MACKENZIE VALLEY HIGHWAY PROJECT, WRIGLEY TO NORMAN WELLS – CLIMATE LENS PART 1: GREENHOUSE GAS MITIGATION ASSESSMENT

May 13, 2021

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Attestation of Completeness

I/we the undersigned attest that this GHG Mitigation Assessment was undertaken using recognized assessment tools and approaches (i.e., *ISO 14064-2: Specification with guidance at the project level for quantification, monitoring, and reporting of greenhouse gas emissions reductions or removal enhancements, and the GHG Protocol for Project Accounting) and* complies with the General Guidance and any relevant sector-specific technical guidance issued by Infrastructure Canada for use under the Climate Lens. Stantec is an accredited ISO 14065 verification body.

Respectfully submitted,

Kãlo Stantec Limited

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Executive Summary

The Mackenzie Valley Highway Project is a proposed 321 km stretch of all-season gravel roadway between the communities of Wrigley and Norman Wells. The project is located in the Mackenzie Valley of the Northwest Territories (NWT).

The Government of the Northwest Territories (GNWT) Department of Infrastructure (INF) is seeking federal funding under the Investing in Canada Infrastructure Program (ICIP). This Greenhouse Gas (GHG) Mitigation Assessment has been prepared in accordance with Infrastructure Canada requirements, specifically their Climate Lens General Guidance v.1.2 (the Guidance) (Infrastructure Canada 2019). The objective of the GHG Mitigation Assessment is to estimate the expected GHG emissions associated with the Project and to estimate the potential changes in GHGs associated with the Project compared to a functionally equivalent baseline scenario. In the case of this assessment, the baseline scenario is the annual construction and maintenance of a 321 km winter road to allow traffic to flow to and from local communities. The Project scenario involves the construction and annual maintenance of an all-season 321 km gravel road.

Construction of the Project is anticipated to occur over several years; the construction schedule has not yet been finalized. The construction period, if there is no non-construction wait time, could take up to 3 years. To align with the temporal boundaries applied in the Project's Climate Resilience Assessment, the estimate of service life for this GHG Mitigation Assessment is 20 years. Therefore, the total timeframe for this assignment is 23 years.

The baseline scenario GHG emissions are estimated to result in the release of 33,539 tonnes of carbon dioxide equivalent (t CO_2e). The Project-related GHG emissions from on- and off-road vehicles and equipment during the construction period are estimated to result in the release of 81,191 t CO_2e. Operation of the Project is expected to result in the release of approximately 3,443 t CO_2e per year. Additionally, 366 t CO_2e per year is expected from the loss of an available carbon sink (i.e., the boreal forest and supportive ecosystems) as a result of widening the existing right-of-way. The total net Project emissions are expected to result in the release of 3,809 t CO_2e per year, for a total of 157,370 t CO_2e over the lifetime of the Project. The Project is expected to result in a net cumulative increase of 123,830 t CO_2e over the baseline scenario. A summary of funding for the Project and a summary of the expected GHG emissions is provided in Table 1.

Table 1 Project Funding and GHG Emissions Summary

Aspect	Amount
Total Project Costs (Estimated and has not yet been Finalized)	$700,000,000
Total Requested Funding Contribution (Estimated to be Approximately 75% of the Total Project Costs))	$525,000,000
2030 GHG Results	
Baseline Scenario Emissions, in 2030 (1 year)	1,458 t CO_2e
Project Scenario Emissions, in 2030 (1 year)	3,809 t CO_2e
Net GHG Emissions, in 2030 (1 year)	2,351 t CO_2e
Federal Dollars/GHG Emissions in 2030 (Non-Cumulative)	$233,336 per t CO_2e
2030 GHG Results – Cumulative to 2030	
Baseline Scenario Emissions, Cumulative to 2030	13,124 t CO_2e
Project Scenario Emissions, Cumulative to 2030	Construction Period: 81,191 t CO_2e Operation Period (2025 – 2030, inclusive): 22,854 t CO_2e Total Project Emissions: 104,044 t CO_2e
Net GHG Emissions, Cumulative to 2030	90,920 t CO_2e
Federal Dollars/GHG Emissions by 2030 (Cumulative)	$5,774 per t CO_2e
Lifetime GHG Results	
Baseline Scenario Emissions, Lifetime (23 Years)	33,539 t CO_2e
Project Scenario Emissions, Lifetime (23 Years)	157,370 t CO_2e
Net GHG Emissions, Lifetime (23 Years)	123,830 t CO_2e
Total Project Cost (Construction Cost Over Lifetime/Cumulative GHG Emissions Over Lifespan)	$5,653 per t CO_2e
Note: The Project is expected to result in a net cumulative increase of GHG emissions.	

Abbreviations

CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CCASAR	Canyon Creek All-Season Access Road
GHG	greenhouse gas
GNWT	Government of the Northwest Territories
GWP	global warming potential
ECCC	Environment and Climate Change Canada
h	hour
HDV	heavy duty vehicle
HFC	hydrofluorocarbon
ha	hectares
ICIP	Investing in Canada Infrastructure Program
INF	Department of Infrastructure
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
km	kilometre
kW	kilowatt
L	litre
LDV	light duty vehicle
m^3	cubic meters
N_2O	nitrous oxide
NF_3	nitrogen trifluoride
NIR	National Inventory Report
NWT	Northwest Territories
PFC	perfluorocarbon
SF_6	sulphur hexafluoride
t	metric tonne
WRI	World Resources Institute

1.0 INTRODUCTION

This report summarizes the Greenhouse Gas (GHG) Mitigation Assessment, performed as Part 1 of the Climate Lens Assessment, as required by the Investing in Canada Infrastructure Program (ICIP). The ICIP is a bilateral agreement between Infrastructure Canada and the provinces and territories.

The Government of the Northwest Territories (GNWT) Department of Infrastructure (INF) is seeking federal funding under the ICIP. This GHG Mitigation Assessment has been prepared in accordance with Infrastructure Canada requirements, specifically Climate Lens General Guidance v.1.2 (the Guidance) (Infrastructure Canada 2019). The objective of the GHG Mitigation Assessment is to estimate the expected GHG emissions associated with the Project and to estimate the potential changes in GHGs associated with the Project compared to a functionally equivalent baseline scenario.

1.1 PURPOSE

The objective of the GHG Mitigation Assessment is to assess whether the Project will result in a net increase or decrease in GHG emissions compared to a representative baseline scenario.

In the case of this assessment, the baseline scenario is the annual construction and maintenance of a 321 km winter road to allow traffic to flow to and from local communities. The Project scenario involves the construction and annual maintenance and operation of an all-season 321 km gravel road.

In accordance with the Guidance, the following components are included in this GHG Mitigation Assessment:

- Definition of the review area
- Characterization of the baseline scenario conditions within the review area, including
  - Baseline conditions for construction emissions
  - Baseline conditions for operation-related emissions.
- Characterization of the Project conditions within the review area, including
  - Project conditions for construction emissions
  - Project conditions for operation-related emissions.
- Mitigation measures to reduce/limit GHG emissions.

2.0 METHODOLOGY

The methods used to estimate GHG emissions in the baseline and Project scenarios are based on the accounting and reporting principles of the GHG protocol developed by the World Resource Institute (WRI) and the World Business Council for Sustainable Development (2013). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions.

