Appendix V

Greenhouse Gas Assessment and Climate Change Resilience Documentation

Greenhouse Gas Mitigation Assessment (GHD 2018)

Greenhouse Gas Mitigation Assessment

Boat Harbour Remediation
Planning and Design
Pictou County, Nova Scotia

Nova Scotia Lands Inc.

Attestation of Completeness

GHD has examined the supporting evidence provided by the project proponent for the calculation of GHG emissions for the baseline and remediation scenarios. We have no responsibility to update this report for events and circumstances occurring after the date of this report.

In our opinion:

- As at the date of this report, the project structure, quantification and projections are suitably supported and provide a reasonable basis for the calculation of emission reductions.
- The emission estimates reflect the project structure and quantification.

Based on our examination, in our opinion the project is presented fairly and completely in all material aspects. This opinion is based on a limited level of assurance, meaning that nothing has come to our attention indicating that the greenhouse gas reduction assertions are not materially correct.

Since the project emission calculations are based on future events, actual results will vary from the information presented and the variations may be material.

Executive Summary

This document has been completed for the purposes of undertaking a Greenhouse Gas (GHG) Mitigation Assessment for the Boat Harbour Remediation Project (the Project), located in Pictou County, Nova Scotia. This report will be used for federal funding application and is of value to the environmental permitting process.

The main components of the BHETF include: the wastewater effluent pipeline (over 3 kilometres in length) that runs from the Kraft Mill and extends eastward, below the East River of Pictou (East River), to the BHETF property; twin settling basins and an Aeration Stabilization Basin (ASB) west southwest of Boat Harbour; and the Boat Harbour stabilization lagoon. Effluent from Boat Harbour discharges through a dam (northeast of Boat Harbour) into an estuary before being released to the Northumberland Strait. Prior to the construction of the twin settling basins and ASB in 1972, effluent was routed by open ditch from the pipeline on the east side of Highway 348 to a natural wetland area (Former Ponds 1, 2, and 3) before being discharged into the stabilization lagoon.

The remedial solution for BHETF requires the following:

- Management of residual mill effluent within the BHETF
- Risk management and/or removal, treatment, and disposal of impacted sediments/sludge and dewatering effluent from former effluent ditch and natural wetlands, twin settling basins, ASB, Boat Harbour, and the estuary
- Remediation of impacted surface water and potentially groundwater and soil
- Use and closure of the existing sludge disposal cell, or transportation and disposal at an approved off Site facility
- Decommissioning of BHETF infrastructure including the pipeline, causeway, dam, and support facilities
- Restoration of Highway 348 including construction of a bridge in the location of the existing causeway

The remediation project is anticipated to commence in mid-2020 and is anticipated to be completed within 5 to 7 years.

The baseline scenario considered is the business as usual scenario, with no remediation of the BHETF. The project scenario is the remediation scenario described above. Emission sources from the baseline scenario included diesel-powered equipment, methane generation from Boat Harbour and the sludge containment cell, and purchased electricity to operate electrical aerators and pumps. The baseline emissions over a 25-year time period were estimated to be 368,580 tonnes of CO_{2e}. It was assumed that pulp and paper effluent would continue to be deposited the the BHETF at the current rate for 25 years.

The proposed remediation option is described in Section 4. Emission sources from the remediation project scenario included diesel-powered equipment used in the remediation process methane generation from the on-site containment cell, and purchased electricity to operate the pilot plant for 14 weeks and the full-scale WWTP for 3 years. A separate scenario was evaluated where waste is trucked to an off-site containment cell. The project scenario emissions over a 25-year time period were estimated to be a maximum of 53,500 tonnes of CO_{2e}.

The project would result in a net decrease in emissions of 315,080 tonnes of CO2e over a 25-year time period.

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1. Introduction

This document has been completed for the purposes of undertaking a Greenhouse Gas (GHG) Mitigation Assessment for the Boat Harbour Remediation Project (the Project), located in Pictou County, Nova Scotia. This report will be used for federal funding application and is of value to the environmental permitting process.

This document is intended to meet the requirements of the Draft General Guidance – Climate Lens document issued by Infrastructure Canada's Investing in Canada Infrastructure Program (ICIP) and has been prepared in keeping with Federal and Provincial guidance on considering project level-greenhouse gas (GHG) mitigation assessment.

All calculations will be done in accordance with ISO 14064-2 and/or the GHG Protocol for Project Accounting using emission factors identified in the National Inventory Report or from the emission factor database maintained by the Intergovernmental Panel on Climate Change (IPCC).

