Project intersects three, level III ecoregions: the Taiga Plains Low Subarctic, Taiga Cordillera Low Subarctic, and Boreal Cordillera High Boreal. These ecoregions are mainly conifer-dominated though differ in terrain, wetland occurrence, and climate. The Taiga Plains Low Subarctic is the most northerly ecoregion intersected by the Project and is characterized by undulating plains, upland communities of white and black spruce, and permafrost-influenced wetlands (Ecosystem Classification Group, 2007). Further south, within the Taiga Cordillera Low Subarctic ecoregion, fewer waterbodies and peatlands exist and mountainous terrain, foothills, tundra, and spruce woodlands become more common (Ecosystem Classification Group, 2010). The most southerly ecoregion intersected by the Project is the Boreal Cordillera High Boreal. In comparison to the Taiga Cordillera Low Subarctic, the Boreal Cordillera High Boreal has a milder climate, greater precipitation, and taller, more dense stands of spruce woodland (Ecosystem Classification Group, 2010).

Other than local communities, the existing MVWR and the Norman Wells Pipeline, the LAA and RAA are relatively anthropogenically undisturbed. Oil and gas exploration and production infrastructure in the RAA occurs on the west side of, and near, the Mackenzie River (Deh Cho) close to Norman Wells (Auld and Kershaw, 2005). Other existing disturbances include borrow sources and quarries, a fibre optic line, and bridges associated with the MVWR. Landcover in the LAA includes exposed land, which includes areas recently burned in forest fires.

18.2.2.1 Landcover

A total of 64.9% of the LAA (40,759.4 ha), and 61.6% of the RAA (622,993.1 ha), is upland (Table 18.4). The majority of upland area (59.6% of the LAA [37,582.2 ha] and 58.2% of the RAA [602,905.9 ha]) is likely natural vegetation, including broadleaf forest, coniferous forest, mixedwood forest, and bryoid landcover types. Areas of herb and rock rubble, as well as exposed land in the LAA, are mostly a result of human disturbance. However, there are some naturally occurring thinly vegetated areas in the RAA, including barren areas bordering the Mackenzie River (Deh Cho). Of the natural upland vegetation, coniferous forest is the most abundant landcover type occupying 33.9% (21,311.1 ha) of the LAA and 31.7% (320,215.5 ha) of the RAA. Most coniferous forest cover types are located east of the Mackenzie River (Deh Cho) in the Dehcho Region portion of the LAA and west and northeast of the Mackenzie River (Deh Cho) in Sahtu Region portions of the LAA (Figure 18.2 and Figure 18.3).

Wetlands are present in the LAA and RAA in similar abundance, occupying 23.5% (14,760.5 ha) of the LAA and 26.6% (269,092.1 ha) of the RAA (Table 18.4). Wetland-shrub and wetland-treed are the most common wetland type in both the LAA and RAA, occupying 8.7% and 9.4% respectively in the LAA and 9.7% and 11% in the RAA. Wetland-herb wetlands occupy similar percentages of the LAA and RAA at 5.4% in the LAA and 5.7% in the RAA. Wetlands are located throughout the LAA, with highest concentrations of wetlands in the Dehcho Region of the LAA occurring along watercourses adjacent to Mackenzie River (Deh Cho) (Figure 18.2) and the highest concentrations in the Sahtu Region of the LAA occurring near areas of open water (Figure 18.3).

Table 18.4 Landcover Abundance in the LAA and RAA

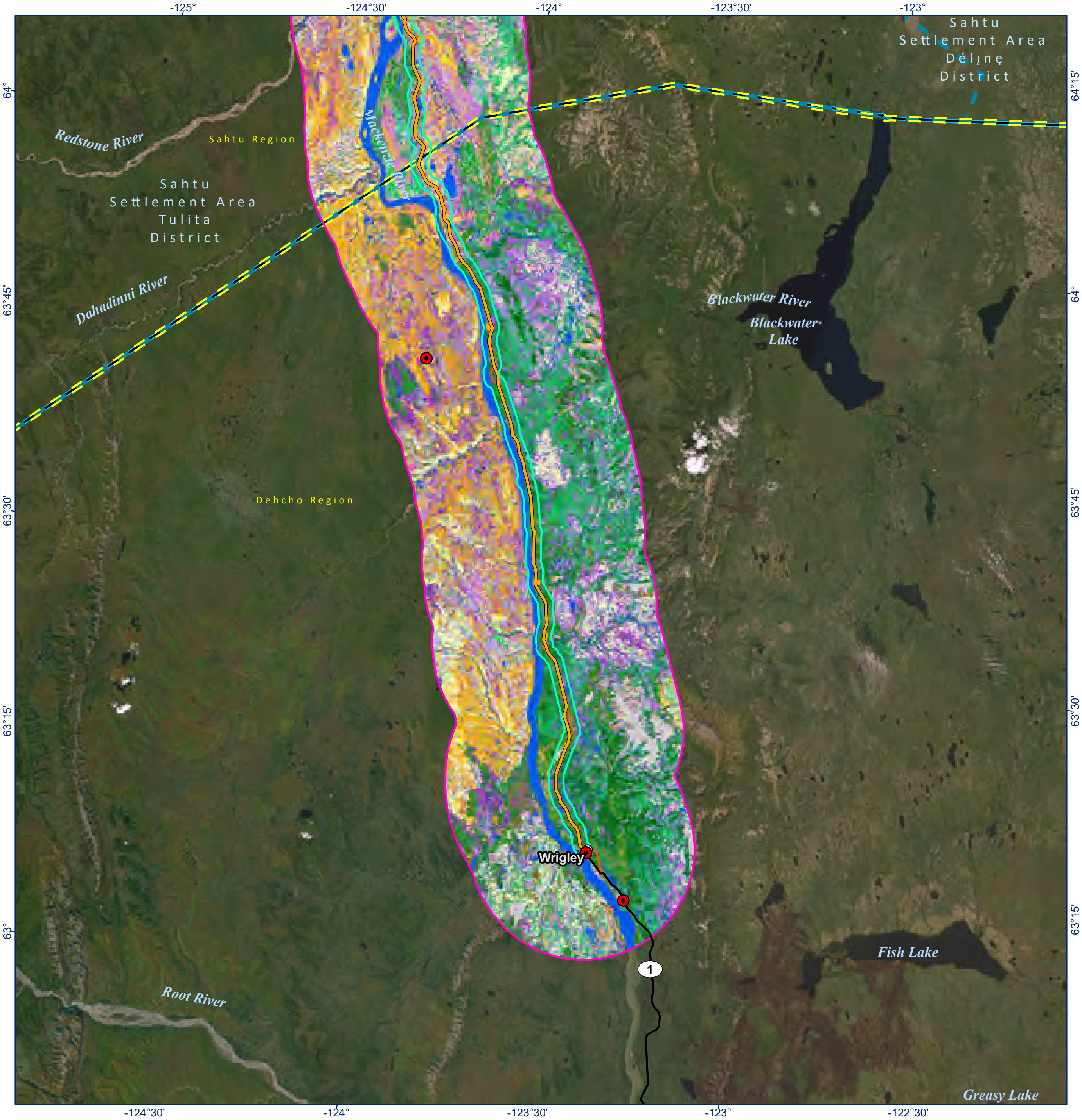
Landcover Type	Cover Type Class	LAA		RAA[2]	
		ha	%	ha	%
Broadleaf Forest	Broadleaf Dense	2,669.3	4.2	78,054.2	7.7
	Broadleaf Open	956.4	1.5	18,757.5	1.9
Broadleaf Forest Subtotal		**3,625.7**	**5.8**	**96,811.6**	**9.6**
Coniferous Forest	Coniferous Dense	3,617.8	5.8	43,662.5	4.3
	Coniferous Open	9,250.3	14.7	153,328.3	15.2
	Coniferous Sparse	8,442.9	13.4	123,224.8	12.2
Coniferous Forest Subtotal		**21,311.1**	**33.9**	**320,215.5**	**31.7**
Mixedwood Forest	Mixedwood Dense	1,144.4	1.8	14,265.0	1.4
	Mixedwood Open	2,098.4	3.3	26,548.9	2.6
	Mixedwood Sparse	5.1	<0.1	11.7	<0.1
Mixedwood Forest Subtotal		**3,247.9**	**5.2**	**40,825.6**	**4.0**
Shrubland	Shrub low	7,282.3	11.6	111,571.8	11.0
	Shrub tall	1,996.1	3.2	18,165.1	1.8
Shrubland Subtotal		**9,278.4**	**14.8**	**129,736.9**	**12.8**
Herbaceous and Unvegetated	Bryoids	12.9	<0.1	157.4	<0.1
	Exposed land[1]	2,943.5	4.7	14,744.8	1.5
	Herb	233.7	0.4	5,342.4	0.5
	Rock / Rubble	106.2	0.2	15,158.9	1.5
Herbaceous and Unvegetated Subtotal		**3,296.3**	**5.2**	**35,403.5**	**3.5**
Wetland	Wetland-herb	3,384.1	5.4	57,480.5	5.7
	Wetland-shrub	5,486.2	8.7	100,003.5	9.9
	Wetland-treed	5,890.3	9.4	111,608.0	11.0
Wetland Subtotal		**14,760.5**	**23.5**	**269,092.1**	**26.6**
Open Water	Water	7,383.1	**11.7**	118,138.8	**11.7**
No Data	No Data	0.0	**0.0**	259.9	**<0.1**
Total		**62,903.1**	**100**	**1,010,483.8**	**100**

Note:

1 Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as the existing MVWR, Norman Wells Pipeline, and other areas of infrastructure development.

2 Occurs within the RAA outside the LAA and PDA

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).



Alien and Alien Invasive (weed) Occurrence*

Landcover Type

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Project Route
- Local Assessment Area (LAA)
- Regional Assessment Area (RAA)
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

* More than one alien or alien invasive plant may occur at each mapped location

0 10 20 Kilometers

(At original document size of 8.5x11)
1:800,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/3/2023
TR by AJ on 8/3/2023

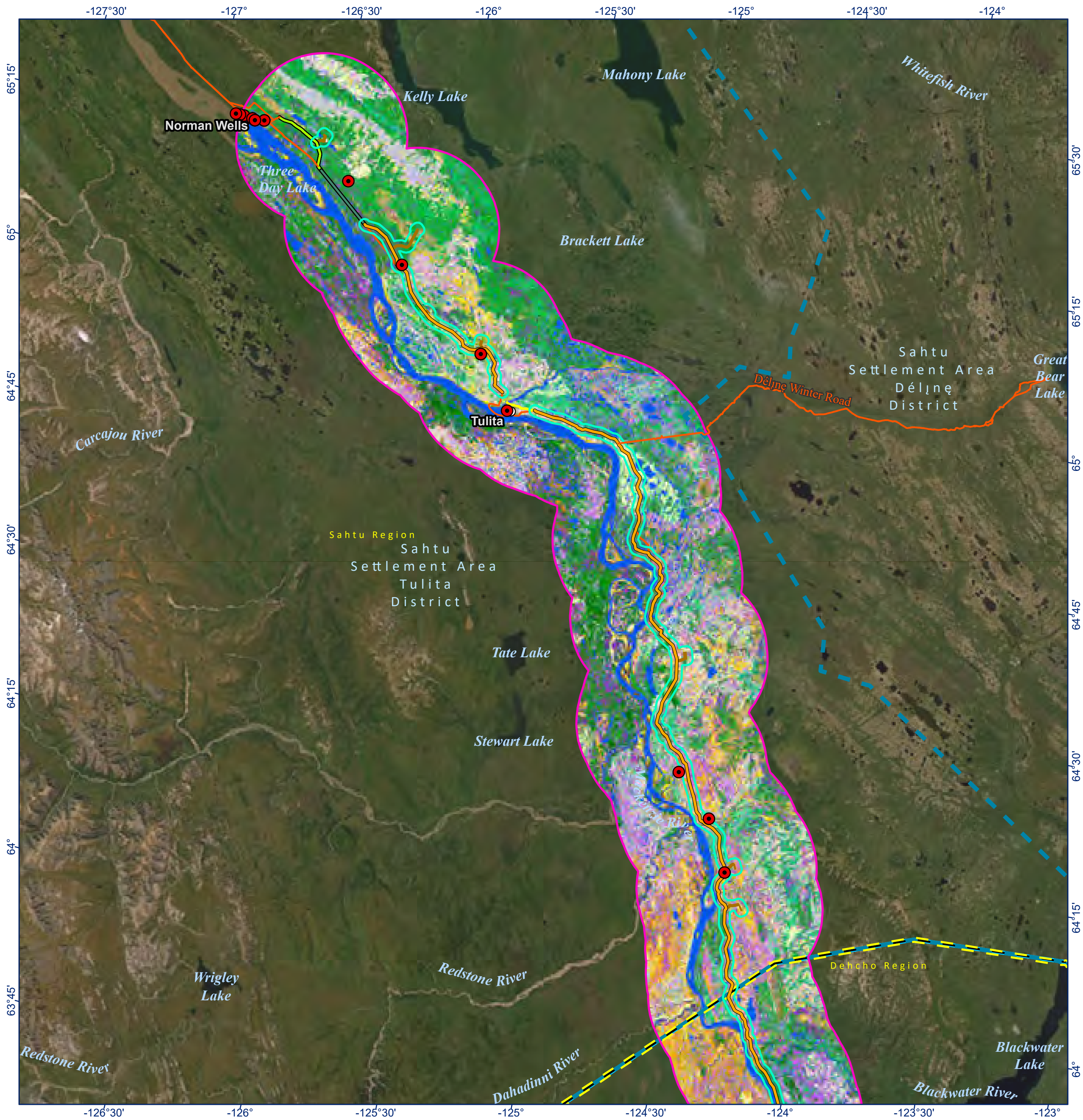
Client/Project
144903025-0103-REVA

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
18.2

Title
Landcover Types and Documented Alien and Invasive Alien Species Occurrences within the Mackenzie Valley Highway Project LAA and RAA – Dehcho Region