The guiding principles of the protocol for compiling an inventory of GHG data are relevance, completeness, consistency, transparency, and accuracy. The principles described are also consistent with IS0-14064-2. In cases where uncertainty is high, conservative quantification parameters and assumptions were applied, resulting in a conservative (e.g., higher) estimate of GHG emissions reductions (WRI, 2004).

2.1 PROJECT BOUNDARY

2.1.1 Project Overview and Spatial Boundaries

The baseline scenario consists of the annual construction and maintenance of a 321 km winter road located between Wrigley and Norman Wells, NWT.

The Project scenario consists of the construction and operation of a 321 km all-season roadway, also located between Wrigley and Norman Wells, NWT.

In both the baseline and Project scenarios, the roadway is an extension to an existing segment of gravel road that extends in the northerly direction from the Town of Norman Wells to the Canyon Creek bridge, parallel to the Mackenzie River. Because GHG emissions disperse in the atmosphere and contribute cumulatively to global climate change, the boundaries of this assessment depict the limits of this assessment and are not necessarily or simply the physical boundaries of the Project.

A site location map for both the baseline and Project scenarios is provided in Figure 1. There are currently two sections of road that are currently being constructed and are therefore excluded from this assessment: 1) Canyon Creek to Prohibition Creek, and 2) Wrigley to Mount Gaudet. These sections of road are depicted in Figure 1.

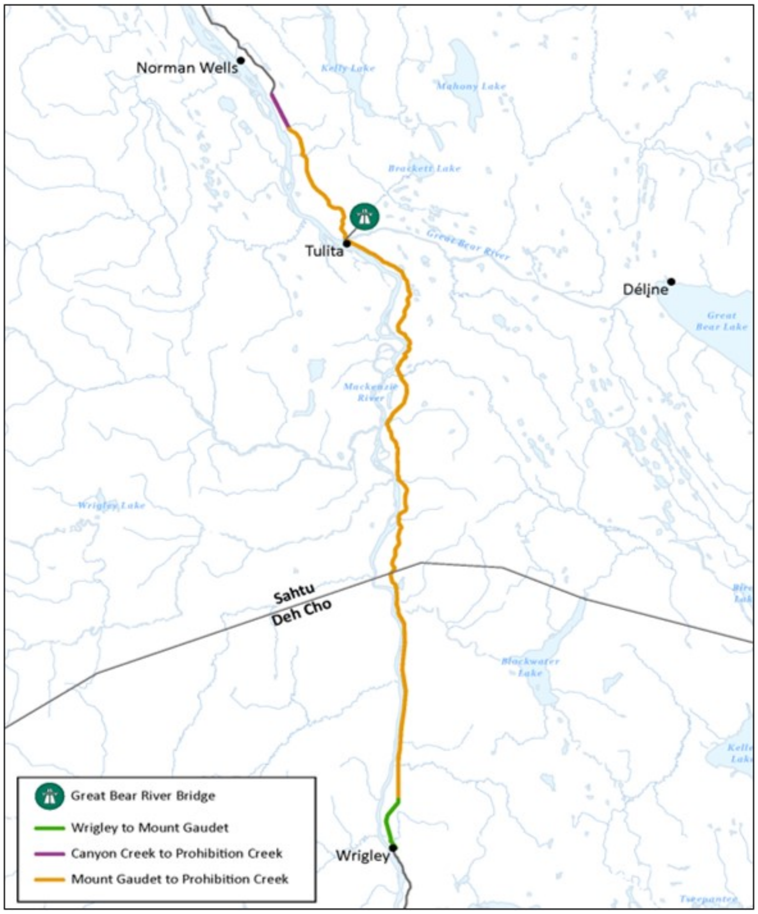

Figure 1 Site Location Map

2.1.2 Temporal Boundaries

The temporal boundaries used in this assessment include the Project construction and operation phases. Construction of the Project is anticipated to occur over several years; the construction schedule has not yet been finalized. The construction period, if there is no non-construction wait time, could take up to three years. Realistically, the construction timeframe could be much longer than three years as it is expected there will be periods of time when construction is not occurring due to wait times (e.g., for funding, materials, or equipment). Nevertheless, for this assessment, construction is assumed to take three consecutive years. To align with the temporal boundaries applied in the Project's Climate Resilience Assessment, the estimate of service life for this GHG Mitigation Assessment was 20 years. The total timeframe for this assessment is therefore 23 years for both the baseline and Project scenarios.

The assessment excludes anticipated major rehabilitative maintenance or decommissioning activities, supply chain, and embodied GHG emissions. See Section 2.4 and 2.5 for a comprehensive list of activities are included in the assessment. This approach is consistent with the Guidance.

2.2 GREENHOUSE GASES CONSIDERED

A GHG is any atmospheric gas that absorbs and re-emits infrared radiation, thereby acting as a thermal blanket for the planet and warming the lower levels of the atmosphere. Several natural and anthropogenic (human activity) sources release GHGs to the atmosphere (IPCC 2014).

Emissions of each of the specific GHGs are multiplied by their 100-year global warming potential (GWP) and are reported as carbon dioxide equivalent (CO_2e). As per the Guidance, the GWPs from the most up-to-date version of Canada's National Inventory Report (NIR) must be used. Therefore, GWPs have been obtained from the 2019 NIR – Part 1, Table 1-1 IPCC Global Warming Potentials (GWPs). The GWP of these GHGs are:

- Carbon dioxide (CO_2) = 1.0
- Methane (CH_4) = 25
- Nitrous oxide (N_2O) = 298
- Sulphur hexafluoride (SF_6) = 22,800
- Nitrogen trifluoride (NF_3) = 17,200
- Hydrofluorocarbon (HFC) gases range from 12 to 14,800
- Perfluorocarbon (PFC) gases range from 7,390 to 17,340

Not all GHGs listed above are applicable to this assessment. Those included in this assessment are CO_2, CH_4 and N_2O. Four GHGs and groups of GHGs have been excluded from the GHG assessment for reasons explained below:

- 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.
- 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. NF_3 is not expected to be used or released by the Project or the baseline.
- HFCs and PFCs – 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.

On this basis, carbon dioxide equivalents (CO_2e) for the Project are calculated as:

$$CO_2e = (\text{mass } CO_2 \times 1) + (\text{mass } CH_4 \times 25) + (\text{mass } N_2O \times 298)$$

2.3 GHG EMISSIONS SCOPES

This assessment considered the Project direct and indirect GHG emissions as well as any emission reductions linked to the Project as directed by the Guidance. Direct and indirect emissions are defined by Infrastructure Canada as follows:

- **Direct GHG Emissions**: Refers to GHG emissions or removals from sources or sinks that are owned or controlled by the proponent. At the GHG inventory level, direct emissions are also commonly referenced as Scope 1 emissions (Infrastructure Canada 2019).
- **Indirect GHG Emissions**: Refers to GHG emissions or removals that are a consequence of the Project, but which occur at GHG sources or sinks not owned or controlled by the applicant (Infrastructure Canada 2018). For example, reduced electricity consumption would be considered an indirect effect, as the GHG emissions generated from the production of electricity for this Project are outside of the Project's boundaries.