The Project requires the consideration of baseline scenario (business as usual) and GHG emissions from the project over its life span for both construction and operation and maintenance of the Project. This document summarizes the findings of the GHG Assessment prepared as part of Boat Harbour Remediation Planning and Design.

Boat Harbour, formerly known as A'se'k in Mi'kmaq, was originally a tidal estuary connected to the Northumberland Strait in Nova Scotia. The Province of Nova Scotia (the Province) constructed the Boat Harbour Effluent Treatment Facility (BHETF) (Facility) in 1967 to treat effluent from industrial sources including a chlor alkali plant and a kraft bleached pulp mill, reconstructing the natural tidal estuary into a closed effluent stabilization lagoon. The Kraft Mill owner is currently responsible for operating the facility under a lease agreement with the Province. The Province has committed to ceasing the reception and treatment of new effluent to the BHETF by January 31, 2020 in accordance with the Boat Harbour Act. Once operations have ceased, the Province will remediate Boat Harbour and lands associated with the BHETF and restore Boat Harbour to a tidal estuary. As part of the restoration work, the existing causeway along Highway 348 and the dam will be removed and replaced with a bridge that will permit boat access to Boat Harbour.

The main components of the BHETF include: the wastewater effluent pipeline (over 3 kilometres [km] in length) that runs from the Kraft Mill and extends eastward, below the East River of Pictou (East River), to the BHETF property; twin settling basins and an Aeration Stabilization Basin (ASB) west southwest of Boat Harbour; and the Boat Harbour stabilization lagoon. Effluent from Boat Harbour discharges through a dam (northeast of Boat Harbour) into an estuary before being released to the Northumberland Strait. Prior to the construction of the twin settling basins and ASB in 1972, effluent was routed by open ditch from the pipeline on the east side of Highway 348 to a natural wetland area (Former Ponds 1, 2, and 3) before being discharged into the stabilization lagoon.

The Study Area (or Site) for this Project spans from the effluent pipeline, described above, from the first standpipe on the Kraft Mill property, existing and historic BHETF lands, and Boat Harbour and its banks to the dam. The Study area also extends beyond the BHETF to Northumberland Strait and on to adjacent lands including a portion of Pictou Landing First Nation (PLFN) IR 24, 24G and 37

Lands. The total Site area is approximately 546 hectares (ha) of which 142 ha is Boat Harbour. A plan showing the Study Area is provided on Figure 1.

The remedial solution for BHETF requires the following:

- Management of residual mill effluent within the BHETF
- Risk management and/or removal, treatment, and disposal of impacted sediments/sludge and dewatering effluent from former effluent ditch and natural wetlands, twin settling basins, ASB, Boat Harbour, and the estuary
- Remediation of impacted surface water and potentially groundwater and soil
- Use and closure of the existing sludge disposal cell, or transportation and disposal at an approved off Site facility
- Decommissioning of BHETF infrastructure including the pipeline, causeway, dam, and support facilities
- Restoration of Highway 348 including construction of a bridge in the location of the existing causeway

The remediation project is anticipated to commence in mid-2020 and is anticipated to be completed within 5 to 7 years.

2. Methodology

2.1 Boundary of the Assessment

The GHG assessment boundary encompasses all primary effects and significant secondary effects associated with the remediation of the BHETF. The physical boundaries of the project are shown in Figure 1.

2.2 Greenhouse Gases Considered

The GHGs considered are as follows:

- General Stationary Combustion Emissions (Carbon Dioxide [CO2], Methane [CH4], Nitrous Oxide [N2O])
- Mobile combustion emissions (CO2, CH4, N2O)
- Containment cell (CH4)
- Electricity consumption (CO_2, CH_4, N_2O)

2.3 Emission Scopes

Based on the information and data provided by the mill, GHD separated GHG emissions sources based on the appropriate scope as follows:

1. Direct Emissions (Scope 1):

   - Stationary Combustion: combustion of fuel oil in stationary combustion equipment such as generators, diesel, and gasoline in stationary combustion units and in mobile equipment.
   - Methane generation from on-site sludge containment.

2. Indirect Emissions (Scope 2):

   - Purchased Electricity: emissions from non-Facility sources used to supply the BHETF with electricity from the source grid.

2.4 Data Collection and Calculation Procedures

For Scope 1 and Scope 2 emissions, the mill provided total fuel use and purchased electricity for the BHETF. GHD applied the calculation methodologies and emission factors outlined below to quantify Scope 1 and Scope 2 GHG emissions.