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS. Imagery date: 2021



- Alien and Alien Invasive (weed) Occurrence*

Landcover Type

- Water
- Rock/Rubble
- Exposed Land
- Bryoids
- Shrub - Tall
- Shrub - Low
- Wetland - Treed
- Wetland - Shrub
- Wetland - Herb
- Herb
- Coniferous - Dense
- Coniferous - Open
- Coniferous - Sparse
- Broadleaf - Dense
- Broadleaf - Open
- Mixedwood - Dense
- Mixedwood - Open
- Mixedwood - Sparse
- Proposed Mackenzie Valley Highway Project Route
- Canyon Creek All Season Access Road (Constructed)
- Prohibition Creek Access Road (In Construction)
- Proposed Great Bear River Bridge
- Proposed Borrow / Rock Quarry Site and Access
- Local Assessment Area
- Regional Assessment Area
- Community
- Northwest Territories Highway
- Winter Road
- Settlement Area Boundary
- Region Boundary

* More than one alien or alien invasive plant may occur at each mapped location

0 10 20 Kilometers

(At original document size of 8.5x11)
1:1,100,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 8/3/2023
TR by AJ on 8/3/2023

Client/Project
144903025-0105-REVA
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
18.3

Title
Landcover Types and Documented Alien and Invasive Alien Species Occurrences within the Mackenzie Valley Highway Project LAA and RAA – Sahtu Region

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS
Imagery date: 2021

Large portions of the LAA and RAA have burned in the past. However, fires in the LAA are not common, with a maximum of two fires per decade recorded (1990-1999). The percentage of the LAA burned ranged from 0% to 12.8% per decade from 1960 to 2019 (Appendix 18A; K'alo-Stantec, 2022). In comparison to the LAA, the RAA burned more frequently, and had a greater proportion burned. However, this is likely an artifact of the size difference between the LAA and RAA and is not suspected to reflect a greater chance of burning.

Similar to the Dehcho Region, large portions of the LAA and RAA in the Sahtu Region have burned in the past. Fires were generally common in the LAA, with every decade since 1960 experiencing at least one burn. The number of fires ranged from one (1960-1969, 2010-2019) to a maximum of five (1990-1999). Less than 1% to 61.1% of the LAA burned each decade between 1960 and 2019 (Appendix 18A; K'alo-Stantec, 2022).

18.2.2.2 Timber

Merchantable timber includes trees without defects with a diameter at breast height (dbh) of at least 14 centimetres (cm). More detailed information from ground data is needed to provide detailed merchantable timber volume estimates, but merchantable timber volume is expected to be approximately 65% of total timber volume (National Forestry Database, 2022).

Coniferous forests have the greatest total volume of timber in the LAA (448,465 m^3) and mixedwood forests had the highest average stand volume density per hectare in the LAA. On average, trees within mixedwood forest of the LAA were tallest (9.5 m, standard deviation (SD) = 1.6), followed by coniferous forest (9.1 m, SD = 2.2), then broadleaf forest (8.5 m, SD = 2.2). Within the LAA, coniferous forest had the tallest maximum tree height (19 m) (Appendix 18A; K'alo-Stantec, 2022).

Coniferous forest also had the greatest total volume within the RAA, although average stand volume density was lower in the RAA (31.0 cubic metres per hectare [m^3/ha]) than in the LAA (40.2 m^3/ha). In comparison to the LAA, average tree height in coniferous forest within the RAA was also shorter (7.7 m, SD = 2.5). Within the RAA, average tree height was greatest for mixedwood forest (8.9 m, SD = 2.1), followed by coniferous forest (7.7 m, SD = 2.5), then broadleaf forest (6.7 m, SD = 1.9). Tallest maximum tree height occurs in coniferous and mixedwood forest (22 m) (Appendix 18A; K'alo-Stantec, 2022).

Similar to the Dehcho Region, coniferous forests in the Sahtu Region have the greatest total volume in the LAA (288,702 m^3) and mixedwood forests had the highest stand volume density. Tree heights within the LAA range from 5 m to 18 m and were tallest on average within mixedwood forest (8.2 m, SD = 1.9). Tallest maximum tree height within the LAA occurs within broadleaf forest (Appendix 18A; K'alo-Stantec, 2022).

Similar to the LAA, within the RAA of the Sahtu Region total volume was greatest for coniferous forest (5,590,767 m^3) but mixedwood forest had the greatest average stand volume density (30.2 m^3/ha). In comparison to the LAA, maximum tree heights were greater within the RAA for all forest cover types. Tree heights within the RAA range from 4 m to 22 m and on average were greatest within mixedwood forest (7.8 m, SD = 2.0). Tallest maximum tree height also occurs in mixedwood forest within the RAA (Appendix 18A; K'alo-Stantec, 2022).

18.2.2.3 Plant Species of Conservation Concern

A search of the NWT Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016) queried to ecoregions intersecting the RAA, identified 215 plant and lichen SOCC in the Sahtu region. Specifically, 167 rare vascular plant, 42 rare lichen, and 6 rare bryophyte (moss and liverwort) species potentially occur in the intersected ecoregions of the Sahtu Region. No plant, including bryophytes, or lichens occurring in the Boreal Cordillera ecoregion or the Taiga Cordillera ecoregion are listed under SARA or COSEWIC. No rare vegetation assemblages are listed by the NWT Species Monitoring Infobase, SARA, or COSEWIC.

Within the Sahtu Region of the RAA, seven rare vascular plant occurrences have been documented, six of which are considered Sensitive and one is considered May Be At Risk (5658 NWT Ltd. And GNWT, 2011 [PR#16]) (Table 18.5).

Table 18.5 Documented Rare Plant Occurrences within the RAA – Sahtu Region

Scientific Name[1]	Common Name	NWT General Species Rank[1]	SARA Status[2]	COSEWIC Assessment[2]
Elymus canadensis	Canada nodding wild rye	Sensitive	-	-
Potamogeton natans	floating pondweed	Sensitive	-	-
Potamogeton foliosus	leafy pondweed	Sensitive	-	-
Juncus stygius	moor rush	Sensitive	-	-
Danthonia spicata	poverty wild oat grass	Sensitive	-	-
Najas flexilis	slender naiad	Sensitive	-	-
Rhynchospora alba	white beakrush	May Be At Risk	-	-

Notes:

1 Working Group on General Status of NWT Species (2016).

2 Government of Canada (2019).

Source: 5658 NWT Ltd. And GNWT (2011 [PR#16]).

The search of the NWT Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016) queried to ecoregions intersecting the RAA of the Dehcho Region (Boreal Cordillera and Taiga Cordillera ecoregion) identified 107 SOCC including 77 rare vascular plants, 6 rare mosses or liverworts, and 24 rare lichens with potential to occur within the RAA (Vegetation and Wetlands TDR, Appendix 18A; K'alo-Stantec, 2022). All 107 of the SOCC intersecting the Dehcho Region are included in the 215 SOCC identified in the Sahtu Region.

No rare plant occurrences have been documented within the Dehcho Region of the RAA (Dessau, 2012 [PR#13]). Several species reported by Dessau (2012 [PR#13]) were previously considered rare but have since been downgraded and are no longer considered rare. No plant, including mosses, or lichen SOCC potentially occurring in the Dehcho Region of the RAA are listed under SARA or COSEWIC. No vegetation assemblages are listed by the NWT Species Monitoring Infobase, SARA, or COSEWIC.

18.2.2.4 Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

A total of 150 plant, lichen, and fungus species were identified to be plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties in the Dehcho and Sahtu regions from publicly available reports. A total of 144 plants or groups of plants are used for traditional purposes in the Dehcho Region and 28 in the Sahtu Region, with 123 expected in the ecoregions intersected by the LAA and RAA (Appendix 18B). Of the 150 plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, 11 are trees, 47 are shrubs, 8 are subshrubs, 74 are forbs, 8 are graminoids, 1 is a lichen, and 1 a fungus. No bryophyte species were identified to be of plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. Vegetation, lichen and fungal species of interest, used for a variety of traditional purposes, have been identified through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies.
See Appendix 18B for a consolidated table of this information.

Eleven plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are also listed as plant SOCC, with seven listed as May Be At Risk (S1S2, meaning species occurrences range from critically imperiled to imperiled; very high to high risk of extirpation) and four listed as Sensitive (S3, meaning vulnerable, at moderate risk of extirpation) (NatureServe, 2012) (Appendix 18A; K'alo-Stantec, 2022). Most of the plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are ranked as secure (meaning very low or no risk of extirpation) within the NWT and occupy a range of landcover types such as coniferous, broadleaf, mixedwood forest, or shrubland upland sites or treed, shrub, or herbaceous wetland sites. Seven of the plants are alien in the NWT: lily pad root (*Aeonium* sp.), lamb's quarters (*Chenopodium album*), hemp nettle (*Galeopsis tetrahit*), broad-leaved plantain (*Plantago major*), blackcurrant (*Ribes nigrum*), sage (*Salvia officinalis*), and dandelion (*Taraxacum officinale*). Ox-eye daisy (*Leucanthemum vulgare*) is an alien invasive plant.

Many plant species serve different purposes, including medicinal, food, craft, ritual, spiritual, and home fuel. For example, birch bark (*Betula papyrifera, Betula neoalaskana*) is used for baskets, berries (e.g., blueberries [*Vaccinium* spp.]) are collected for food and for dyeing materials, and pasture sage (*Artemisia frigida*) is used for spiritual, ritual, or medicinal purposes (IMG-Golder Corporation, 2006).

Of the 142 plant species identified, 85 occur in uplands, 35 occur in wetlands, and 22 occur in unknown landscape position (Appendix 18B).

Table 18.6 lists specific plant harvesting locations as identified by Indigenous Governments, Indigenous Organizations, and other affected parties through the project-specific engagement program, a review of publicly available literature, and project-specific TLRU studies. Sahtu Dene and Métis and Dehcho First Nations and Pehdzéh Kį First Nation reported 12 locations within the PDA, LAA, and RAA that are of interest relative to plants and plant harvesting, as described in Table 18.6 (EBA, 2006, IMG-Golder-Corporation, 2006; TRRC, 2022; NWRRC, 2023).

Table 18.6 Plant Harvesting Locations identified by Indigenous Governments, Indigenous Organizations and Other Affected Parties Relative to the Project

Location	Within LAA	Within RAA[1]	Identified By:
Dehcho Region	✓*	✓	Dehcho First Nations
Sahtu Region	✓*	✓	Sahtu Dene and Métis; Sahtu Renewable Resources Board (SRRB)
Pehdzéh Kį N'deh area[2]	✓*	✓	Pehdzéh Kį First Nation
Mackenzie Valley Winter Road KM 724 (north or Wrigley)	✓*	-	Pehdzéh Kį First Nation
Mackenzie Valley Winter Road KM 782 (approximately halfway between Tulita and Wrigley)	✓*	-	Pehdzéh Kį First Nation
Wrigley (area)[3]	✓*	-	Pehdzéh Kį First Nation
Along the Mackenzie Valley Winter Road (between Norman Wells and Tulita)[4]	✓*	-	Sahtu Dene and Métis; SRRB; Tulita Renewable Resources Council (TRRC)
Tulita (area)[5]	✓*	-	TRRC
Plane Lake	✓*	-	TRRC
Dehdéleįǫ Tué (Sucker Lake/Three Day Lake)	-	✓	Sahtu Dene and Métis; SRRB
Great Bear River (West) (intersecting with the LAA and RAA)	✓	✓	TRRC
Canyon Creek	-	✓	Norman Wells Renewable Resources Council (NWRRC)

Notes:
1 Occurs within the RAA outside the LAA and PDA
2 Pehdzéh Kį area boundary was not identified or disclosed in the report.
3 Specific locations were not identified in the report.
4 Specific locations were not identified in the report.
5 Specific locations were not identified in the report.
* May occur within the PDA

Sources: EBA, 2006; IMG-Golder Corporation, 2006; NWRRC, 2023; SLUPB, 2022; TRRC, 2022; Dessau, 2012 (PR#13).

18.2.2.5 Alien and Invasive Alien Species

Sixteen alien and four invasive alien plant species have been documented in the RAA (Appendix 18A; K'alo-Stantec, 2022). For these species, there are 42 occurrences of 13 alien and invasive alien plant species documented within the RAA in the Sahtu Region and 14 occurrences of 12 alien and invasive alien plant species documented within the RAA in the Dehcho Region.

18.3 Project Interactions with Vegetation and Wetlands

Table 18.7 identifies the Project's physical activities that might interact with vegetation and wetlands and potentially result in one of the identified potential effects. Interactions that have the potential to result in effects on vegetation and wetlands within the LAA are indicated by a check mark or a dash and are discussed in detail in Section 18.4 in the context of effects pathways, standard and project-specific mitigation measures, and residual effects. A justification for no effect is provided following the table.