The following GHG emission sources have been included in this assessment (Table 2).

Table 2 Sources of GHG Emissions – Project and Baseline Scenarios

Phase	Item	Description	Source / Removal	Direct / Indirect	Scope
Baseline GHG Emissions Sources					
Construction	Mobile Equipment - Construction Equipment and Vehicles	GHG emissions are expected to result from the use of construction equipment, and on-road and off-road vehicles during construction of the winter road on an annual basis.	Source	Direct	Scope 1
Operation	Mobile Equipment – Construction Equipment and Vehicles	GHG emissions are expected from the use of on-road vehicles to maintain the winter road.	Source	Direct	Scope 1
Operation	Mobile Equipment - Vehicles	GHG emissions are expected to result from vehicle use in the winter months.	Source	Direct	Scope 1
Operation	Mobile Equipment – Vessels and Aircraft	GHG emissions are expected to result from the use of aircrafts, vessels, and trucks to transport goods to and from communities along the winter road	Source	Direct	Scope 1
Project GHG Emissions Sources					
Construction	Mobile Equipment	GHG emissions are expected to result from the use of construction equipment, and on-road and off-road vehicles to construct the all-season road.	Source	Direct	Scope 1
Construction	Worker Transport and Housing	GHG emissions are expected to result from the transportation of workers to the construction site, and from the operation of a construction camp to house construction workers.	Source	Direct	Scope 1

Table 2 Sources of GHG Emissions – Project and Baseline Scenarios

Phase	Item	Description	Source / Removal	Direct / Indirect	Scope
Construction	Blasting and Transportation of Materials	GHG emissions are expected to result from blasting rock from a quarry, and the transportation of the blasted rock to the construction site.	Source	Direct	Scope 1
Operation	Mobile Equipment	GHG emissions are expected to result from the use of on-road and off-road vehicles to maintain the all-season road.	Source	Direct	Scope 1
Operation	Mobile Equipment	GHG emissions are expected to result from vehicle use year-round.	Source	Direct	Scope 1
Operation	Mobile Equipment	GHG emissions are expected to result from the use of aircrafts, vessels, and trucks to transport goods to and from communities along the year-round road.	Source	Direct	Scope 1

Emissions are expected from the loss of an available carbon sink as a result of the widening of the existing right of way during construction of the Project. No indirect (Scope 2) GHG emissions are expected to occur as a result of the Project. No other indirect (Scope 3) GHG emissions, including upstream, downstream, or embodied GHG emissions, have been estimated, as these are not required by the Guidance.

2.4 DATA COLLECTION AND CALCULATION PROCEDURES

2.4.1 Baseline Scenario

The baseline scenario involves the annual construction and maintenance of a 321 km winter road. The purpose of winter road maintenance is to reduce the negative effects of snow and ice on traffic using the road (Hinkka, V. et al. 2016). For this assessment, the equipment that is expected to be used includes a grader, snowcat and a water truck.

Direct emissions resulting from the construction and maintenance of the winter road, related to on-road and off-road activities, are based on equipment inventories and project activity schedules that are expected to release GHG emissions (i.e., equipment with internal combustion engines).

Off-road sources of GHG emissions include equipment, engines or vehicles that are primarily used for construction activities (e.g., graders, excavators, and loaders). These emission sources are typically not approved to be driven on highways or public roads as they are designed for construction activities. On-road GHG sources include mobile equipment that are approved to travel on highways and public roads. All on-road and off-road equipment are assumed to be powered by diesel fuel. Estimations of GHG emissions for on-road and off-road construction equipment/vehicles are based on equipment inventories, hours operated, fuel consumption, in combination with GHG emission factors (i.e. CO_2, CH_4, and N_2O) from the 2019 NIR (ECCC 2019).

To estimate the emissions from annual construction and maintenance of the winter road, equipment inventories and data provided by GNWT staff were used. Specifically, a GHG emissions profile for the Canyon Creek All-Season Access Road (CCASAR) was used as the basis for generating an emissions profile for the baseline scenario. The CCASAR project involved the construction of a 14 km all-season gravel road and repairs to 4.75 km of existing road. The data was pro-rated per km to estimate construction and maintenance emissions in the baseline scenario.

For more information on emissions estimations related to the use of the winter road, as well as vessel and aircraft trips for the transportation of goods/cargo, see Section 2.5 and Appendix A.

No indirect (Scope 2) GHG emissions are expected to occur as a result of the baseline scenario. No other indirect (Scope 3) GHG emissions, including upstream, downstream, or embodied GHG emissions, have been estimated, as these are not applicable or required by the Guidance.

2.4.2 Project Scenario

The Project scenario involves the construction, and annual maintenance and operation, of a 321 km all-season gravel road. The emissions generated from this scenario are expected to be higher in comparison to the emissions generated from the construction and maintenance of the winter road (baseline scenario). More effort is required to clear snow and ice from an all-season road (which includes the use of a grader, plow truck, water trucks and a light duty truck) compared to maintaining a winter road (which includes the use of a grader, snowcat and a water truck).

Direct GHG emissions resulting from the construction and operation of the all-season road, related to on-road and off-road activities, are based on equipment inventories and project activity schedules that are expected to release GHG emissions (i.e., equipment with internal combustion engines).

The on-road and off-road equipment for the Project are assumed to be powered by diesel fuel. Estimations of GHG emission for on-road and off-road construction equipment/vehicles are based on equipment inventories, hours operated, fuel consumption, in combination with GHG emission factors (i.e., CO_2, CH_4, and N_2O) from the 2019 NIR (ECCC 2019).

To estimate the emissions from the construction and annual maintenance of the all-season road, equipment inventories and data provided by GNWT staff were used. Specifically, a GHG emissions profile for the Canyon Creek All-Season Access Road (CCASAR) was used as the basis for generating an emissions profile for the Project scenario. The data was pro-rated per km to estimate construction and maintenance emissions for the Project scenario. See Section 2.5 and Appendix A for more information.

For more information on emissions estimations related to annual use of the road, vessel and aircraft trips for the transportation of goods/cargo, worker transportation and housing, blasting/transportation of materials to the construction site, and emissions associated with a reduction in land carbon sequestration, see Section 2.5 and Appendix A.

No indirect (Scope 2) GHG emissions are expected to occur as a result of the Project activities. No other indirect (Scope 3) GHG emissions, including upstream, downstream, or embodied GHG emissions, have been estimated, as these are not required by the Guidance.

2.5 ASSUMPTIONS

The following assumptions have been made to estimate construction GHG emissions resulting from the baseline scenario:

- The GHG emissions calculations herein were completed prior to full Project design completion. As such, emission estimations are high-level; actual values depend on the actual equipment and fuels used over time and the use of the winter road.
- The winter road is 321 km long.
- The timeframe for the baseline scenario is the same as the Project scenario (23 years).
- The list of construction and maintenance equipment for the winter road and hours of operation data are from the CCASAR project (see Appendix A for details); the data were pro-rated per km for use in the baseline scenario calculations.
- Off-road and on-road equipment is assumed to be powered with diesel fuel.
- Fuel consumption rates (litres/hour) are based on Kãlo Stantec Limited’s (Stantec) experience with construction projects, and various information sources including NRCan (2019 and 2020) and Generator Source (2020).
- The winter road in the baseline scenario is expected to have relatively low traffic volumes (50 vehicles per day, with an estimated 15% of those as heavy truck traffic) due to the low overall population in the area; it is assumed the winter road is used between December 15 and April 5, based on data provided by GNWT.