Although ISO 14064 Part Two: Specification with Guidance at the Project Level for Quantification, Monitoring, and Reporting of Greenhouse Gas Emission Reductions or Removal Enhancements and The Greenhouse Gas Protocol for Project Accounting are identified in the Climate Lens General Guidance as the generally recommended framework, Infrastructure Canada does not specify a single reporting framework for which the GHG inventory must adhere. Where possible, GHD has quantified emissions using reputable reporting frameworks and protocols that are relevant and geographically specific.

Diesel-fired heavy equipment emissions

For the diesel-fired heavy equipment used for baseline operation and remediation, a list of equipment and operating schedules was provided. GHD used equation 5.1 from the document "Standards for Quantification, Reporting, and Verification of Greenhouse Gas emissions" (Nova Scotia Environment, 2018) where fuel consumption was provided. Where fuel consumption was not known (remediation scenario), GHD used equation 5.2 and typical values for the types of equipment provided.

GHG emissions from sludge disposal cell

The evaluation of potential GHG emissions from the BHETF sludge containment cell was conducted in accordance with a Tier 1 approach described in the MOE (1992) guideline: "Interim Guide to Estimate and Assess Landfill Air Impacts" (MOE Interim Guide). The Scholl Canyon model, a first-order decay model is accepted and recommended by both the MOE and United States Environmental Protection Agency (USEPA) to evaluate landfill gas (LFG) production rates. Due to the relative uncertainty in the estimation GHG and based on the Facility-specific conditions, consideration of the GHG production processes, it was considered appropriate to use the Scholl Canyon model to develop order of magnitude estimates.

LFG is produced by the biological decomposition of wastes placed in a containment cell (sludge disposal cell). LFG composition is highly variable and depends upon a number of site-specific conditions including waste composition, density, moisture content, and age. LFG is typically comprised of methane (approximately 50 percent by volume) and carbon dioxide (approximately 50 percent by volume).

The production rate and total volume of LFG that will be generated in a containment cell depends on the mass and characteristics of the sludge. Important characteristics include the organic content, age of sludge, and moisture content.

Purchased Electricity

Emissions from purchased electricity for both the baseline and remediation scenario were estimated using emission factors specific to Nova Scotia from Table A11-7; National Inventory Report 1990 - 2015 Part 3 (Canada's 2017 Submission), Environment Canada (2017).

Global Warming Potential

The conversion to equivalent units of carbon dioxide (CO_2) takes into account the global warming potential (GWP) of the GHG. The global warming potential (GWP) compares the radiative forcing of a tonne of a greenhouse gas over a given time period (e.g., 100 years) to a tonne of CO_2. The GWPs listed in the table below are updated values taken from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, stemming from improvements in climate change science. The GWPs used are outlined in the following table:

Table 2.1 Global Warming Potential

GHG	GWP
CO2	1
CH4	25
N2O	298

2.5 Exclusions from the Assessment

All significant GHG emission sources have been included in the assessment.

2.6 Assumptions

Assumptions are outlined in Section 2.4 above and Sections 3 and 4.

3. Baseline Scenario

The BHETF became operational in 1967 and has been the primary processing system for wastewater created by a pulp and paper mill, currently named the Northern Pulp Nova Scotia Corporation.

As previously noted, the main components of the BHETF, include: the wastewater effluent pipeline, from the Kraft Pulp Mill and extending eastward, below the East River of Pictou (East River), to the BHETF property; twin settling basins and an Aeration Stabilization Basin (ASB) west-southwest of Boat Harbour; and the stabilization lagoon (Boat Harbour). Effluent from Boat Harbour discharges through a dam (northwest of Boat Harbour) into an estuary before being released to the Northumberland Strait.

The total area of the Site is approximately 546 ha. Approximately half of the Site is water covered and most of the water features on the Site were formerly or are currently utilized as part of the wastewater effluent treatment process. The Boat Harbour lagoon covers 142 ha (350 acres).

The effluent flows to two settling basins that allow for sedimentation and heavy particles to fall to the bottom, which are ultimately excavated and relocated to the mill. The effluent then flows into an aeration-stabilizing basin where oxygen is added to help remove contaminants in the effluent. The effluent reportedly meets the Pulp and Paper Effluent Discharge Criteria where it enters Boat Harbour. Finally, the effluent flows into the stabilization lagoon where it remains for approximately 20-30 days, allowing suspended solids to settle to the bottom, after which the remaining water flows into an estuary and then to the Northumberland Strait.