Table 18.7 Project-Environmental Interactions with Vegetation and Wetlands

Physical Activities	Timing	Effects			
		Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Construction Phase					
Mobilization of equipment, materials, and fuel, resupply, and demobilization	Summer and winter	-	-	-	-
Establishment and operation of camps	Year-round	-	-	-	-
Site preparation of ROW, access, and workspaces	Winter	✓	✓	✓	✓
Borrow source and quarry development and operations, including blasting, crushing, sorting, and stockpiling	Year-round	✓	✓	✓	✓
Material haul	Year-round	✓	✓	✓	✓
Embankment and quarry access road construction, including road cuts	Winter; road cuts in summer or winter	✓	✓	✓	✓
Culvert installations	Summer or winter	-	-	-	✓
Road base placement, compaction and surfacing	Summer	-	-	-	-
Water withdrawal to support construction activities	Year-round	-	-	-	✓

Physical Activities	Timing	Effects			
		Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Closure and reclamation of MVWR and temporary borrow sources/quarries, camps, and workspaces	Summer	✓	✓	✓	✓
Employment and contracted goods and services[1]	Year-round	-	-	-	-
Operations and Maintenance Phase					
Borrow source and quarry operations, including blasting, crushing, sorting, and stockpiling	Summer	✓	✓	✓	✓
Material haul and stockpiling	Summer	✓	✓	✓	✓
Operation of, and activities at, maintenance yards	Year-round	-	-	-	-
Water withdrawal for dust control	Summer	-	-	-	✓
Employment and contracted goods and services[1]	Year-round	-	-	-	-
Presence and use of the highway	Year-round	✓	✓	✓	✓
Highway and access road maintenance including snow clearing, repair, grading, dust control	Year-round	-	-	-	-
Vegetation control	Summer	✓	✓	✓	✓
Bridge and culvert maintenance	As needed	-	-	-	-

Notes:

✓ = Potential interaction

– = No interaction

1 Project employment and expenditures are generated by most project activities and components and are the main drivers of many socio-economic effects. Rather than acknowledging this by placing a check mark against each of these activities, "Employment and contracted goods and services" have been introduced as an additional component under each project phase.

During construction, interactions between the Project and vegetation and wetlands will occur during site preparation, quarry and borrow source development, material haul, preparation of road embankment, road cuts, culvert installation, access road construction, water withdrawal as well as closure and reclamation of the MVWR, temporary borrow sources/quarries, camps, and workspaces. After construction, interactions between the Project and vegetation and wetlands are expected to continue due to the presence of the highway and at some borrow source and quarry locations.

Mobilization and demobilization of project equipment is not expected to interact with vegetation and wetlands as construction materials and equipment will be transported by barge on the Mackenzie River (Deh Cho), along the existing Mackenzie Highway, or by the MVWR in the winter to designated staging areas. Staging areas identified for equipment and supplies include existing locations on the Mackenzie Highway near Wrigley, existing staging areas within municipal boundaries of nearby towns, locations of permanent borrow/quarry sources, and other previously disturbed areas identified during community engagement. Vegetation and wetlands will likely not be affected by construction camps because camp locations will be located in existing disturbed areas such as existing camp facilities within Norman Wells; dedicated camp locations within municipal boundaries of Norman Wells, Tulita, and/or Wrigley; and one or more borrow sources or quarries to be accessed from the MVWR.

Culvert installations, road base, compaction, and surfacing are not expected to interact with vegetation and wetlands because such work will occur in areas where vegetation has already been removed during the site preparation stage of construction. Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. However, although culvert installation may affect wetland function, culverts will be installed to maintain flow in wetlands crossed by the Project. Employment and contracted goods and services during construction are not expected to affect vegetation and wetlands in any way.

Interactions between the Project and vegetation and wetlands will continue due to road embankment vegetation control and dust contaminant deposition associated with borrow source and quarry operations, material haul and stockpiling, and traffic on the completed highway. Dust control will require water withdrawal, however no interactions with vegetation or wetlands are expected as a result of summer water withdrawal activities because withdrawal locations are likely to be located on larger watercourses, such as the Mackenzie River (Deh Cho) and those crossed by existing bridges, which will not infringe on wetlands. Water withdrawal will be within the limits of water licences and in accordance with DFO measures to protect fish and fish habitat (e.g., DFO, 2010, 2013a, 2013b). Snow clearing and grading will be ongoing as part of road maintenance and repair. These activities will occur within the road ROW and are not anticipated to extend into adjacent vegetation or wetlands. The quantity and quality of water leaving the ROW is not expected to change based on snow grading. Bridge and culvert maintenance will also be ongoing but are not expected to affect vegetation and wetlands outside of the road ROW.

18.4 Assessment of Residual Effects on Vegetation and Wetlands

Based on project interactions with the environment identified in Table 18.7, the Project may affect vegetation and wetlands. Potential effects, effect pathways, and mitigation measures that will reduce or eliminate the effects on vegetation and wetlands are identified in Table 18.8. Residual effects and associated analytical assessment techniques are also described.

Table 18.8 Potential Effects and Mitigation Measures for Vegetation and Wetlands

Effect Name	Effect Pathway	Mitigation Measures
Change in Landscape Diversity	• Fragmentation of native plant communities/landcover types arising from clearing • Indirect alteration of native communities/landcover types, including riparian areas, from the introduction or spread of alien and invasive alien plant species and pests, or dust contaminant deposition	• The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical. • Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged. • Removal of vegetation will be limited to the width of the ROW and workspaces. • Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive species. • Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired. • Erosion and sedimentation control measures will be implemented per the Erosion and Sedimentation Control Plan (ESCP) and will be in place prior to construction activities and before the spring melt/freshet. • Vegetation buffers will be used to protect riparian vegetation, as appropriate. • During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain. • The GNWT will undertake regular inspection for invasive alien plant occurrences during construction and apply management through mowing to reduce introduction and spread in the ROW and surrounding natural vegetation. • Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression.

Effect Name	Effect Pathway	Mitigation Measures
Change in Landscape Diversity (cont'd)		• Closure and reclamation will promote re-establishment of vegetation. • Abandoned sections of MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation ground cover. • The Project will adhere to mitigation measures in the ESCP, Permafrost Protection Plan (PPP), Waste Management Plan (WMP) and Spill Contingency Plan (SCP) to reduce effects on vegetation and wetlands.
Change in Community Diversity	• Direct loss or alteration of native communities/land-cover types from clearing and ground disturbance • Removal of merchantable timber	• Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged. • Travel of vehicles will be confined to existing roads and trails as much as possible to avoid disturbing vegetated areas. • Project vehicles will travel on designated winter roads or constructed embankment only. • The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent possible. • Removal of vegetation will be limited to the width of the ROW and workspaces. • Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads. • Merchantable timber will be limbed and decked in a dry area and made available to a receiver with an authorization (timber cutting permit or timber cutting licence) from the GNWT. Merchantable timber includes trees without defects with a dbh of at least 14 cm. • During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain.

Effect Name	Effect Pathway	Mitigation Measures
Change in Community Diversity (cont'd)		• Where vegetation must be cut but is not removed, the cut will be made > 10 cm above the ground to retain the root structure. Clearing will be completed by hand, where required, to prevent damage to the ground such as rutting, compaction and erosion. • Tree roots will be grubbed only in areas required for construction or stripping. Grubbing operations will be conducted to preserve soil surface organic material. • Organic material and topsoil will be set aside for use during reclamation, where possible. • Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW where possible. • Closure and reclamation will promote re-establishment of vegetation. • Borrow source vegetated surface material, where present, will be replaced after excavation is completed. • Off-road travel will be limited to winter (December 15 to April 1) where possible. • Abandoned sections of MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation.
Change in Species Diversity	• Direct loss of plant SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils from clearing and ground disturbance • Indirect loss or alteration of SOCC or plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties such as renewable resources councils from the introduction or spread of invasive alien plants, invasive plant species or, plant pests and dust contaminant deposition	• The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects on plant species of interest to Indigenous Governments, Indigenous Organizations and other affected parties. • Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. Options are identified in Chapter 18.

Effect Name	Effect Pathway	Mitigation Measures
Change in Species Diversity (cont'd)		• Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible. • Monitoring programs will be implemented to evaluate if mitigation measures are being implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required. • Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive alien species. • Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired. • Erosion and sedimentation control measures will be implemented per the ESCP, and will be in place prior to construction activities and before the spring melt/freshet. • Quarry dewatering will be conducted in a manner that discharge will not directly enter wetlands or lead to soil erosion. • Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression. • Invasive alien plants will be managed through mowing to reduce introduction and spread in the PDA and surrounding natural vegetation. • Abandoned sections of MVWR ROW and access roads will be closed and reclaimed. • Closure and reclamation will promote re-establishment of vegetation.
Change in Wetland Function	• Direct loss of wetland area or alteration of wetland function (i.e., hydrology, structure, plant composition, nutrient cycling and litter accumulation) from clearing or infilling of wetlands	• Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. • During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain. • Use of equipment on highly saturated soil will be avoided, where possible. Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.

Effect Name	Effect Pathway	Mitigation Measures
Change in Wetland Function (cont'd)	• Indirect alteration of wetland area or function (i.e., hydrology, structure, plant composition, nutrient cycling and litter accumulation) from changes in surface or groundwater flow patterns	• Erosion and sedimentation control measures will be implemented per the ESCP. • Silt fencing will be used downgradient of the works where required. • Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended. • Erosion and sedimentation control measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measure. • An SCP will be developed and implemented. • All site personnel will receive SCP training and will have awareness of spill prevention. • Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container. • Equipment such as vehicles, generators, and pumps will have secondary containment installed capable of containing fuel drips or leaks during operations and refueling. • Equipment laydown and staging areas will be located at least 100 m from the ordinary high water mark of any waterbody. • Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the ordinary high-water mark and in a manner to prevent any deleterious substances from entering the water. • Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies. • Quarry dewatering will be conducted in a manner such that discharge will not directly enter wetlands or lead to soil erosion.

18.4.1 Analytical Assessment Techniques

Potential effects on vegetation and wetlands were assessed by comparing existing baseline conditions in the LAA and RAA (described in the overview section and the TDR [Appendix 18A; K'alo-Stantec, 2022]) to conditions anticipated to occur with construction of the Project. Specifically, changes in vegetation and wetland resources anticipated to result from construction of the Project were determined by comparing baseline conditions in the LAA with anticipated conditions in the LAA following clearing of the PDA. It is conservatively assumed that clearing, grubbing, stripping, and grading will take place in the entire PDA and that vegetation and wetlands will be directly and completely lost within the full extent of the PDA. The amount of change in patch size, patch edge/area, landcover, plant SOCC, plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, and wetland function in the LAA was then assessed comparing baseline and anticipated post-construction conditions. Anticipated indirect effects on vegetation and wetlands due to potential changes in light and moisture levels, dust deposition, and invasive alien plant introduction in vegetated areas near but outside the PDA were also assessed.

Changes in wetland function were qualitatively assessed based on professional judgement of wetland responses to changes in hydrology and plant conditions gained from surveying wetlands in the field, including in the NWT, and evaluating changes on other development projects following construction. Effects on landscape diversity and community diversity were quantitatively assessed by examining the change in patch metrics (e.g., patch size and area to perimeter length) and change in area of landcover types. Landcover types were mapped for the PDA, LAA, and RAA using Earth Observation of Sustainable Development NWT data (Natural Resources Canada and the Government of the Northwest Territories, 2017) and forest fire polygon data from the Canadian National Fire Database (CNFDB) (Canadian Forest Service, 2020). Changes to species diversity were evaluated using changes in natural landcover types expected or known to support SOCC plants and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. Information on landcover types supporting SOCC plants and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties was obtained from available literature and relevant internet sources.

18.4.2 Change in Landscape Diversity

18.4.2.1 Effects Pathways

Project activities could result in changes to the abundance of native vegetation communities at the landscape level, through the direct loss of vegetation due to site clearing and grubbing. Specifically, vegetation will be cleared for preparation of the ROW, development of quarry and borrow sources and associated access roads, and embankment construction, including road cuts in steep grade terrain. Indirect effects resulting from construction activities may occur via changes to hydrology, soil conditions after clean-up and reclamation, dust contaminant deposition, and light and moisture level alteration from creation of new forest edges.

Landscape diversity was evaluated by assessing the natural distribution of patch size and perimeter of vegetation types in the RAA, and how they will change as a result of the Project. Larger patches provide necessary habitat for plants and animals requiring mature habitat, and such species may be vulnerable to fragmentation (Jules, 1998). Fragmentation occurs when larger patches are converted to smaller, spatially separated patches due to clearing activities. Fragmentation also typically results in a loss of mature interior habitat and habitat connectivity (Morrison et al., 1998). Clearing activities also increase the ratio of edge to interior habitat. Increasing isolation of mature habitat patches is a primary cause of declining biodiversity and increasing extinction risk (Wilcox and Murphy, 1985). Populations can become isolated if there is reduced breeding between populations in isolated patches of suitable habitat.

Habitat fragmentation generally results in a change in plant community composition, including vascular and non-vascular plants, and lichens. Fragmentation provides generalist species, edge-adapted species, and invasive species with additional habitat, resulting in increased abundance for such species (Jules, 1998). Species that require mature habitat, however, often experience a loss of suitable living area (Wilcox and Murphy, 1985). Increased light penetration can result in preferential regeneration of suckering tree species, such as aspen (Harper and Macdonald, 2002). Harper et al. (2005) describe examples of shifts in plant community composition and reduction of species diversity due to fragmentation, reduction of patch sizes, and increase in patch perimeter length. Pehdzéh Kį First Nation and Dehcho First Nations expressed concerns about potential effects during construction to the land and forest (Dessau, 2012 [PR#13]). SRRB raised concerns about potential effects on resident species, including effects of increasing invasive species which can influence potential for wildfires (SRRB, 2016).