- In the baseline scenario, aircrafts and vessels are used to transport goods and cargo to and from Norman Wells and Tulita, which then is transported to nearby communities in trucks. Stantec was provided with data from GNWT (Locke, pers.comm., 2020), who sourced data from various aircraft carriers and vessels.
  - The mass shipped by marine vessel is the average of 2018 and 2019 mass shipped, divided by the total trips per year. The total mass shipped for the year is included in these calculations.
  - CH_4 and N_2O emissions are not included in the calculation of GHG emissions from tugs/barges because emission factors are not readily available.
  - The aircraft GHG emissions estimation includes the transportation of cargo, but not people.
  - The distances travelled by the aircrafts are estimations.
  - It is assumed the cargo received via aircraft and vessel is transported no more than 100 km by a pick-up truck with a capacity of half a tonne.

The following assumptions have been made to estimate construction GHG emissions resulting from the Project:

- The GHG emissions calculations herein were completed prior to Project design completion. As such, the emission estimations are high-level; actual values depend on the actual equipment and fuels used over time and the use of the Project infrastructure.
- The all-season road will be 321 km long.
- The timeframe for the Project scenario is the same as the baseline scenario (23 years).
  - The construction period, if there is no non-construction wait time, could take up to three years. Realistically, the construction timeframe could be much longer than three years as it is expected there will be periods of time when construction is not occurring due to wait times (e.g., for funding, materials, or equipment). For this assignment, construction is assumed to take three consecutive years.
  - The Project's operational service life is 20 years.
- During the construction period, as the Project is built, the length of the winter road that is constructed annually will shorten, causing a reduction in GHG emissions. This reduction is not accounted for in the calculations due to insufficient information about the Project schedule.
- The list of construction equipment and hours of operation data are from the CCASAR project (see Appendix A for details). The construction equipment data was pro-rated per km for use in the calculations.
- Off-road and on-road equipment is assumed to be powered with diesel fuel.
- Fuel consumption rates (L/h) are based on Stantec's experience with construction projects, and various information sources including NRCan (2019 and 2020) and Generator Source (2020).
- For construction of the all-season road (the Project), it is assumed that 60 people (4 people per truck) travel half the length of the highway (to and from) for 3 years. An estimation of 5-60 people will be required per construction spread. For this assignment, it is assumed that two construction spreads are used, for a total of 120 people.
- A construction camp will be set up during the construction period, to house construction workers, and will use diesel for heat and electricity. The generators are assumed to run for 12 hours per day during the construction period (3 years).

- Approximately 50,000 m^3 of blasted rock will be required for every 13 km of the Project. The weight of the rock is assumed to be 2.3 tonnes/m^3, according to Stantec personnel working on projects along the Mackenzie Valley Highway (Pireaux, pers.comm., August 2020).
- It is assumed the blasted rock is transported 20 km by a typical large dump truck, capable of carrying 28,000 lbs, or 12.7 tonness per trip.
- It is assumed that the existing cleared right of way will increase from 10 to 30 m to 60 m wide, on average, which would eliminate 963 hectares (ha) of carbon-sequestering land.
- The road construction will involve the use of woven geotextile, placed on the existing ground, which would result in minimal ecological disturbance (i.e. no uproot and burn activities are expected).
- The all-season roadway is expected to have relatively low traffic volumes (50 vehicles per day, with an estimated 15% of those as heavy truck traffic) due to the low overall population in the area. The all-season road will be used 365 days per year.
- It is anticipated that there will be reduced aircraft and vessel trips, and an increase in transport truck activity in the summer months once the Project is complete. Insufficient data is available to understand how the completed all-season road would impact the transportation of goods/cargo. Therefore, Stantec assumed the same amount of cargo is going to be moved during the baseline scenario and the Project scenario by the same modes of transportation, and that the emissions from these activities will therefore be the same. These GHG emissions then effectively cancel each other out. Additional information can be provided when available.
- The installation and management of the road could result in permafrost melt resulting in the release of methane (CH_4). Due to limited data on the correlation between road construction and a measurable release of GHG emissions from permafrost decay in the Northwest, the release of CH_4 from permafrost decay was not factored into the analysis. See Appendix B for more information about permafrost melt.

3.0 GHG MITIGATION ASSESSMENT

The GHG emissions associated with the baseline and Project scenarios, and net GHG emissions, are presented in the following sections. A summary of GHG reductions and costs, and a list of GHG mitigation actions are also presented below.

3.1 BASELINE SCENARIO

The baseline scenario is estimated to result in the release of 33,539 t CO_2e over the full periods of construction and operation. Details are presented in the table below.

Table 3 Baseline GHG Emissions Estimates

Year	Baseline Emissions (A) (tCO_2e)	Baseline Removals (B) (tCO_2e)	Net Baseline Emissions & Removals (A-B) (tCO_2e)
Construction Period (2021-2024)	4,375	-	4,375
Operation Year 1 (2025)	1,458	-	1,458
Operation Year 2 (2026)	1,458	-	1,458
Operation Year 3 (2027)	1,458	-	1,458
Operation Year 4 (2028)	1,458	-	1,458
Operation Year 5 (2029)	1,458	-	1,458
Operation Year 6 (2030)	1,458	-	1,458
Operation Year 7 (2031)	1,458	-	1,458
Operation Year 8 (2032)	1,458	-	1,458
Operation Year 9 (2033)	1,458	-	1,458
Operation Year 10 (2034)	1,458	-	1,458
Operation Year 11 (2035)	1,458	-	1,458
Operation Year 12 (2036)	1,458	-	1,458
Operation Year 13 (2037)	1,458	-	1,458
Operation Year 14 (2038)	1,458	-	1,458
Operation Year 15 (2039)	1,458	-	1,458
Operation Year 16 (2040)	1,458	-	1,458
Operation Year 17 (2041)	1,458	-	1,458
Operation Year 18 (2042)	1,458	-	1,458
Operation Year 19 (2043)	1,458	-	1,458
Operation Year 20 (2044)	1,458	-	1,458
Total	**33,539**	**-**	**33,539**

3.2 PROJECT SCENARIO

The Project scenario is estimated to result in the release of 157,370 t CO_2e. Project emissions (3,809 t CO_2e per year) are expected to result from the operation of the Project (3,443 t CO_2e per year) and from the loss of an available carbon sink as a result of the widening of the existing right-of-way (366 t CO_2e per year). Details are presented in the Table 4 below.