The major components of the Site include:

Pipeline Corridor | This sector includes the area of the pipeline, from the Kraft Pulp Mill at Abercrombie Point to Pictou Landing Road and former railway tracks east of the East River. The pipeline has 2,305 metres (m) section of 0.915 m diameter fiberglass reinforced plastic pipe (RPP) buried on land and a 1,220 m section of 1.1 m diameter high density polyethylene (HDPE) pipe buried at the bottom of the East River.

Twin Settling Basins/Sludge Disposal Cell/ASB | This sector includes the area of the current and former settling ponds, the sludge disposal cell, the ASB.

The twin settling basins are used to remove suspended solids from the effluent. They are approximately 4.3 ha in size, have a capacity of 114,000 m^3, and are lined with a low permeable material (likely clay/till). From the settling basins, the effluent is conveyed by a ditch to the ASB.

The 6.7 ha disposal cell was designed as a single cell with a total capacity of 220,000 m^3 (waste) to facilitate placement of sludge to the top of the perimeter berm (elevation 12 metres above mean sea level [mAMSL]). The disposal cell is lined with 0.6 m of clay-till, with a hydraulic conductivity of approximately $1x10^{-6}$ cm/s.

The disposal cell includes leak detection, leachate, and decanting collection systems. All collection systems are connected by a 0.3 m diameter PVC pipe gravity pipe and manhole system that discharges to the ASB. The disposal cell is currently used for placement of dredged material from the ASB.

The ASB is 18.3 ha in size and has a capacity of 567,750 m^3. Twenty-three to twenty-five floating aerators are used to aerobically treat the effluent prior to discharge into the BH. Three silt curtains divide the ASB into four cells to improve mixing and reduce areas of sludge build up. An automated nutrient addition system adds urea and diammonium phosphate to the effluent before it discharges to the ASB.

Treatment Buildings | There are 10 buildings and several small structures that form part of the BHETF. Buildings are typically slab on grade construction or trailer based. Structures include inlet/outlet weirs, retaining walls, maintenance holes, etc.

Boat Harbour Stabilization Lagoon (or simply Boat Harbour or BH) | This sector includes the area of the Boat Harbour Stabilization Lagoon, from the ASB discharge point to the Highway 348 bridge. Effluent from the ASB is discharged into the BH, which is approximately 142 ha in size and has a capacity of 2,458,545 m^3 based on average water elevation of 0.78 mAMSL and using bathymetry data provided by Acadia University. The effluent from the BH is discharged via a dam located north of Highway 348 into the tidal estuary and ultimately to the Northumberland Strait.

Estuary | This sector includes the area of the estuary, from the bridge at Pictou Landing Road to Pictou Road Harbour. The estuary area is approximately 7.6 ha in size and is located north of Highway 348 and the dam. The estuary is delineated to the south by the dam and to the north by the Northumberland Strait.

Wetlands | The delineation of impacted wetland areas is shown in the figure below. The impacted area is approximately 38 ha and contains approximately 260,000 m^3 of sludge and root mass to be managed.

Dam | The dam is located north of the Highway 348 causeway and is designed to allow the levels in the Boat Harbour stabilization lagoon to be controlled while blocking the tidal inflow. The dam is approximately 25 m wide and is connected to the banks of the estuary with earthen berms.

Bridge | A causeway along Highway 348 crosses Boat Harbour at the downstream end. The causeway is constructed with three 1500 millimetres (mm) diameter concrete culverts and two 3600 x 3000 mm concrete box culverts connecting Boat Harbour to the downstream dam. A water main running from the PLFN well field to the PLFN community is buried within the causeway.

The GHG emission sources in the baseline scenario include:

- Methane generation from pulp and paper sludge
- Diesel-fired equipment
- Purchased electricity to operate large pumps and aerators

Methane Generation from Pulp and Paper Sludge

The sludge disposal cell currently contains 180,000 m^3 of sludge and has been placed in the cell since 1994 on an annual basis. For calculation purposes, it was assumed that an equal amount of waste was placed in the disposal cell every year from 1994 to 2018.

The production rate and total volume of methane that will be generated in a containment cell depends on the mass and characteristics of the sludge. Important characteristics include the organic content, age of refuse, and moisture content.