As the level of landscape fragmentation increases, connectivity between vegetation community habitat types decreases. Reduced connectivity has different effects on wildlife species, with differing abilities for movement through various habitat types and seed dispersal abilities in various plant species (Monkkonen and Reunanen, 1999). As fragmentation continues, connectivity declines at a steady rate until a certain threshold is reached. At that point, an exponential increase will occur in the discontinuity of the landscape (McIntyre and Wiens, 1999; Monkkonen and Reunanen, 1999). The linkage between habitat distribution and connectivity is supported by recent simulation studies (Keymer et al., 2000; Fahrig, 2001). The ability of plants specifically to disperse between patches or remain in patches determines gene flow and the survival of populations and subpopulations.

Vegetation clearing will likely change the light intensity along the edge of the PDA and some distance within remaining adjacent plant communities in the LAA, and this change in light could alter temperature and moisture (Luken et al., 1992). Increased light intensity has been found to support increased white spruce (*Picea glauca*) growth and abundance of grasses, such as bluejoint (*Calamagrostis canadensis*) (Lieffers and Stadt, 1994). Changes in light intensity have also been found to alter species richness and plant diversity, particularly forbs and grasses (Bartemucci et al., 2006), and reduce bryophyte cover and conifer regeneration (Harper et al., 2015). Stand attributes (e.g., tree heights, coniferous versus broadleaf cover), landscape heterogeneity, and time since disturbance can influence the degree of response and the distance of effects from the edge, with effects more pronounced in areas of higher tree canopy cover and tree height, and less pronounced in landscapes of high heterogeneity, more open stands, and areas dominated by pioneer species (Harper et al., 2005). These effects will tend to decrease with time as vegetation communities mature. The distance of edge effects for boreal forest has been found to be weak and is anticipated to extend to a maximum of 20 m (Harper et al., 2015).

Vehicles using newly constructed roads may also spread alien or invasive alien plant species by bringing in seed of such species in mud and plant material on tires. Forman (1995) cites an Australian study where seeds of 259 plant species were identified in mud washed off vehicle tires at a car wash. Although most alien and invasive alien species establish primarily along newly created edges of cleared areas, some species may colonize interior forest over time (MacFarlane, 2003). Available information on effects from dust contamination indicates dust deposition can cause increased soil pH, decreased plant biomass, and altered species composition (Myers-Smith et al., 2006). Other changes from dust contamination include decreases in tree seedlings/saplings, low shrubs, and forbs and an increase in graminoid species (Brandt and Rhoades, 1972; Gunn, 1998; Myers-Smith et al., 2006; Gill et al., 2014). Covering with or absorption of dust contaminants can also alter plant growth and flowering (Farmer, 1993; Saikkonen et al., 1998). Lichens are susceptible to dust contamination since they receive nutrients from the air rather than the soil (Nash and Gries, 1995), and both mosses and lichens are vulnerable to reductions in light and increases in surface temperature, which can occur from dust contaminant deposition (Adamson and Seppelt, 1990).

Construction of the Project will likely have an effect on fire distribution in the RAA. Fire behaviour across the landscape will likely be affected due to creation of a continuous, wide firebreak. The MVWR is an existing firebreak which will be widened in most places. The highway road surface will be kept unvegetated and vegetation within the ROW will be kept mowed. The presence of the road will result in new sources of fire ignition, including sparks from vehicles and equipment, and potentially increase risk of anthropogenic fires (e.g., unextinguished campfires or arson) due to increased access.

Through the project-specific engagement program, Indigenous Governments, Indigenous Organizations, and other affected parties including the Pehdzéh Kį First Nation, Dehcho First Nations and Sahtu Dene and Métis, expressed concerns about habitat and effect on the land and forest, including plant SOCC. Community members expressed concern that development may affect human health through changes in water and air quality and the health of the region’s wildlife, fish, and vegetation (see Chapter 11, Culture and Traditional Land Use, Including Harvesting).

18.4.2.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project, as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project on landscape diversity include the following:

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged.
- Removal of vegetation will be limited to the width of the ROW and workspaces (including active quarry and borrow sources)
- Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired.
- Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive species.
- Erosion and sedimentation control measures will be implemented per the ESCP (Volume 5).
- Vegetation buffers will be used to protect riparian vegetation, as appropriate.
- During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain.
- The ROW will be regularly inspected for invasive alien plant occurrences and invasive alien plants will be managed through mowing to reduce introduction and spread in the ROW and surrounding natural vegetation.
- Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression.
- Closure and reclamation will promote re-establishment of vegetation.
- The ESCP, PPP, WMP and SCP will be followed. These plans include measures to reduce and monitor direct and indirect effects on vegetation and wetlands. Draft management plans are included in Volume 5.
- Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.

18.4.2.3 Residual Effects

Table 18.9 presents average patch size, maximum and minimum patch sizes, and the standard deviation for each landcover type in the LAA for existing conditions and with the Project. For existing conditions, the landcover types with the largest average, maximum, and standard deviation patch size are open water, herbaceous, and coniferous forest. Much of the open water area indicated in Table 18.9 is within the Mackenzie River (Deh Cho). Patches of herbaceous and unvegetated area are mostly represented by the MVWR.

With the exception of herbaceous and unvegetated patches, the average patch sizes in the LAA are unchanged between existing conditions and project construction and operations, except for a 0.1 hectare (ha) reduction in average patch size in coniferous forest and shrubland. The large reduction in average patch size for herbaceous and unvegetated areas is associated with the conversion of the existing MVWR to the PDA. The small amount or no change in the average patch size for all other landcover classes in the LAA indicates only a small amount of change to the average patch size in the LAA resulting from the Project.

There is no reduction in maximum patch size for any of the wetland landcover classes and only a very small reduction in maximum open water patch size because the Project avoids many large wetlands and open water areas. There is a large reduction in maximum patch size for herbaceous and unvegetated areas because, as indicated for average patch size, many patches of this landcover type are associated with the MVWR, much of which will be converted to the PDA. The reduction in maximum patch size for other landcover classes ranges from 3% for shrubland to 35.3% for mixedwood forest. The reduction in maximum patch size for upland landcover types indicates that the Project will fragment some of the larger forested areas along the highway portion of the PDA.

The minimum patch size for all landcover classes is less than 0.1 ha for existing conditions and does not change for construction and operation.

Table 18.10 provides statistics for the perimeter to area ratio of patches of each landcover type in the LAA. For each landcover type, the average, standard deviation, maximum, and minimum perimeter to area ratio are presented for existing conditions and construction and operations. For existing conditions, the average ratio for all landcover types is similar, ranging from 1,300 metres per hectare (m/ha) to 1,700 m/ha. For all landcover types, except herbaceous and unvegetated, the ratio of perimeter to area increases during construction and operations by a small to moderate amount, between 100 m/ha and 1,000 m/ha, indicating that the construction of the Project will make a small to moderate increase in edge length relative to size for patches of all landcover types due to the creation of long edges on both sides the PDA. The large increase in the ratio of herbaceous and unvegetated landcover reflects the creation of the linear edges of the PDA.

Table 18.9 Anticipated Alteration of Landcover Patch Sizes within the LAA

Landcover Type	Existing Conditions				Construction and Operation			
	Average Size (ha)	SD (ha)	Maximum (ha)	Minimum (ha)	Average Size (ha)	SD (ha)	Maximum (ha)	Minimum (ha)
Broadleaf Forest	0.8	3.1	117.7	<0.1	0.8	2.9	107.5	<0.1
Coniferous Forest	2.5	19.7	796.8	<0.1	2.4	16.7	606.2	<0.1
Herbaceous and Unvegetated	3.2	19.6	368.1	<0.1	0.7	3.0	92.4	<0.1
Mixedwood Forest	0.9	3.4	116.0	<0.1	0.9	2.8	75.0	<0.1
Open Water	3.5	44.4	1,808.2	<0.1	3.5	44.2	1,807.5	<0.1
Shrubland	1.0	6.5	326.9	<0.1	0.9	6.2	317.5	<0.1
Wetland-herb	0.5	0.8	17.0	<0.1	0.5	0.8	17.0	<0.1
Wetland-shrub	0.6	1.5	74.4	<0.1	0.6	1.5	74.4	<0.1
Wetland-treed	0.6	1.3	29.9	<0.1	0.6	1.2	29.9	<0.1

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

Table 18.10 Ratio of Perimeter to Area of Patches in the LAA

Landcover Type	Existing Conditions				Construction and Operation			
	Average Ratio (m/ha)	SD (m/ha)	Maximum (m/ha)	Minimum (m/ha)	Average Ratio (m/ha)	SD (m/ha)	Maximum (m/ha)	Minimum (m/ha)
Broadleaf Forest	1,300	8,100	490,100	200	2,300	38,800	2,191,800	200
Coniferous Forest	1,600	22,900	1,992,100	100	1,900	23,500	1,992,100	100
Herbaceous and Unvegetated	1,500	8,500	240,800	100	4,500	24,600	920,800	100
Mixedwood Forest	1,700	34,800	2,079,000	200	2,100	36,800	2,079,000	200
Open Water	1,300	5,800	158,900	100	1,400	6,100	158,900	100
Shrubland	1,400	9,300	751,300	100	1,600	10,700	751,300	100
Wetland-herb	1,500	19,800	1,633,000	300	1,600	19,900	1,633,000	300
Wetland-shrub	1,300	12,500	1,110,100	200	1,500	13,100	1,110,100	200
Wetland-treed	1,700	36,700	3,562,600	200	1,900	37,600	3,562,600	200

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

The increase in the perimeter to edge ratio will allow indirect effects in all landcover types along both edges of the PDA, including increased light levels, decreased moisture levels, dust contaminant deposition, and the potential for introduction of alien and invasive alien species. With project mitigation measures listed, indirect effects are anticipated to be reduced to low levels.

As the Project will result in an increase in fragmentation of the landscape, including a decrease in the average and maximum patch size of some landcover types and an increase in the average perimeter to area ratio of all landcover types, the effect on landscape diversity is considered moderate and extends to the LAA. This determination includes uncertainty of accuracy of landcover mapping from published sources.

Project effects are not expected to result in the loss of any landcover types in the LAA, and patches of many sizes and shapes of all landcover types are expected to remain abundant in the LAA and surrounding RAA. Effects are expected to be long-term due to the presence of the highway and the retention of some quarry sites. Dust contaminant deposition and the potential for alien and invasive alien species introduction adjacent to the highway will be ongoing. The VC is not sensitive to seasonal timing because all vegetation will be removed from the PDA (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

18.4.3 Change in Community Diversity

18.4.3.1 Effects Pathways

Construction activities that include vegetation clearing and ground disturbance for site preparation will result in vegetation loss, including in wetlands. Other activities, such as temporary and permanent quarry and borrow source development, associated access roads, and workspaces might change vegetation community abundance and distribution as well. Changes in microclimate as a result of tree and shrub removal, soil compaction, rutting, and admixing can also alter plant communities, particularly in wetland areas when construction occurs in spring or summer months (Dube et al., 2011).

In particular, the Project may affect vegetation community diversity in the following ways:

- Directly, through vegetation clearing as a result of site preparation
- Indirectly, from changes in water quantity where road development results in changes to drainage patterns

The highway alignment will avoid wetlands to the extent possible; however, complete avoidance of wetlands in the ROW is not feasible. There may be wetlands that are cleared within the 60 m wide ROW, as the Project is expected to follow the existing cleared MVWR ROW as much as possible. Wetland intersects will be reduced where possible, including locating temporary workspaces and access roads beyond wetland boundaries.

18.4.3.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project, as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project community diversity include the following:

- Activities will be restricted to workspaces and access roads. Prior to the start of construction, the boundaries of the work area, staging areas, and access roads will be staked and/or flagged.
- Project vehicles will be confined to existing roads and trails to avoid disturbing vegetated areas.
- Removal of vegetation will be limited to the width of the ROW and workspaces (including active borrow sources and quarries).
- Trees will be felled toward the ROW and access roads wherever possible to reduce damage to vegetation outside of the ROW and access roads.
- Merchantable timber will be limbed and decked in a dry area and made available to a receiver with an authorization (timber cutting permit or timber cutting licence) from the GNWT. Merchantable timber includes trees without defects with a dbh of at least 14 cm.
- During spring, summer, and fall, suitable ground equipment will be used to prevent effect on sensitive terrain.
- Where vegetation must be cut but is not removed, the cut will be made > 10 cm above the ground to retain the root structure.
- Tree roots will be grubbed only in areas required for construction or stripping. Grubbing operations will be conducted to preserve soil surface organic material.
- Organic material and topsoil will be set aside for use during reclamation, where possible.
- Cleared brush and unsalvageable trees will be windrowed, mulched, and spread on the ROW where possible.
- Closure and reclamation will promote re-establishment of vegetation.
- The ESCP, PPP, WMP and SCP will be followed. These plans include measures to reduce and monitor direct and indirect effects on vegetation and wetlands Draft management plans are included in Volume 5.
- Borrow source vegetated surface material, where present, will be replaced after excavation is completed.
- Off-road travel will be limited to winter (December 15 to April 1) where possible.
- Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.

18.4.3.3 Residual Effects

Project construction will result in the direct loss or alteration of up to 655.2 ha of upland forest, 204.1 ha of shrubland, 1,185.3 ha of herbaceous and un-vegetated communities, and 300.0 ha of wetlands (Table 18.11). Landcover types with largest change in area will be exposed land (1,210.3 ha), open coniferous forest (246.0 ha) and sparse coniferous forest (158.8 ha), and low shrub (151.0 ha). The percent change in landcover type will be greatest for exposed land (41.1%), herbaceous (8.0%), and rock/rubble (5.6%) landcover. Much of the non-forested landcover affected by the Project is associated with either the existing MVWR or the Norman Wells Pipeline ROW.