Table 4 Project GHG Emissions

Year	Project Emissions (A) (tCO_2e)	Project Removals (B) (tCO_2e)	Net Project Emissions & Removals (A-B) (tCO_2e)
Construction Period (2021-2024)	81,191	-	81,191
Operation Year 1 (2025)	3,809	-	3,809
Operation Year 2 (2026)	3,809	-	3,809

Table 4 Project GHG Emissions

Year	Project Emissions (A) (tCO_2e)	Project Removals (B) (tCO_2e)	Net Project Emissions & Removals (A-B) (tCO_2e)
Operation Year 3 (2027)	3,809	-	3,809
Operation Year 4 (2028)	3,809	-	3,809
Operation Year 5 (2029)	3,809	-	3,809
Operation Year 6 (2030)	3,809	-	3,809
Operation Year 7 (2031)	3,809	-	3,809
Operation Year 8 (2032)	3,809	-	3,809
Operation Year 9 (2033)	3,809	-	3,809
Operation Year 10 (2034)	3,809	-	3,809
Operation Year 11 (2035)	3,809	-	3,809
Operation Year 12 (2036)	3,809	-	3,809
Operation Year 13 (2037)	3,809	-	3,809
Operation Year 14 (2038)	3,809	-	3,809
Operation Year 15 (2039)	3,809	-	3,809
Operation Year 16 (2040)	3,809	-	3,809
Operation Year 17 (2041)	3,809	-	3,809
Operation Year 18 (2042)	3,809	-	3,809
Operation Year 19 (2043)	3,809	-	3,809
Operation Year 20 (2044)	3,809	-	3,809
Lifespan Total	**157,370**	**-**	**157,370**

3.3 PROJECT NET GHG EMISSIONS

The annual GHG emissions for the Project are assessed against the baseline scenario and presented in the table below. Over the lifetime of the Project, it is estimated to result in a cumulative release of 123,830 t CO_2e over the baseline scenario.

Table 5 Net Change in GHG Emission

Year	Total Net Project Scenario Emissions & Removals (A) (tCO_2e)	Total Net Baseline Scenario Emissions & Removals (B) (tCO_2e)	Total Net Change In Emissions & Removals (A-B) (tCO_2e)
Construction Period (2021-2024)	81,191	4,375	76,816
Operation Year 1 (2025)	3,809	1,458	2,351
Operation Year 2 (2026)	3,809	1,458	2,351
Operation Year 3 (2027)	3,809	1,458	2,351

Table 5 Net Change in GHG Emission

Year	Total Net Project Scenario Emissions & Removals (A) (tCO_2e)	Total Net Baseline Scenario Emissions & Removals (B) (tCO_2e)	Total Net Change In Emissions & Removals (A-B) (tCO_2e)
Operation Year 4 (2028)	3,809	1,458	2,351
Operation Year 5 (2029)	3,809	1,458	2,351
Operation Year 6 (2030)	3,809	1,458	2,351
Operation Year 7 (2031)	3,809	1,458	2,351
Operation Year 8 (2032)	3,809	1,458	2,351
Operation Year 9 (2033)	3,809	1,458	2,351
Operation Year 10 (2034)	3,809	1,458	2,351
Operation Year 11 (2035)	3,809	1,458	2,351
Operation Year 12 (2036)	3,809	1,458	2,351
Operation Year 13 (2037)	3,809	1,458	2,351
Operation Year 14 (2038)	3,809	1,458	2,351
Operation Year 15 (2039)	3,809	1,458	2,351
Operation Year 16 (2040)	3,809	1,458	2,351
Operation Year 17 (2041)	3,809	1,458	2,351
Operation Year 18 (2042)	3,809	1,458	2,351
Operation Year 19 (2043)	3,809	1,458	2,351
Operation Year 20 (2044)	3,809	1,458	2,351
Lifespan Total	**157,370**	**33,539**	**123,830**

3.4 COST-PER-TONNE

During the 21st Conference of Parties (COP21) held in 2015 in Paris, Canada committed to a 30% reduction of national GHG emissions below the 2005 level by 2030 (ECCC 2019). Achieving this target would mean that the national GHG emissions total will be 511,000,000 t CO_2e in 2030 (down from 730,000,000 t CO_2e in 2005) (ECCC 2019). By 2030, the Project is estimated to increase baseline GHG emissions by 90,920 t CO_2e (cumulatively), which represents 0.02% of Canada's 2030 emissions target.

The construction costs are estimated to be $700,000,000 and requested federal funding contribution for this Project is estimated to be $525,000,000. Operational costs (e.g., maintenance activities) have not been estimated. Costs associated with maintenance would be negligible relative to overall Project construction costs.

Table 6 Project Cost-Per-Tonne

Aspect	Amount
Total Project Costs (Estimated and has not yet been Finalized)	$700,000,000
Total Requested Funding Contribution (Estimated to be Approximately 75% of the Total Project Costs))	$525,000,000
2030 GHG Results	
Baseline Scenario Emissions, in 2030	1,458 t CO_2e
Estimated Project Emissions, in 2030	3,809 t CO_2e
Net GHG Emissions, in 2030	2,351 t CO_2e
Federal Dollars/GHG Emissions in 2030 (Non-Cumulative)	$233,336 per t CO_2e
2030 GHG Results – Cumulative	
Baseline Scenario Emissions, Cumulative to 2030	13,124 t CO_2e
Estimated Project Emissions, Cumulative to 2030	Construction Period: 81,191 t CO_2e Operation Period (2025 – 2030, inclusive): 22,854 t CO_2e Total Project Emissions: 104,044 t CO_2e
Net GHG Emissions, Cumulative to 2030	90,920 t CO_2e
Federal Dollars/GHG Emissions by 2030 (Cumulative)	$5,774 per t CO_2e
Lifetime GHG Results	
Baseline Scenario Emissions, Lifetime (23 Years)	33,539 t CO_2e
Estimated Project Emissions, Lifetime (23 Years)	157,370 t CO_2e
Net GHG Emissions, Lifetime (23 Years)	123,830 t CO_2e
Total Project Cost (Construction Cost Over Lifetime/Cumulative GHG Emissions Over Lifespan)	$5,653 per t CO_2e
Note: The Project is expected to result in a net cumulative increase of GHG emissions.	

3.5 GHG MITIGATION ACTIONS

Since a key objective of the Climate Lens is the facilitation of climate-focused change at the Project level, the following section presents GHG mitigation actions for the construction and operation/maintenance phases of the Project.

3.5.1 Construction

Mitigative management measures will be implemented during construction activities, where economically reasonable, to reduce the quantities of GHGs released to the atmosphere. The following are highlighted mitigative management measures proposed at this time:

- Procuring fuel-efficient equipment models, equipped with run-time indicators where possible, to assist in monitoring and lowering fuel consumption and cost.
- Assessing the capacity of the equipment being considered, and using only equipment that meets minimum size requirements, to reduce unnecessary fuel consumption.
- Regularly maintaining equipment to ensure efficient operation (e.g. regularly checking tire pressure, operational maintenance on the basis of engine hours. etc.).
- Where practical and applicable, multi-passenger vehicles will be used to transport crews to and from job sites.
- Installing energy efficient security and task lighting (e.g., LED lights)
- Minimizing area of disturbance by constructing the road in heavily disturbed areas, where possible.
- Arrange site toolbox talks to encourage compliance with the mitigation measures listed above, and to raise awareness of the benefits of the mitigation measures.

3.5.2 Operation and Maintenance

The following are highlighted operational and maintenance mitigation measures are proposed at this time:

- Monitoring energy use and GHG emissions and taking reasonable steps to minimize GHG emissions from Project-related sources.
- Completing preventative maintenance on vehicles and equipment according to them manufacturer's specifications for optimal performance.