Abandoned sections of the MVWR ROW and access roads will be closed and reclaimed to promote re-establishment vegetation such as upland and wetland landcover types. Borrow sources and quarries and associated access roads not required for highway maintenance will be closed and reclaimed. Wetland and open water landcover values in the LAA are 23.5% and 11.7% of the LAA, respectively. Landcover percentages between the Dehcho and Sahtu sections are similar but with somewhat higher percentages of forest and open water and somewhat lower percentages of wetland and shrubland landcover in the Dehcho section compared to the Sahtu section.

The removal of forest and other native vegetation communities will decrease the area available for native vegetation species, particularly species which grow in boreal forest (including many plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, discussed in Section 18.4.4). In addition, the Project will also increase the amount of habitat available for pioneer species and invasive alien plants. Direct effects on vegetation communities will result from clearing activities, and indirect results may occur over time through changes in light and moisture levels and dust contaminant deposition in remaining adjacent vegetation communities in the LAA.

The percentage of native vegetation communities directly lost due to clearing will be a small percentage of the LAA, ranging from 2.0% of wetland communities and 3.2% of broadleaf forest communities in the LAA (Table 18.11). Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA, based on findings of Gleason et al. [2007]) could affect an additional 2.0% of wetland habitat and 3.8% of forest in the LAA. Indirect effects from all sources, up to a distance of 100 m from the PDA, could affect an additional 5.2% of wetland habitat and 8.3% of forest in the LAA.

Table 18.11 Change in Landcover Types within the LAA

Landcover Type	Cover Type Class	Existing Conditions		Construction and Operation		Change from Existing Conditions[1]	
		ha	% of Total Area	ha	% of Total Area	ha	% Change
Broadleaf Forest	Broadleaf – Dense	2,669.3	4.2	2,582.6	4.1	-86.7	-3.2
	Broadleaf – Open	956.4	1.5	927.2	1.5	-29.1	-3.0
	Broadleaf Subtotal	**3,625.7**	**5.8**	**3,509.8**	**5.6**	**-115.9**	**-3.2**
Coniferous Forest	Coniferous – Dense	3,617.8	5.8	3,560.5	5.7	-57.3	-1.6
	Coniferous – Open	9,250.3	14.7	9,004.3	14.3	-246.0	-2.7
	Coniferous – Sparse	8,442.9	13.4	8,284.2	13.2	-158.8	-1.9
	Coniferous Subtotal	**21,311.1**	**33.9**	**20,849.0**	**33.1**	**-462.1**	**-2.2**
Mixedwood Forest	Mixedwood – Dense	1,144.4	1.8	1,116.6	1.8	-27.8	-2.4
	Mixedwood – Open	2,098.4	3.3	2,049.5	3.3	-48.9	-2.3
	Mixedwood – Sparse	5.1	<0.1	4.6	<0.1	-0.5	-10.1
	Mixedwood Subtotal	**3,247.9**	**5.2**	**3,170.7**	**5.0**	**-77.2**	**-2.4**
Shrubland	Shrub – Tall	1,996.1	3.2	1,943.0	3.1	-53.1	-2.7
	Shrub – Low	7,282.3	11.6	7,131.3	11.3	-151.0	-2.1
	Shrubland Subtotal	**9,278.4**	**14.8**	**9,074.3**	**14.4**	**-204.1**	**-2.2**
Herbaceous and Unvegetated	Herb	233.7	0.4	215.0	0.3	-18.7	-8.0
	Bryoids	12.9	<0.1	12.5	<0.1	-0.4	-3.0
	Rock/Rubble	106.2	0.2	100.3	0.2	-5.9	-5.6
	Exposed Land[2]	2,943.5	4.7	4,153.8	6.6	1,210.3	41.1
Herbaceous and Unvegetated Subtotal		**3,296.3**	**5.2**	**4,481.7**	**7.1**	**1,185.3**	**36.0**
Upland Subtotal		**40,759.5**	**64.8**	**41,085.5**	**65.3**	**326.0**	**0.8**

Landcover Type	Cover Type Class	Existing Conditions		Construction and Operation		Change from Existing Conditions[1]	
		ha	% of Total Area	ha	% of Total Area	ha	% Change
Wetland	Wetland – Treed	5,890.3	9.4	5,780.3	9.2	-109.9	-1.9
	Wetland – Shrub	5,486.2	8.7	5,360.8	8.5	-125.4	-2.3
	Wetland – Herb	3,384.1	5.4	3,319.4	5.3	-64.6	-1.9
	Wetland Subtotal	**14,760.5**	**23.5**	**14,460.6**	**23.0**	**-300.0**	**-2.0**
Open Water		7,383.1	11.7	7,357.0	11.7	-26.1	-0.4
	Total	**62,903.1**	**100.0**	**62,903.1**	**100.0**	**0.0**	**0.0**

Note:

[1] The change in area of each landcover type from Existing Conditions to Construction and Operation is the area of the PDA intersecting that landcover type.

[2] Exposed land includes areas which naturally have less than 5% vegetative cover, such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as roads, particularly the MVWR, and areas of infrastructure development. Exposed land also includes land cleared for the Project (under Construction and Operation). For this reason, the amount of exposed land increases under Construction and Operation while all other landcover types decrease, and the total area of all landcover remains the same between Existing Conditions and Construction and Operation.

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

The total volume of coniferous, broadleaf, and mixedwood timber to be cleared during construction is presented in Table 18.12. The amount of merchantable timber (trees with a diameter at breast height of at least 14 cm) is not known, but merchantable timber volume is expected to be approximately 65% of the total timber volume, estimated to be approximately at 12,080 m^3 of merchantable timber (National Forestry Database, 2022). The GNWT will conduct a survey of merchantable timber volume in the PDA to support its applications for timber cutting permit / licence. In locations where sufficient quantities of merchantable timber are present, the trees will be limbed and decked in a dry area and made available to a receiver with an authorization (a timber cutting permit or licence) from the GNWT. If after five years post harvest the trees have not been removed, they will be burned, chipped, or disposed of by another authorized method. Non-merchantable trees will be limbed and stacked for community use, where possible. Other non-merchantable debris will be used for rollback (in areas to be revegetated) or chipped.

Table 18.12 Change in Total Timber Volumes per Landcover Type in the LAA

Cover type	Existing Conditions [1]		Construction and Operation [1]		Change From Existing Conditions	
	m^3	% of Total Volume	m^3	% of Total Volume	m^3	% Change in Volume
Coniferous Forest	737,167.5	83.7	722,300.1	82.0	-14,867.5	-1.7
Broadleaf Forest	70,245.4	8.0	68,138.2	7.7	-2,107.2	-0.2
Mixedwood Forest	73,830.1	8.4	72,219.4	8.2	-1,610.7	-0.2
Timber Volume Cleared	0.0	0.0	18,585.4	2.1	18,585.4	2.1
Total	**881,243.0**	**100.0**	**881,243.0**	**100.0**	**0.0**	**0.0**

Note:

[1] Volume determined by multiplying average stand volume by landcover area (ha) in LAA.

Source: Natural Resources Canada and the Government of the Northwest Territories (2017).

Project effects on different forest stand age classes in the LAA are presented in Table 18.13. Forest stand ages differences are a result of fires that have occurred in the LAA since fire records have been collected (starting in the 1960). Fires have burned irregularly through portions of the LAA and have resulted in a mosaic of forest stand ages. The spatial distribution of fires and associated forest stand establishment have been tracked by decade from 1960 to 2020. Forest older than 62 years is present at the south end of the PDA near Wrigley, while large areas of younger forest are present east of the PDA. In central and northern sections of the PDA, young and old forest stands are interspersed with large wetland areas. Forest stands established before 1960 and between 1990 and 1999 will be most affected by the Project, with 853.5 ha of pre-1960 forest stands and 1,053.4 ha of forest stands established between 1990 and 1999 to be removed. This represents 3.4% of stands of pre-1960 forest stands in the LAA and 3.9% of forest stands established between 1990 and 1999 in the LAA. In total, 36.9% of forest to be removed was established prior to 1960 and 63.1% was established 1960 or later, and 51.4% was established since 1990.

The Project will reduce the area of all landcover types in the LAA. The percentage loss of landcover types ranges from 1.6% of dense coniferous forest in the LAA to 10.1% of sparse mixedwood forest in the LAA (Table 18.11). Abandoned sections of the MVWR ROW and access roads will be allowed to regenerate to natural upland and wetland landcover types. Borrow sources and quarries and associated access roads not required for highway maintenance will be closed and remediated to promote natural revegetation. Therefore, with the large amount of remaining area of all landcover types in the LAA, along with some regenerating landcover area, the effect on community diversity is considered low and extends to the LAA. This determination includes uncertainty of accuracy of landcover mapping from published sources; however, all landcover types are expected to remain abundant in the LAA.

Effects are expected to be long-term due to the presence of the highway and the retention of some borrow sources and quarries for project operations and maintenance. Dust contaminant deposition and the potential for alien and invasive alien plant introduction adjacent to the PDA will be ongoing. Because of complete removal of vegetation from the PDA, the VC is not sensitive to seasonal timing (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

Table 18.13 Change in Stand Age Composition in the LAA

Decade of Establishment of Forest Stands [1]	Existing Conditions		Construction and Operation		Change From Existing Conditions	
	ha	% of Total Area	ha	% of Total Area	ha	% of Existing
Prior to 1960	25,031.4	39.8	24,177.9	38.4	-853.5	-3.4
1960-1969	257.7	0.4	247.5	0.4	-10.3	-4.0
1970-1979	4,441.4	7.1	4,257.0	6.8	-184.5	-4.2
1980-1989	2,160.2	3.4	2,084.2	3.3	-76.0	-3.5
1990-1999	26,920.4	42.8	25,867.1	41.1	-1,053.4	-3.9
2000-2009	3,320.4	5.3	3,211.4	5.1	-109.0	-3.3
2010-2019	771.5	1.2	742.9	1.2	-28.6	-3.7
Area of Forest Removed by the Project	0.0	0.0	2,315.2	3.7	2,315.2	Undefined
Total	62,903.1	100.0	62,903.1	100.0	0.0	0.0

Source: Canadian Forest Service (2020).

18.4.4 Change in Species Diversity

18.4.4.1 Effects Pathways

A direct loss of plant SOCC and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may occur within the PDA because of vegetation clearing during project construction and indirectly due to dust contaminant deposition, introduction and spread of alien and invasive alien species, and edge effects on intersected native vegetation communities during both construction and operations. Indirect effects will extend beyond the PDA.

As indicated, vegetation will be cleared during construction for preparation of the ROW, development of quarry and borrow sources, and associated access roads and embankment construction, including road cuts in steep grade terrain. Plant SOCC present in areas of vegetation clearing will be removed along with plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. Plants will be permanently removed within the PDA; however, some SOCC and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may re-establish in reclaimed temporary disturbances, such as workspaces and quarry/borrow sources not retained for operations.

Removal of vegetation may also indirectly alter light, moisture, and temperature levels through edge effects on remaining vegetation (Luken et al., 1992). These altered conditions can affect plant species composition and abundance (Harper et al., 2015; Dabros et al., 2017; Kohmori et al., 2019), including reduced bryophyte cover (Bartemucci et al., 2006). Changes to ground thermal regime and soil moisture due to vegetation removal can result in permafrost degradation which will likely influence shifts in vegetation community structure and composition. Studies by Cameron and Lantz (2017) found permafrost thaw influenced transformation of woodland sites to graminoid-dominated wetlands. Such changes to site conditions will likely alter species composition and may result in loss of upland plant SOCC or plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties that are unable to tolerate newly created wetland conditions.

Bare areas and areas of low vegetation cover created during construction, along with altered edge effects of nearby vegetation, may also provide opportunities for alien and invasive alien species to establish. Vegetation clearing will remove native plant cover, potentially allowing alien and invasive alien species to establish and spread, particularly within disturbed sites (Davis et al., 2000). In addition, spread of alien and invasive alien species may be transported by project equipment and vehicles. Von der Lippe and Kowarik (2007) found vehicle vectors to be a major contributor for spread of alien and invasive alien species along roadways, with buildup of mud and other substrates on vehicles enabling spread of alien and invasive alien seeds.

Dust contaminant emissions generated during project construction, development and operation of quarry and borrow sources, vehicle use of project access roads, and embankment construction, as well as material haul and stockpiling, could further alter plant composition through changes in plant health and altered competitive ability. Dust contaminant deposition can affect fruit setting, pollen germination, and other attributes (Farmer, 1993).

18.4.4.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project to species diversity include the following:

- The GNWT is committed to ongoing engagement with Indigenous Governments, Indigenous Organizations, and other affected parties regarding perceived effects on plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.
- Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. Options are identified in Chapter 18.
- Monitoring programs will be implemented to evaluate if mitigation measures are being implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required.
- Known areas of collection of plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties will be avoided where possible. Clearing schedules will be communicated in advance of clearing to provide an opportunity to collect plant material from the PDA.
- Equipment originating from outside of the NWT will be cleaned prior to mobilization to avoid introduction of invasive species.
- Machinery will be maintained and regularly inspected for fuel, oil, or other fluid leaks. Machinery found to be leaking will be withdrawn from service until repaired.
- Erosion and sedimentation control measures will be implemented per the GNWT Erosion and Sediment Control Manual (GNWT, 2013) and will be in place prior to construction activities and before the spring melt/freshet.
- Quarry dewatering will be conducted in a manner that discharge will not directly enter wetlands or lead to soil erosion.
- Water will only be used for dust suppression, except as provided in the GNWT Guideline for Dust Suppression.
- Regular inspection for invasive alien plant occurrences will be undertaken during construction and invasive alien plants will be managed through mowing to reduce introduction and spread of invasive alien plants in the PDA and surrounding natural vegetation.
- Closure and reclamation will promote re-establishment of vegetation.
- Abandoned sections of MVWR ROW and access roads will be closed and reclaimed.