4.0 CLOSURE

This report summarizes the GHG Mitigation Assessment performed as part of the Climate Lens Assessment as required by Infrastructure Canada's Disaster Mitigation and Adaptation Fund. The methods used to estimate GHG emissions for the baseline and Project scenarios are based on accounting and reporting principles of the GHG Protocol and aligned with ISO 14064-2. The report includes estimated depictions of the inputs and outputs of the scenarios based on a combination of data provided by the Government of the Northwest Territories Department of Infrastructure, third party studies, and available literature and documents. Stantec has completed this assessment using reasonably ascertainable information, obtained from a desktop review of documentation, informal data compilations, and telephone conversations. The assessment represents the information provided at the time of the assessment. Stantec did not conduct direct GHG emissions monitoring, site visits, or other environmental sampling and analysis in conjunction with this assessment. Readers of this report should ensure that they are aware of the assumptions made in the assessment and any limitations so created.

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APPENDIX A

Assessment of Construction and Operation GHG Emissions

Appendix A ASSESSMENT OF CONSTRUCTION AND OPERATION GHG EMISSIONS

This appendix describes the assessment of the construction, maintenance, and operation GHG emissions in the baseline and Project scenarios.

A.1 BASELINE SCENARIO

The baseline scenario is the annual construction and maintenance of a 321 km winter road. Construction GHG emissions are expected to originate from on-road and off-road construction equipment, on-road vehicles, and the transportation of goods/cargo. For more information, see Section 2.4.1 and Section 2.5.

A.1.1 On-Road and Off-Road Construction Equipment for Construction and Maintenance of the Winter Road

The table below provide inventories of potential construction equipment to be used during the baseline scenario. On-road and off-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Table 7 Construction Off-Road and On-Road Equipment – Operation of the Winter Road

Equipment	Quantity	Fuel Type	Classification	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
2012 Cat 14M Grader	1	Diesel	Off Road Diesel >= 19kW, Tier 4	60.00	17.00	1,020.00
2005 SnowCat	1	Diesel	Off Road Diesel < 19kW	60.00	19.00	1,140.00
2008 Water Trucks	1	Diesel	On Road Diesel, HDV	48.00	19.00	912.00

Sample calculations are provided in Section A.1.1.

A.1.2 On-Road Vehicles

During the baseline scenario, vehicles will be driven along the winter road between December 15 and April 5. Fuel consumption data was obtained from the Natural Resources Canada 2020 Fuel Consumption Guide. On-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Equipment	Quantity	Fuel Type	Classification	KM Travelled Per Day (km/day)	Fuel Consumption (L/100km/Unit)	Fuel Consumed (L)
Light Duty Trucks	4,675*	Diesel	On Road Diesel, LDT	321.00	10.00	150,068
Heavy Duty Trucks	825*	Diesel	On Road Diesel, HDV	321.00	39.50	104,606
*Traffic counts indicate approximately 50 vehicles are expected to travel per day. Stantec estimated approximately 15% of these vehicles are heavy duty trucks, and the remaining 85% are light duty trucks.						

Sample calculations are provided in Section A.1.2.

A.1.3 Transportation of Goods/Cargo

In the baseline scenario, aircrafts and vessels are used to transport goods and cargo to and from Norman Wells and Tulita, which then is transported to nearby communities in trucks. A summary of the activity data used in the calculations is provided below.

Table 8 Transportation of Goods/Cargo via Vessel, Air and Transport Truck – Baseline

	Destination	Distance Travelled (km)	Mass Shipped per year (on average) (tons)	tonne km
Equipment - Vessel				
Pusher - Towing Tug, Nunakput (789 gross tonnage)	Norman Wells (from Hay River)	901	189	154,484
Pusher - Towing Tug, Johnny Hope/Henry Christoffersen (783 gross tonnage)	Norman Wells (from Hay River)	901	189	154,484
Pusher - Towing Tug, Nunakput (789 gross tonnage)	Tulita (from Hay River)	816	57	42,195
Pusher - Towing Tug, Johnny Hope/Henry Christoffersen (783 gross tonnage)	Tulita (from Hay River)	816	57	42,195
Equipment - Aircraft				
North-Wright Airways (3,000 lbs of air cargo per month)	Tulita from Yellowknife)	614	16	10,026.20
Canadian North (airline) (1,500 lbs of air cargo every day)	Norman Wells (from Yellowknife)	682	248	169,368.98
Canadian North (airline) (3300 lbs of air cargo once a week)	Norman Wells (from Yellowknife)	682	78	53,084.42
Canadian North (airline) (2,600 lbs of air cargo once per week)	Tulita (from Norman Wells)	72	61	4,415.45
Buffalo (airline) (up to 520,000 lbs of air cargo per year)	Norman Wells (from Yellowknife)	682	236	160,861.87
Buffalo (airline) (approximately 318864 lbs of air cargo per year)	Tulita (from Yellowknife)	614	145	88,805.37

Equipment – Transport Truck	Quantity (Total Weight of Cargo / Truck Capacity)	Classificatio n	KM Travelled (from airport/ port to destination)	Fuel Consumption (L/100 km)	Fuel Consumed (L)
Transportation of goods/cargo on land - Light Duty Trucks (F150 Pick Up Truck)	2,316	On Road Diesel, LDT	100	10.00	23,157

A sample of calculations are provided below.

Sample Calculation, Transportation of Goods/Cargo via Vessel and Air, Pusher - Towing Tug, Nunakput (789 gross tonnage)

tonne-km =	Distance travelled	km	x	Mass shipped	tons	x	0.907185	tonnes
								ton
tonne-km =	901	km	x	189	tones	x	0.907185	tonnes
								ton
tonne-km =	**154,484**							

The total may not sum due to rounding

Sample Calculation, Transportation of Goods/Cargo via Vessel and Air, Transportation of goods/cargo on land - Light Duty Trucks (F150 Pick Up Truck)

Fuel Consumed (L) =	weight of cargo (tons)	x	0.91	tonnes (t)	x	Distance per trip (km)	x	Fuel Consum -ption	L		
	capacity of truck (tonnes)			ton					100 km		
Fuel Consumed (L) =	1,276	tons	x	0.91	t	x	100	km	x	10	L
	0.5	t			ton					100 km	
Fuel Consumed (L) =	**23,157**										

The total may not sum due to rounding

A.2 PROJECT SCENARIO

The Project scenario is the construction and annual maintenance of an all-season 321 km gravel road. Emissions are expected to originate from on-road and off-road construction equipment, on-road vehicles, stationary equipment, blasting of rock and transportation of the rock to the construction site, lost land carbon storage capability and the transportation of goods/cargo. For more information, see Section 2.4.2 and Section 2.5.

A.2.1 On-Road and Off-Road Equipment for Construction and Operation of the All-Season Gravel Road

The tables below provide inventories of potential construction equipment to be used during the Project scenario. On-road and off-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Table 9 Construction Off-Road and On-Road Equipment List – Construction

Equipment	Fuel Type	Classification	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
2006 Cat D8K Dozer	Diesel	Off Road Diesel >= 19kW, Tier 4	1,530	39.12	59,854
1987 Cat D7G Dozer	Diesel	Off Road Diesel >= 19kW, Tier 4	1,250	39.12	48,900
2005 Cat D6N Dozer	Diesel	Off Road Diesel >= 19kW, Tier 4	300	24.70	7,410
2004 Cat 330C Excavator	Diesel	Off Road Diesel >= 19kW, Tier 4	600	31.00	18,600
2011 Cat 345DL Excavator	Diesel	Off Road Diesel >= 19kW, Tier 4	700	31.00	21,700
2012 Cat 14M Grader	Diesel	Off Road Diesel >= 19kW, Tier 4	2,800	17.00	47,600
2007 Cat 980H Loader	Diesel	Off Road Diesel >= 19kW, Tier 4	1,530	21.75	33,278
2012 John Deere 644k Loader	Diesel	Off Road Diesel >= 19kW, Tier 4	1,200	21.75	26,100
1000lb Plate Tamper	Diesel	Off Road Diesel >= 19kW, Tier 4	620	2.27	1,409
Skidoo	Diesel	Off Road Diesel < 19kW	150	14.29	2,143
Walk Behind Packer	Diesel	Off Road Diesel >= 19kW, Tier 4	100	2.27	227
2004 Cat 262B Skid Steer	Diesel	Off Road Diesel >= 19kW, Tier 4	100	31.00	3,100
1998 Cat CS563 Packer Smooth Drum	Diesel	Off Road Diesel >= 19kW, Tier 4	2,000	31.00	62,000
2005 SnowCat	Diesel	Off Road Diesel < 19kW	110	19.00	2,090
Hydraulic 3500 Reed Drill	Diesel	Off Road Diesel >= 19kW, Tier 4	1,200	22.38	26,856
Hydraulic 345 Reed Drill	Diesel	Off Road Diesel >= 19kW, Tier 4	1,200	22.80	27,360
Rock Crusher	Diesel	Off Road Diesel >= 19kW, Tier 4	480	10.79	5,179
2002 Cat 730 articulating dump truck	Diesel	On Road Diesel, HDV	6,660	31.60	210,456
End dump truck	Diesel	On Road Diesel, HDV	6,000	31.60	189,600
4-F350 Pick Up Truck	Diesel	On Road Diesel, LDT	1,200	10.60	12,720
2-F450 Flat Deck Truck	Diesel	On Road Diesel, LDT	150	10.60	1,590
2007 Kenworth Winch Truck & Trailer	Diesel	On Road Diesel, HDV	100	31.60	3,160
2008 Water Trucks	Diesel	On Road Diesel, HDV	200	19.00	3,800
2008 Kenworth Fuel/Lube Service Truck	Diesel	On Road Diesel, HDV	200	19.00	3,800
2007 Ford Mechanic Welder Truck	Diesel	On Road Diesel, HDV	200	10.60	2,120

Table 10 Construction Off-Road and On-Road Equipment List – Operation

Equipment	Quantity	Fuel Type	Classification	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
2012 Cat 14M Grader	1	Diesel	Off Road Diesel >= 19kW, Tier 4	100.00	17.00	1,700.00
Plow truck	1	Diesel	On Road Diesel, HDV	100.00	31.60	3,160.00
2008 Water Trucks	1	Diesel	On Road Diesel, HDV	100.00	31.60	3,160.00
4-F150 Pick Up Truck	1	Diesel	On Road Diesel, LDT	100.00	10.00	1,000.00

The following is an example calculation for emissions from fuel combustion from on-road and off-road equipment:

Sample Calculation - Construction Equipment GHG Emissions, 2006 Cat D8K Dozer

Fuel Consumed (L) = hours x $\frac{L}{hour}$

Fuel Consumed (L) = 1,530.00 hours x 39.12 $\frac{L}{hour}$

Fuel Consumed (L) = **59,854**

Annual t CO_2e Emissions* = L x $\frac{t\ CO_2e}{L}$

Annual t CO_2e Emissions* = 59,854 L x 0.0028 $\frac{t\ CO_2e}{L}$

Annual t CO_2e Emissions* = **165**

This calculation is also used for other sources of GHG emissions and will not be repeated below

The total may not sum due to rounding

A.2.2 On-Road Vehicles During Construction and Operation

Construction workers will travel to and from the Project site during construction. During operation of the Project, vehicles will be driven along the year-round road. Fuel consumption data was obtained from the Natural Resources Canada 2020 Fuel Consumption Guide. On-road GHG emission factors were obtained from the 2019 National Inventory Report (ECCC 2019).

Table 11 Equipment List for On-Road Vehicle Use of the Road during Construction and Operation (Non-Construction Vehicles)

Equipment	Quantity	Fuel Type	Classification	KM Travelled Per Day (km/day)	Fuel Consumption (L/100km/Unit)	Fuel Consumed (L)
Worker Transportation to and from the Construction Site (Construction)						
F150 Pick Up Trucks	30*	Diesel	On Road Diesel, LDT	321.00	10.60	1,117,754
On-Road Vehicles (Annual Road Use – Operation)						
Light Duty Trucks (F150 Pick Up Truck)	15,513**	Diesel	On Road Diesel, LDT	321.00	10.00	497,968
Heavy Duty Trucks	2,738**	Diesel	On Road Diesel, HDV	321.00	39.50	347,165

* Assuming 60 workers (4 per truck) travel half the length of the highway (to and from) for 3 years. Assumed there will be 2 construction spreads with 60 workers each.

**Traffic counts indicate approximately 50 vehicles are expected to travel per day. Stantec estimated approximately 15% of these vehicles are heavy duty trucks, and the remaining 85% are light duty trucks.

The following is a sample calculation for on-road worker transport (fuel consumed):

$$\text{Fuel Consumed (L)} = \frac{\text{km}}{\text{day}} \times \frac{\text{L}}{\text{km}} \times \frac{\text{Quantity per day}}{\text{(60 people, 4 per vehicle)}} \times \text{days}$$

$$\text{Fuel Consumed (L)} = \frac{321\ \text{km}}{\text{day}} \times \frac{0.11\ \text{L}}{\text{km}} \times 30 \times 1095\ \text{days}$$

Fuel Consumed (L) = **1,117,754**

The total may not sum due to rounding

A.2.3 Camp Operation

A construction camp will be required during to house workers. Fuel consumption data was obtained from Generator Source (2020). Emission factors were obtained from the 2019 National Inventory Report (ECCC 2019). An equipment list and fuel estimation are provided below.

Table 12 Construction Camp Equipment List

Equipment	Fuel Type	Hours Operated	Fuel Consumption (L/h/unit)	Fuel Consumed (L)
60 kW Diesel Generator	Diesel	13,140.00	18.17	238,753

The following is a sample calculation for the construction camp (fuel consumed):

Sample Calculation Camp Operation GHG Emissions, 60 kW Diesel Generator					
Fuel Consumed (L) =	hours	x	L / hour		
Fuel Consumed (L) =	13,140	hours	x	18.17	L / hour
Fuel Consumed (L) =	**238,753**				
The total may not sum due to rounding					

A.2.4 Blasting and Materials Transport

Rock will be blasted at a nearby quarry and transported to the Project site for use in the construction of the road. The emission factors used in calculating blasting emissions are from Dyno Mobel (2010) and Rescan Environmental Services (2013). Details on activity data used in the calculations are provided in the following tables.