Monitoring programs will be implemented to evaluate if mitigation measures are implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required.

18.4.4.3 Residual Effects

18.4.4.3.1 Species of Conservation Concern

18.4.4.3.1.1 Direct Effects on Species of Conservation Concern

Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have potential to occur based on a review of the NWT Species Monitoring Infobase (Working Group on General Status of NWT Species, 2016) and ecoregions intersected by the RAA. A considerable part of the PDA (1,104.9 ha [47.7%]), overlaps areas of the existing MVWR. However, potential direct loss of undocumented SOCC could occur for SOCC forbs, graminoids, subshrubs, and potentially bryophytes and lichens. Direct loss of undocumented SOCC may also occur due to removal of upland forest and shrubland vegetation, which comprises 859.3 ha (37.1%) of the PDA, and removal of wetlands, which comprise 300.0 ha (13.0%) of the PDA (Table 18.11). Shrub, forb, graminoid, lichen, and bryophyte SOCC could be affected in wetlands, upland forest, and shrubland areas as these areas are known to support a diversity of plant species, including many SOCC (Gilliam, 2007).

In the RAA, there are 7 forb and graminoid SOCC species known to occur in wetlands, 4 SOCC which occur in wetlands or uplands, and 11 SOCC which occur only in uplands (Table 18.14). Eight SOCC are shrubs and two SOCC are subshrubs. No tree SOCC are known to occur in the RAA. One shrub SOCC, arctic seashore willow (*Salix ovalifolia*), is known to occur in upland areas and is ranked S2 (defined as imperiled with a high risk of extirpation) in the NWT. The landscape position is unknown for seven other shrub SOCC and the two subshrubs which have been previously found in the RAA.

Of the forb and graminoid SOCC potentially present in the RAA, 141 are perennial plants. These may be at greater risk of loss due to their longer life span and less frequent production of seeds. Annual plants may not be actively growing during construction. Potential effects on perennial forb and graminoid plant SOCC include 73 S2 ranked species, 5 S2S3 ranked species (defined as species either imperiled or vulnerable to extirpation, though uncertainty exists), 58 S3 ranked species (defined as vulnerable with a moderate risk of extirpation), and 5 S3S4 ranked species (defined as species either vulnerable or apparently secure, though uncertainty exists) (GNWT, 2016a; NatureServe, 2012).

Temporary disturbance to SOCC will likely occur in temporary workspaces, such as laydown or staging areas. Trees and shrubs will be cut near ground level in temporary disturbance areas, but the roots and low vegetation will be left in place. As a result, shrub and subshrubs SOCC may be lost or damaged during clearing and use of temporary workspaces. Vegetation is expected to recover from the root layer following use of temporary workspaces. To a lesser extent, low vegetation such as forb, graminoid, lichen, and bryophyte SOCC may also be lost or damaged during clearing and use of temporary workspaces. As noted, a pre-construction survey of SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties in the PDA will provide additional information on species presence and determine which species are most likely to be affected by project construction.

Table 18.14 Potential Plant SOCC Habitat, Form and Provincial S-Rank Summary for the RAA

Landscape Position[1]	Form[2]	NWT Provincial Rank[3]	Number of Species
Upland	Shrub	S2	1
	Graminoid	S3	1
	Forb	S2	5
		S3	5
		Upland Total	**12**
Wetland	Forb	S2	1
		S3	1
		S3S4	1
	Graminoid	S2	1
		S3	2
		S3S4	1
		Wetland Total	**7**
Wetland/Upland	Forb	S2	1
		S3	3
		Wetland/Upland Total	**4**
Unknown Landscape Position	Shrub	S2	4
		S3	3
	Subshrub	S2	1
		S3	1
	Forb	S2	52
		S2S3	5
		S3	39
		S3S4	3
	Graminoid	S2	18
		S2S3	1
		S3	15
		S3S4	2

Landscape Position[1]	Form[2]	NWT Provincial Rank[3]	Number of Species
Unknown Landscape Position (cont'd)	Lichen	S1	1
		S1S2	2
		S1S3	4
		S2?	1
		S2S3	17
		S2S4	17
	Bryophytes	Not ranked	6
		Unknown Landscape Position Total	**192**
		Total	**215**

Notes:

[1] United States Department of Agriculture (USDA) Plants Database (2022).

[2] USDA Plants Database (2022), GNWT (2016b), Roland et al. (2016), E-Flora BC (2021).

[3] GNWT (2016a).

18.4.4.3.1.2 Indirect Effects on Species of Conservation Concern

Indirect effects on plant SOCC from dust contaminants and changes in light levels and moisture availability are expected to extend up to 40 m from road and quarry sites based on findings of Gleason et al. (2007) and Luken et al. (1992), potentially resulting in various levels of dust deposition on up to 2,368 ha. A study by Auerbach et al. (1997) found altered conditions in plant communities adjacent to gravel roadways including higher soil pH, increased nutrient availability, shallower organic horizons, and lower soil moisture. Alteration of soil pH can contribute to colonization and survival of certain species and influence species composition. Species most susceptible to dust contamination include lichens, due to the lack of roots and other absorptive surfaces (Nash and Gries, 1995), and both mosses and lichens due to blockage of light required for photosynthesis and an increase in surface temperature (Adamson and Seppelt, 1990). Potential indirect effects on vascular plant SOCC may also occur, as dust contaminant deposition can negatively affect plants by clogging leaf stomata, altering water balances within leaves, and reducing respiration capacity (Eller, 1977).

The spread of alien and invasive alien species could also result in a loss of plant SOCC. Removal of vegetation can create disturbed, open conditions, which can lead to an increase in abundance of alien and invasive alien species (Charbonneau and Fahrig, 2004). Project roadways may also act as dispersal corridors for spread of alien and invasive alien species. Sixteen alien and four invasive alien species occur within the Dehcho and Sahtu regions and have primarily been observed in areas of anthropogenic disturbance (AKEPIC, 2020). Documented alien invasive species include narrow-leaf hawksbeard (*Crepis tectorum*), reed canary grass (*Phalaris arundinacea*), white sweet-clover (*Melilotus albus*), and alsike clover (*Trifolium hybridum*). These species commonly establish in areas of disturbance or roadways and disperse via wind, water, stolon expansion, and rapid seed production (USDA, 2022).

No SARA- or COSEWIC-listed plants will be affected by the Project as none occur in the ecoregions intersected by the RAA and are therefore unlikely to occur in the PDA.

As the Project may result in the loss of SOCC plants, if present, effects on species diversity from changes to SOCC are considered moderate to high magnitude. It is possible, though unlikely, that occurrences of a plant SOCC removed from the PDA are the only occurrences of that species in the LAA or RAA. In that case, the effect on that particular SOCC would extend to the LAA or RAA, respectively. This determination includes uncertainty in the occurrence of imperiled plants.

Information on plant SOCC growing requirements, such as light and moisture tolerance, is not available or suitably compiled in public sources to support further assessment and determination of whether the plants are present or absent from the PDA. Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. Options are identified in Chapter 18.

Monitoring programs will be implemented to evaluate if mitigation measures are implemented and are effective. These include monitoring in accordance with the terms and conditions of permit approvals, as required.

Potential loss of SOCC is expected to be less in areas of the existing MVWR due to past alterations of vegetation layers and potential changes in soil conditions; however, SOCC may still occur. Effects are expected to be long-term due to the presence of the highway and the retention of some quarry sites. Dust contaminant exposure will continue through use of the highway once constructed. Because of removal of vegetation from the PDA, the VC is not sensitive to seasonal timing (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

18.4.4.3.2 Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

18.4.4.3.2.1 Direct Effects on Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Removal of vegetation in the PDA will result in loss of occurrences plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties, where present. The abundance of 65 plant species may be reduced due to the removal of upland forested areas (626.9 ha), and 14 plant species due to removal of upland shrubland (204.1 ha), within the PDA (Table 18.14). Loss of forested areas may reduce the abundance of 25 shrub, 24 forb, 9 tree, and 7 sub-shrub species typically occurring in forested areas and potentially present in forested lands in the PDA (Appendix 18B).

Removal of shrubland may affect five forb plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties and one shrub. Two of the plant species potentially occurring in forested landcover types in the PDA, spiney wood fern (*Dryopteris carthusiana*) and rocky mountain pond lily (*Nuphar polysepala*), are ranked May Be At Risk in the NWT and are likely not abundant in the RAA. These species have not been documented in the RAA; however, based on landcover types, they may be present in the RAA, LAA, and PDA. Construction could result in the loss of these species from the LAA or RAA if occurrences are present in the PDA only, although occurrences may remain elsewhere in the LAA or RAA. In addition, two other plant species of interest found in forest landcover types: sand heather (*Hudsonia tomentosa*) and choke cherry (*Prunus virginiana*) (both of which are ranked Sensitive in the NWT) may also be lost if present in the PDA (although occurrences may remain elsewhere in the LAA or RAA).

Other plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties affected by the removal of forested areas of the PDA are ranked secure, have not been ranked territorially, or are alien or invasive alien species. Traditional plant species found in shrubland areas of the RAA are ranked secure, have not been ranked territorially, or are alien or invasive alien species. Although the spatial distribution of these species within forested and shrubland areas in the LAA is unknown, these species are expected to be abundant in the RAA based on the territorial rank and will remain abundant following project construction.

Thirty-four plant and one fungus species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties occur in wetlands and abundance may be altered by the removal of 300.0 ha of wetland by the Project (Table 18.14). None of these plant species occurring in wetlands are ranked as May Be At Risk in the NWT (GNWT, 2016a). Species include 13 forbs, including berry producing plants such as cloudberry (*Rubus chamaemorus*), 15 shrubs, 4 trees, 2 graminoids, (seaside arrow-grass [*Triglochin maritima*] and broad-leaf cattail [*Typha latifolia*]), and 1 fungus.

18.4.4.3.2.2 Indirect Effects on Plant Species of Interest to Indigenous Governments, Indigenous Organizations, and Other Affected Parties

Indirect effects on plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties are anticipated to be similar to those predicted for plant SOCC. Dust contaminant emissions will likely reduce species diversity in areas up to 40 m from project construction sites and potentially introduce contaminants to edible plants (Gleason et al., 2007; Shotyk, 2020). Competition by alien and invasive alien species will likely be greatest to herbaceous forb and graminoid plants because alien and invasive alien species within the Dehcho and Sahtu Regions are all herbaceous species. However, competition effects may also extend to trees and shrubs as well, as alien and invasive alien species can inhibit regeneration of saplings (Lazaro-Lobo et al., 2021). Disturbance resulting in degradation of permafrost and conversion of upland to wetland area could potentially reduce the distribution of 85 species of upland plants of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties.

Vegetation recovery in areas of temporary disturbance may differ among plant groups and life-history characteristics of affected species (Jonsson and Esseen, 1998). Large scale disturbances which remove bryoid and humus layers may negatively affect recovery of vascular plants, as many boreal species form extensive seed banks within humus layers (Granstrom, 1982). Traditional plant abundance in areas of temporary disturbance may differ following construction due to a loss of seed bank and altered competition.

As the Project may result in the loss of May Be At Risk plant species of interest to Indigenous Governments, Indigenous Organizations, and specific other affected parties, effects are considered moderate to high magnitude. It is possible, though unlikely, that occurrences of one of these plant species of interest are the only occurrences of that species in the LAA or RAA. In that case, the effect on that particular species would extend to the LAA or RAA, respectively. This determination includes uncertainty in the occurrence of May Be At Risk plants and the potential use by Indigenous Governments, Indigenous Organizations, and specific other affected parties. Project effects are not expected to result in the local or regional loss of secure or alien plants, and although abundance will be reduced, species of these plants occurring in the LAA are expected to remain abundant. Effects are expected to be long-term due to the presence of the highway and the retention of some quarry sites. Dust contaminant exposure will continue. Because of complete removal of vegetation from the PDA, the VC is not sensitive to seasonal timing (i.e., seasonal aspects are unlikely to affect vegetation and wetlands).

18.4.5 Change in Wetland Function

18.4.5.1 Effects Pathways

In addition to direct loss of wetlands from project construction, wetland functions may also be indirectly altered. Wetland functions are generally recognized as internal natural processes and features of wetlands that are independent of the benefits provided to humans (Novitzki et al., 1997; Kusler, 2004; Hansen et al., 2008; Burton and Tiner, 2009). Ecosystem services are the benefits humans derive from wetlands and can be evaluated separately from functions, but are sometimes evaluated together, as is done by the Federal Wetland Policy (Government of Canada, 1991).

Project construction has the potential to affect the hydrological, biogeochemical, and habitat functions of wetlands through the removal of wetland vegetation, partial infilling of wetlands, and alteration of surface and sub-surface water flows. These changes may result in altered wetland nutrient levels and downstream export, decomposition and carbon accumulation rates, water infiltration and storage, plant diversity, and wildlife habitat. Changes in wetland function from the Project are expected to occur during construction, starting with vegetation clearing and grading, and continue through operations with the presence of the highway leading to potentially permanent alteration of wetland catchments and water inflows to wetlands and outflows from wetlands.

18.4.5.2 Mitigation

Mitigation measures will be implemented during construction and operation of the Project, as identified in the management plans located in Volume 5 and Table 18.8. Key mitigation measures to avoid or reduce the potential effects of the Project to wetland function include the following:

- Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns.
- During spring, summer, and fall, suitable ground equipment will be used to reduce potential effect on sensitive terrain.
- Use of equipment on highly saturated soil will be avoided, where possible.
- Vegetation buffers will be used as visual barriers and to protect riparian vegetation, as appropriate.
- Erosion and sedimentation control measures will be implemented per ESCP (Volume 5) and will be in place prior to construction activities and before the spring melt/freshet.
- Silt fencing will be used downgradient of the works where required.
- Sediment and erosion control measures will be regularly inspected to confirm they are performing as intended.
- Erosion and sedimentation control measures will be maintained until disturbed areas are revegetated or until such areas have been permanently stabilized by other effective measures.

- An SCP will be developed and implemented (Volume 5).
- All site personnel will receive SCP training and will have awareness of spill prevention.
- Fuel will be stored in containers with secondary containment capable of containing 110% of the largest container.
- Equipment such as vehicles, generators, and pumps will have secondary containment installed capable of containing fuel drips or leaks during operations and refueling.
- Equipment laydown and staging areas will be located at least 100 m from the ordinary high water mark of any waterbody.
- Washing, refueling, and servicing machinery and storage of fuel and other materials for machinery will be conducted a minimum of 100 m from the ordinary high-water mark and in a manner to prevent any deleterious substances from entering the water.
- Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies.
- Quarry dewatering will be done such that discharge will not directly enter wetlands or lead to soil erosion.

18.4.5.3 Residual Effects

The hydrology of wetlands partially intersected by the Project may be altered. Wetlands located downstream of the Project in an area of new road alignment or on the downstream side of quarry sites may receive less water following construction and those upstream may have reduced outflow. However, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns, reducing this effect. Wetlands can receive water from precipitation, groundwater seepage, overland flow, and stream discharge (Mitsch and Gosselink, 1993; Winter et al., 1998). Most wetlands lose water by evapotranspiration, but groundwater recharge and surface outflow from channels can also occur. Changes in hydrology have not been quantified but effects are expected to be greatest where the Project cuts across drainage into or out of wetlands. Changes will also occur to wetlands with a loss of larger portions of contributing drainage basins.

Outflow from wetlands could be reduced where the Project alters drainage from a wetland. In these areas both water and nutrient flow to downstream areas could be reduced. Drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns, reducing this effect. Increased or decreased water levels may alter plant composition and the abundance of different structural layers. In areas where wetlands become much wetter than existing conditions, vascular plants, particularly forbs, and grasses will be favoured over non-vascular plants (i.e., mosses, liverworts, and lichens). Larger shifts to drier conditions may reduce vascular plant abundance and favour mosses. In extreme instances some wetlands may convert to upland habitat following loss of contributing catchment area or stream inflow.

The presence of the highway will continue to affect light and moisture conditions in remaining vegetation nearby. The abundance of plants less tolerant of open conditions and higher light exposure will decrease in areas of tree and shrub removal, including many species of mosses and forbs adapted to lower light conditions found under woody cover.

Effects on wetland functions will continue through project operations because drainage alterations will likely remain along with ongoing control (mowing) of woody vegetation and alien and invasive alien species. Dust contamination generated from passing vehicles may also locally alter wetland water chemistry and plant composition in the LAA.

As the Project may result in the reduction of wetland function, effects are adverse. Effects are predicted to be low in magnitude as wetlands and their associated functions will continue in the LAA and RAA. Effects are expected to be predominantly limited to wetlands intersected by the PDA or close to the PDA, although effects may extend into the LAA if contributing drainages are intersected. Effects will be long-term as the road will be permanent, some quarry sites will be retained, the cleared ROW will alter plant conditions throughout operations, and dust contaminant exposure will also continue. Due to seasonal changes in water flow, effects on wetland function have moderate seasonal timing sensitivity.

18.4.6 Summary of Residual Effects

With mitigation (including reclamation of abandoned sections of the MVWR ROW and access roads), residual effects resulting from the Project on landscape diversity, community diversity (including merchantable timber), species diversity (including plant SOCC and plants of interest to Indigenous communities), and wetland function will occur and are predicted to be adverse in direction and low to potentially high in magnitude during construction and operations. The geographic extent of direct effects will be the LAA, and LAA to RAA for change in plant species diversity. Effects will persist due to the presence of the highway (i.e., long term). Effects will be ongoing and are likely irreversible due to the indefinite duration of operation of the Project. A summary of residual effects on vegetation and wetlands is presented in Table 18.15.

With the implementation of the mitigation measures, the Project is anticipated to meet the SLUP conformity requirements related to species introduced, sensitive species and features, and consideration of engagement input and incorporation of Traditional Knowledge.

The design of the Project and mitigation measures for reducing effects on vegetation and wetlands respects the values of the Petiniʔah (Bear Rock) CZ, Mio Lake CZ, Norman Range SMZ, K’ą̨lǫ Tué (Willow Lake Wetlands) SMZ and Deh Cho (Mackenzie River) SMZ, as areas with important wetland habitats and plant harvesting areas. The Project takes into account harvest of merchantable timber.

Table 18.15 Residual Effects on Vegetation and Wetlands

Residual Effect	Residual Effects Characterization*								
	Project Phase	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Landscape Diversity	C/O	A	CE	M	LAA	NS	LT	C	I
Change in Community Diversity	C/O	A	CE	L	LAA	NS	LT	C	I
Change in Species Diversity	C/O	A	CE	M-H	LAA/RAA	NS	LT	C	I
Change in Wetland Function	C/O	A	CE	L	LAA	MS	LT	C	I

KEY

*See Table 18.3 for detailed definitions

Project Phase
C: Construction
O: Operations and maintenance

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

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

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

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

Reversibility:
R: Reversible
I: Irreversible

18.5 Assessment of Cumulative Effects on Vegetation and Wetlands

18.5.1 Residual Effects Likely to Interact Cumulatively

Existing environmental conditions reflect cumulative effects on the environment from past and present projects and physical activities. Past and present projects and physical activities that have been or are being carried out have influenced the existing conditions for vegetation and wetlands (Section 18.4). The assessment of cumulative effects focuses on four adverse residual project effects: change in landscape diversity, change in community diversity, change in species diversity, and change in wetland function.

Table 18.16 presents interactions with other past, present, and reasonably foreseeable future projects and physical activities within the RAA. Chapter 4 presents the names, proponents, use or activity, descriptions, status, and location of these projects and activities.

Where adverse residual effects from the Project act cumulatively with those from other projects and physical activities, a cumulative effects assessment is undertaken to determine their significance. For further information about reasonably foreseeable future projects and physical activities, see Table 4.2.

Table 18.16 Projects and Physical Activities with the Potential to Contribute to Cumulative Effects

Other Projects and Physical Activities with Potential for Cumulative Effects	Effects			
	Change in Landscape Diversity	Change in Community Diversity	Change in Species Diversity	Change in Wetland Function
Past and Present Physical Activities and Resource Use (Base Case)				
Geotechnical	–	–	–	–
Oil, Gas & Seismic*				
Tulita 2D Seismic Program	✓	✓	✓	✓
EL 466 Drilling Program	✓	✓	✓	✓
Windy Island Drilling Program	✓	✓	✓	✓
Summit Creek Drilling Program	✓	✓	✓	✓
Slater River Project	✓	✓	✓	✓
Little Bear Staging Area	✓	✓	✓	✓
Infrastructure				
Mackenzie Valley Winter Road, including bridges and bridge-sized culverts	✓	✓	✓	✓
Canyon Creek All Season Access Road	✓	✓	✓	✓

Other Projects and Physical Activities with Potential for Cumulative Effects	Effects			
	Change in Landscape Diversity	**Change in Community Diversity**	**Change in Species Diversity**	**Change in Wetland Function**
Norman Wells Pipeline	✓	✓	✓	✓
Mackenzie Valley Fibre Link	–	✓	✓	–
Délı̨nę Winter Road	✓	✓	✓	✓
Mackenzie Highway No.1	✓	✓	✓	✓
Prohibition Creek Access Road (PCAR)	✓	✓	✓	✓
Quarries and Borrow Sources				
HRN Quarry	✓	✓	✓	–
Little Bear River Quarry	✓	✓	✓	–
Mining & Exploration				
Wrigley Zinc Property Drilling Program	✓	✓	✓	✓
Municipal Operations, including water, waste, power, and community development				
Wrigley Municipal Activities	–	✓	✓	–
Tulita Municipal Activities	–	✓	✓	–
Norman Wells Municipal Activities	–	✓	✓	–
Project-Related Physical Activities (Project Case)				
Mackenzie Valley Highway Project	✓	✓	✓	✓
Reasonably Foreseeable Physical Activities (Reasonably Foreseeable Case)				
Quarries				
Dhu-1 Quarry	–	✓	✓	–
Infrastructure				
Great Bear River Bridge	–	✓	✓	–
Oil and Gas				
Enbridge Maintenance Camp	✓	✓	✓	✓

Notes:

✓ = Other projects and physical activities whose residual effects are likely to interact cumulatively with project residual effects.

– = Interactions between the residual effects of other projects and residual effects of the Project are not expected.

* = Includes support activities such as production, exploration, remediation, drilling, wells, associated infrastructure, facilities, camp, and staging areas.

Similar to the Project, interactions between other projects and physical activities with vegetation and wetlands are anticipated where there will be physical disturbance of vegetation or wetlands. Checkmarks are given for those other projects and activities. In some cases, the effects of other projects and physical activities are anticipated to affect only vegetation and not wetlands (e.g., the Mackenzie Valley Fibre Link which will likely clear some vegetation but is not anticipated to affect wetland function). For some other projects and physical activities works will occur in vegetated areas but are expected to be sited to avoid wetlands (e.g., municipal activities).

Past and present geotechnical projects to do not interact with vegetation and wetlands as these projects are located within the municipal boundaries of Tulita or existing cleared areas.

18.5.2 Change in Landscape Diversity

18.5.2.1 Cumulative Effects Pathways

Potential cumulative effects on landscape diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including direct and indirect effects on landscape diversity due to fragmentation of landcover types, as discussed in Section 18.4.2. NWRRC study participants raised concerns about changing temperatures and the cumulative effects of climate change on vegetation during project construction and operation (NWRRC, 2023). Sahtu Renewable Resources Board expressed concern that changes in vegetation and wetlands and changes resulting from removal of permafrost may result in decreased plants, and plant harvesting locations available to Indigenous harvesters (SRRB, 2016).

18.5.2.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects are the same as those presented in Section 18.4.2. The MVWR will be incorporated into the Project along most of its length. Abandoned sections of the MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation.

18.5.2.3 Cumulative Effects

Similar to residual Project effects, cumulative effects on landscape diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways: directly through fragmentation of landcover types during clearing and indirectly due to edge effects. Specifically, the MVWR, Canyon Creek All Season Access Road (CCASAR), the Mackenzie Valley Fibre Link, the Norman Wells Pipeline, quarries and borrow sources, and mining and exploration have resulted in cumulative landscape diversity fragmentation. It is expected that the PCAR, Dhu-1 Quarry and Great Bear River Bridge will also contribute cumulatively to landscape diversity landcover fragmentation and edge effects. Specifically, it is estimated that PCAR will remove 77.8 ha, Great Bear River Bridge will remove 46.5 ha, and Dhu-1 Quarry will remove 23.0

ha of native vegetation. The Project will contribute to both direct and indirect cumulative effects on landscape diversity due to landcover fragmentation and edge effects.

Past, present, and reasonably foreseeable projects and physical activities have resulted and will continue to result in an increase in fragmentation of the landscape. The Project will increase fragmentation; however, fragmentation effects will be reduced by aligning the Project with the MVWR along most of its length. Specifically, the Project will result in a reduction in average patch size of 0.1 ha for coniferous forest and shrubland and there will be a small to moderate increase in perimeter length to patch area, between 100 m/ha and 1,000 m/ha, for all natural landcover types.

The effect on landscape diversity from all projects and physical activities is considered moderate based on the known or anticipated extent of effects. Other projects and physical activities are known or anticipated at various locations in the RAA. This determination includes uncertainty of the extent of future projects. Even with all projects and physical activities, patches of many sizes and shapes of all landcover types are expected to remain abundant in the RAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent. Effects will be medium-term for abandoned sections of the MVWR ROW and access roads, which will be closed and reclaimed to promote re-establishment of vegetation, and for borrow sources and quarries and associated access roads not required for highway maintenance, which will be closed and reclaimed. Many projects and physical activities have the potential for indirect effects, particularly fragmentation edge effects.

18.5.3 Change in Community Diversity

18.5.3.1 Cumulative Effects Pathways

Potential cumulative effects on community diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including the direct loss or alteration of landcover types and indirectly on landcover types from the spread of dust contamination, alien, and invasive alien plant species, as discussed in Section 18.4.3.

18.5.3.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects for the Project are the same as those presented in Section 18.4.3.