Table 13 Blasting and Material Transport to Site for Construction – Equipment List

Aspect	Quantity of Rock (m^3)	Typical Weight of Blast Rock (tonnes / m^3)	Total Weight (tonnes)	Powder Factor (tonne explosive / m^3 rock)*	Total Explosive Required (Tonnes)
Blasting GHG Emissions	12,346,154	2.30	28,396,154	0.00035	4,321

Table 14 Material Transport to Site for Construction – Fuel Consumed

Aspect	Quantity (Total Weight of Blasted Rock / Truck Capacity)	Fuel Type	Classification	KM Travelled (from Quarry to the Project Site)	Fuel Consumption (L/100km/ Unit)	Fuel Consumed (L)
Transportation of Blasted Rock to Project Site - Dump Truck	2,235,918	Diesel	On Road Diesel, HDV	20.00	31.60	14,130,999

Sample calculations are provided below in relation to blasting and material transport to site.

Sample Calculation Blasting GHG Emissions					
Required Explosive (tonnes) =	m3 (rock)	x	Powder factor	tonnes explosive / m^3 (rock)	
Required Explosive (tonnes) =	12,346,154	m^3	x	0.00035	tonnes explosive / m^3 (rock)
Required Explosive (tonnes) =	**4,321**				
The total may not sum due to rounding					

Sample Calculation	**Blasting GHG Emissions**		
$t\ CO_2e$ =	tonnes explosive required	x	$tonnes\ CO_2e$
			tonnes explosive required
$t\ CO_2e$ =	**817**		
The total may not sum due to rounding			

Sample Calculation Materials Transport GHG Emissions								
Fuel Consumed (L) =	tonnes of blasted rock	x	Distance (km)	x	Fuel Consum-ption	L		
	Truck Capacity (tonnes)					100 km		
Fuel Consumed (L) =	28,396,154	tonnes	x	20	km	x	31.60	L
	12.7	tonnes						100 km
Fuel Consumed (L) =	2,235,918		x	20	km	x	0.32	L
								km
Fuel Consumed (L) =	**14,130,999**							
The total may not sum due to rounding								

A.2.5 Lost Land Carbon Storage Capability

It is assumed that the existing cleared right of way will increase from 10 to 30 m to 60 m wide during construction of the road, on average, which would eliminate 963 ha of carbon-sequestering land. The emission factor used for the calculations was obtained from a paper published by Kurz, W.A. et al. (2013).

A.2.6 Transportation of Goods/Cargo

It is anticipated that there will be reduced aircraft and vessel trips, and an increase in transport truck activity in the summer months once the Project is complete. Insufficient data is available to estimate these emissions. Therefore, Stantec assumed the same amount of cargo is going to be moved with the same modes of transportation during the Project scenario as the baseline scenario, and that the emissions from these activities will be the same.

APPENDIX B

Permafrost Melt

Appendix B PERMAFROST MELT

In reviewing the GHG emissions inventory for the MacKenzie Valley Highway Extension Project between Wrigley and Norman Wells, Stantec raised a question on whether GHGs during the construction phase of the Project might arise from the thawing of permafrost in the right of way, and whether this should be accounted for in this assessment. The figure below depicts the layers of permafrost (thermal profile). The active layer at the top of the figure is the section of ground that thaws in the summer.

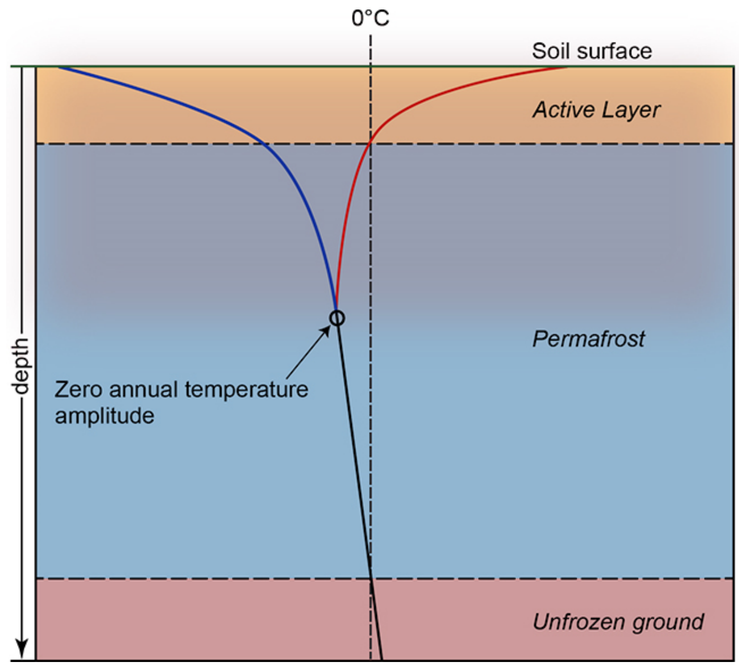

Figure 2 Trumpet Curve of Permafrost Thermal Profile (ADAPT 2020)

A brief literature search was conducted and while there are several sources available on various aspects of methane emissions in the Arctic, no simple emission factors for Arctic tundra were found. Sources of uncertainty related to the permafrost carbon feedstock in the Arctic region, described by Ciais et al. 2013, include:

i) Physical thawing rates
ii) Fraction of carbon released (CO_2 and CH_4) after thawing
iii) The timescales for the releases
iv) Spatially variability in the permafrost degradation
v) The quantity of thawed carbon that will decompose to CO_2 CH_4

Global climate models usually do not account for the soil carbon decomposition to CO_2, CH_4 and N_2O. Although the total quantity of newly thawed soil could be significant by 2100, not all carbon would be immediately transferred to the atmosphere (Ciais et al. 2013). Any significant loss of permafrost soil carbon will likely occur over long periods of time (100s to 1,000s of years). Wetlands and anthropogenic activities are much larger sources of CH_4 than terrestrial permafrost. There is low confidence in the magnitudes of CO_2 and CH_4 losses to the atmosphere from permafrost (Ciais et al. 2013).

Recent research papers describe some ambient monitoring for methane in the Arctic (Thonat et al. 2017, Struzik 2020). Another study presented results from modeling permafrost at the Iqaliut Airport in Nunavut; however, no information related to GHG emissions was included (Ghias et al, 2017).

In 2018, Ellen Gray of NASA reported on the expected gradual thawing of permafrost, and the associated release of GHGs to the atmosphere by abrupt thawing. Abrupt thawing occurs under a certain type of lake in the Arctic, known as a thermokarst lake, that forms when permafrost thaws. This type of permafrost melt could result in an influx of methane into the atmosphere by the mid-21st century. Because thermokarst lakes are small and scattered throughout the Arctic, computer models of their behavior are currently not incorporated into global climate prediction models (Ellen Gray 2018).

On the basis of this review, in the sense that not enough is known just yet, Stantec will assume that the quantities of GHGs that might be released during the construction of the Project are small and negligible, compared to the emissions from burning petroleum fuels during the baseline and Project scenarios.

APPENDIX C

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