18.5.3.3 Cumulative Effects

Based on the known or anticipated areas of disturbance to vegetation and wetlands, past, present, and reasonably foreseeable projects and physical activities have had and will continue to have direct effects on community diversity, including removal of native landcover type area, change in moisture and light levels in adjacent native vegetation communities, introduction or spread of alien or invasive alien plant species, and generation of dust contamination. Specifically, the MVWR, CCASAR, the Norman Wells Pipeline, Mackenzie Valley Fibre Link, quarries and borrow sources, mining and exploration, and municipal operations have resulted in cumulative effects on community diversity. It is expected that the Dhu-1 Quarry, Great Bear River Bridge, and PCAR may also contribute cumulatively to effects on community diversity.

The Project will add to these effects, due to direct loss or indirect alteration of landcover types. However, effects will be reduced by aligning the Project with the MVWR along most of its length. In total, the area of native vegetation communities directly lost due to the Project will be a small percentage of the LAA, ranging from 2.0% of wetland communities to 3.2% of broadleaf forest communities in the LAA. Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA. These effects on community diversity from all projects and physical activities are considered low and extend to the RAA. This determination includes uncertainty of the extent of future projects. Even with all projects and physical activities, all landcover types will remain abundant in the LAA and RAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent, including the Project, except the effect will be medium-term where the MVWR is not incorporated in the Project. The portion of the MVWR not incorporated into the Project will be closed and reclaimed to promote re-establishment of vegetation. In addition, borrow sources and quarries and associated access roads not required for highway maintenance will also be closed and reclaimed.

18.5.4 Change in Species Diversity

18.5.4.1 Cumulative Effects Pathways

Potential cumulative effects on species diversity arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including potential direct loss of occurrences of SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, and potential indirect effects on occurrences of these species as discussed in Section 18.4.4.

18.5.4.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects are the same as those presented in Section 18.4.4.

18.5.4.3 Cumulative Effects

Based on the known or anticipated areas of disturbance to vegetation and wetlands, past, present, and reasonably foreseeable projects and physical activities have had and will continue to have effects on SOCC, if present, and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties through both direct loss and indirect effects. Specifically, the MVWR, CCASAR, PCAR, the Norman Wells Pipeline, Mackenzie Valley Fibre Link, quarries and borrow sources, mining and exploration, and municipal operations have likely resulted in effects on SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties. It is expected that the Dhu-1 Quarry and Great Bear River Bridge may also contribute cumulatively to effects on these same species. The Project will add to these effects, although effects will be reduced by aligning the Project with the MVWR along most of its length. The effect on species diversity from all projects and physical activities is considered moderate and extends to the RAA. Even with all projects and physical activities, habitat for SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties is expected to remain in the LAA and RAA because all landcover types will remain common in the LAA and RAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent.

18.5.5 Change in Wetland Function

18.5.5.1 Cumulative Effects Pathways

Potential cumulative effects on wetland function arising from past, present, and reasonably foreseeable projects and physical activities have the same effect pathways as those resulting from the Project, including the direct loss or alteration of wetlands and indirect effects due to alteration of surface and sub-surface water flows, nutrient levels and downstream export, decomposition and carbon accumulation rates, water infiltration and storage, plant diversity, and wildlife habitat, as discussed in Section 18.4.5.

18.5.5.2 Mitigation for Cumulative Effects

Mitigation measures for cumulative effects are the same as those presented in Section 18.4.5.

18.5.5.3 Cumulative Effects

Some past, present, and reasonably foreseeable projects and physical activities have affected and will continue to affect wetland function including direct loss or alteration of wetlands and indirect effects due to alteration of surface and sub-surface water flows, nutrient levels and downstream export, decomposition and carbon accumulation rates, water infiltration and storage, plant diversity, and wildlife habitat. Specifically, the MVWR, CCASAR, the Norman Wells Pipeline, and mining have likely resulted in effects on wetland function. It is expected that the PCAR may also contribute cumulatively to effects on wetland function.

However, even considering all projects and physical activities, wetlands of all types and sizes are expected to remain abundant in the RAA with many occurring far from projects or physical activities with little or no adverse effects on wetland function. The Project will add to these effects; however, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns. Mitigation presented in Section 18.4.5 will be implemented to reduce effects on nearby wetlands and wetland function. The effect on wetland function from all projects and physical activities is considered low and extends to the LAA. Effects are expected to be long-term as most projects and activities will be long-term or permanent. Many projects and physical activities have the potential for both direct and indirect effects.

18.5.6 Summary of Cumulative Effects

Cumulative effects on landscape diversity, community diversity (including merchantable timber), species diversity (including plant SOCC and plants of interest to Indigenous communities), and wetland function from past, present, and reasonably foreseeable projects and activities have occurred and will likely continue to occur and are predicted to be adverse in direction and low to moderate in magnitude. The Project will make a low to moderate contribution to these effects. However, effects will be reduced by aligning the Project with the MVWR along most of its length and promoting re-establishment of vegetation on abandoned sections of the MVWR ROW and access roads. In addition, borrow sources and quarries and associated access roads not required for highway maintenance will be closed and reclaimed. Mitigation measures presented in Section 18.4 will also serve to reduce cumulative effects on vegetation and wetlands. Cumulative effects will extend from the PDA to the RAA. Effects from many projects and activities, including the Project, will persist for the long term due to long operating life of many projects and activities. For many of these project and activities, effects will be ongoing during construction and operation and may be reversible or irreversible. The summary of vegetation and wetland cumulative effects is presented in Table 18.17.

Table 18.17 Summary of Cumulative Effects

Residual Cumulative Effect	Residual Cumulative Effects Characterization*							
	Direction	Likelihood	Magnitude	Geographic Extent	Timing	Duration	Frequency	Reversibility
Change in Landscape Diversity	A	CE	M	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	The Project will increase fragmentation in the RAA; however, average patch size will only be reduced by 0.1 ha for coniferous forest and shrubland and there will be a small to moderate increase in perimeter length to patch area, between 100 m/ha and 1, 000 m/ha, for all natural landcover types, resulting in a moderate magnitude contribution to cumulative effects on landscape diversity at the RAA level.							
Change in Community Diversity	A	CE	L	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	The Project will reduce abundance of natural upland and wetland landcover categories but all landcover types will remain abundant in the LAA and RAA. Specifically, the area of native vegetation communities directly lost due to the Project ranges from 2.0% of wetland communities to 3.2% of broadleaf forest communities in the LAA. Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA; therefore, will make a low magnitude contribution to cumulative effects on community diversity at the RAA level.							

Residual Cumulative Effect	Residual Cumulative Effects Characterization*							
	Direction	**Likelihood**	**Magnitude**	**Geographic Extent**	**Timing**	**Duration**	**Frequency**	**Reversibility**
Change in Species Diversity	A	CE	M	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have the potential to occur in the PDA. Many plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may be present in the PDA, LAA, and RAA. Therefore, effects on plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties from the Project could occur. Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. This includes monitoring in accordance with the terms and conditions of permit approvals, as required. No plant species, including bryophytes, or lichen SOCC potentially occurring in the RAA are listed under SARA or COSEWIC. For these reasons, the Project could make a moderate magnitude contribution to cumulative effects on landscape diversity at the RAA level.							
Change in Wetland Function	A	CE	L	RAA	N/A	LT	C	R/I
Contribution from the Project to the residual cumulative effect	The Project may result in a reduction of wetland function; however, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns, and mitigation will be implemented to reduce effects on nearby wetlands and wetland function. The Project is therefore predicted to make a low magnitude contribution to cumulative effects on wetland function at the RAA level.							

KEY

* See Table 18.3 for detailed definitions

Direction:
A: Adverse
N: Neutral

Likelihood:
U: Unlikely
P: Possible
CE: Certain

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

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

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

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

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

Reversibility:
R: Reversible
I: Irreversible

N/A: Not applicable

18.6 Determination of Significance

18.6.1 Significance of Residual Effects

A significant adverse residual effect on vegetation and wetlands is one that, following the application of avoidance and mitigation measures, threatens the long-term persistence or viability of plant communities or species, including those of cultural or traditional importance, or threatens the long-term viability of local or regional wetland function.

Residual effects will alter the size and characteristics of vegetation landscape diversity; however, the average patch size will only be reduced by 0.1 ha for coniferous forest and shrubland and there will be a small to moderate change in patch area to perimeter length, between 100 m/ha and 1,000 m/ha. Landcover abundance of natural upland and wetland landcover categories will be reduced but will remain abundant with direct losses of native vegetation communities due to the Project ranging from 2.0% of wetland communities to 3.2% of broadleaf forest communities in the LAA. Indirect effects from dust contaminant deposition (to a distance of 40 m from the PDA) could affect an additional 2.0% of wetlands and 3.8% of forest in the LAA. Although no plant SOCC occurrences have been documented in the PDA or LAA, 215 plant SOCC have potential to occur in the PDA. No thresholds for changes to vegetation and wetlands are known to be applicable in the NWT. Although rate of change in connectivity of vegetation community patches has been shown to differ depending on the degree of fragmentation, with the rate changing considerably past a threshold (McIntyre and Wiens, 1999; Monkkonen and Reunanen, 1999), thresholds are not known for plant species occurring in the NWT or comparable areas of other Canadian provinces.

Many plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties may be present in the PDA, LAA, and RAA. Therefore, effects on plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties from the Project could occur. A pre-construction survey of higher potential areas of the PDA for plant SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties, will be conducted. No plant species, including bryophytes, or lichen SOCC potentially occurring in the RAA are listed under SARA or COSEWIC. The Project may result in a reduction of wetland function. However, drainage culverts will be constructed along the roadway to facilitate water movement and maintain drainage patterns and mitigation measures will be implemented to reduce effects on nearby wetlands and wetland function. Therefore, with the application of mitigation measures, residual effects on vegetation and wetlands are predicted to be not significant.

18.6.2 Significance of Cumulative Effects

The threshold for a significant adverse cumulative effect on vegetation and wetlands is the same as for residual effects. Many past, present, and reasonably foreseeable projects and activities will have adverse effects on landscape diversity, community diversity, species diversity, and wetland function. However, taking into consideration all projects and physical activities, abundance of natural upland and wetland landcover categories will be reduced but all types will remain abundant in the RAA. With the large amount of area of all landcover types remaining in the RAA, plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties are expected to continue to occur, and most would be expected to remain relatively abundant in the RAA. Therefore, cumulative effects on vegetation and wetlands are predicted to be not significant.

18.6.3 Project Contribution to Cumulative Effects

With mitigation, the Project is predicted to make a moderate contribution to cumulative effects on landscape diversity, a low contribution to cumulative effects on community diversity, a moderate contribution to cumulative effects on species diversity, and a low contribution to cumulative effects on wetland function.

18.7 Prediction Confidence

The determination of a not significant effect is made with a moderate level of confidence based on the available data for landcover types, occurrences of plant SOCC and plants of interest to Indigenous Governments, Indigenous Organizations, and other affected parties in the LAA. Prediction confidence will increase with data collected during pre-construction surveys of SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.

18.7.1 Assumptions

It is assumed that all vegetation and wetlands will be removed from the PDA. This is a conservative assumption because parts of the PDA are already cleared for the MVWR. In addition, abandoned sections of the MVWR ROW and access roads will be closed and reclaimed to promote re-establishment of vegetation. It is expected that in time, potentially several decades, vegetation in upland forest in the LAA outside of the PDA will become upland forest of similar composition to surrounding undisturbed forest, and similarly that lower areas will develop hydric soils and wetland vegetation partially offsetting effects from the Project. This assessment also conservatively assumes that all SOCC species and species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties potentially present in the RAA could be present in the PDA and therefore affected during project construction.

18.7.2 Gaps and Uncertainties

All vegetation and wetland data for the RAA is from existing governmental databases. Data is relatively coarse and does not include detailed vegetation and wetland composition. Limited information is available for the distribution of plant SOCC and plant species important to Indigenous Governments, Indigenous Organizations, and other affected parties. In addition, climate change may have unpredictable effects on the plant species growth, composition and diversity which will develop during re-establishment of vegetation during closure and reclamation. This could also include unpredictable effects on plant SOCC and plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.

Prediction confidence will increase with data collected during pre-construction vegetation surveys, including surveys for plant SOCC and rare or may-be-at-risk plant species of interest to Indigenous Governments, Indigenous Organizations, and other affected parties.

18.8 Follow-up and Monitoring

The objectives of vegetation and wetlands monitoring may include:

- Verifying compliance with terms and conditions of authorizations and commitments
- Verifying effectiveness of mitigations
- Verifying effects predictions

Targeted vegetation and wetland surveys of SOCC and specific plant species of interest to Indigenous Governments and Indigenous Organizations, and other affected parties, will be conducted within the PDA in high potential areas, such as fens, bogs, and dry or rocky sites and in a sub-sample of more common landcover types, prior to construction. This will include transplant or seed collection of observed rare or vulnerable plant species. Appropriate mitigation measures (and monitoring if needed) will be developed based on the findings of the surveys. These are not considered part of the compliance monitoring program.

Monitoring of vegetation will include inspection for invasive alien plant occurrences prior, during and after construction. Inspection will occur during the growing season when plants are actively growing and features supporting identification are present. Inspection will occur in the growing season prior to construction to support pre-construction control efforts. A suggested frequency of monitoring is one inspection per year during construction and one in the year following construction, and five years into Project operations. Identified areas with invasive alien plants will be managed through mowing to reduce introduction and spread of invasive alien plants in the PDA and surrounding natural vegetation. The GNWT-INF will develop an invasive plant species monitoring program in discussion with GNWT-ECC. Additional monitoring requirements, if identified as part of the Project's approval and permitting, will be incorporated into the Project's compliance and effects monitoring activities.

18.9 References

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