The evaluation of potential methane emissions from the containment was conducted in accordance with a Tier 1 approach described in the Ontario MOECC (1992) guideline: "Interim Guide to Estimate and Assess Landfill Air Impacts" (MOE Interim Guide). The Scholl Canyon model, a first-order decay model is accepted and recommended by both the MOE and United States Environmental Protection Agency (USEPA) to evaluate methane production rates. Due to the relative uncertainty in the estimation methane and based on the conditions at the BHETF, consideration of the LFG production processes, and GHD's observation of conditions experienced at various lagoons and containment cells, it was considered appropriate to use the Scholl Canyon model to develop order of magnitude estimates.

Model input parameters were selected based on a literature review, the MOE Interim Guide, and USEPA (1996). The following model input parameters were selected:

- Landfill gas generation rate (k) of 0.05 $year^{-1}$ was selected based on the MOE Interim Guide and USEPA (1996)
- A methane generation potential rate (Lo) rate of 120 m^3 methane/tonne of volatile solid was selected based on reported values for pulp and paper waste 240 m^3 , and considering that the methane generation potential is reduced by an estimated 50% due to aerobic treatment prior to deposition of the sludge (Mshandete et al. [2005])
- The model was run for 25 years assuming that pulp and paper waste would continue to be treated and deposited at the current rate. The waste density was assumed to be 0.5 tonnes/m^3.

In order to provide a conservative analysis, the following assumptions were made:

- All dry matter in the sludge is composed of volatile solids; in reality, some portion of the solid matter will be composed of inorganic solids that will not readily decompose to methane. This is a highly conservative assumption that will over-predict the amount of LFG generated.
- No prior degradation of the sludge had occurred during anaerobic storage. As organic matter ages, it produces less LFG as some of the organic component will already have been converted to gas. This is also a highly conservative assumption.
- There is no attenuation of LFG through the landfill cover. At low volumes of landfill gas generated, the assimilative and absorptive capacity of landfill cover can be substantial. Ignoring this potential provides further conservativeness to the analysis.

Diesel-fired Equipment

Based on information provided by the mill, there is a single diesel generator used for emergency backup power that consumes approximately 2,800 litres (L) of diesel annually, as well as an off-road vehicle that consumes approximately 300 L per year. All other equipment on-site is electric.

Purchased Electricity

Purchased electricity is used to run aerators and pumps in the BHETF. The BHETF consumes 11,000,000 kWh of electricity per year.

GHG Emissions

A summary of the total CO_2 equivalent (CO_{2e}) GHG emissions for the baseline scenario from 2018 to 2043 are presented below. Supporting calculations are provided in Appendix A.

Table 3.1 Baseline Scenario GHG Emissions (2018 – 2043)

Emission Source	Consumption	Units	Emissions (tCO_2e)	Percentage of Total Emissions
Scope 1 - Direct Sources				
Diesel	37,200	L	28	0%
Sludge Disposal Cell			184,302	50%
		Scope 1 Subtotal	184,330	50%
Scope 2 - Energy Indirect Sources				
Electricity	275,000,000	kWh	184,250	50%
		Scope 2 Subtotal	184,250	50%
		Grand Total	**368,580**	**100%**

4. Estimated Project Emissions

4.1 Construction

The proposed remedial option is as follows:

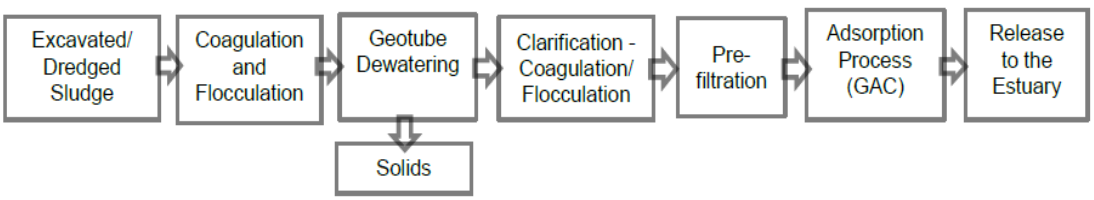
1. Pipeline will be cleaned, inspected and abandoned in place.
2. The twin settling basins other miscellaneous ditches along the system will have the sludge fully removed in the dry.
3. The sediments in the ASB, BH and estuary will be removed in the wet. Removal in the wet will involve dredging sludge/sediment under wet conditions. Removal in the wet will be predominantly completed through hydraulic dredging. The dredged sludge slurry will be subsequently pumped to a designated sludge management area (i.e., onsite disposal cell) into geotubes.
4. The disposal cell will be used to manage the waste [Emissions for trucking waste off site have been added to the construction to represent worst case as detailed below]:
   i. The majority of the sludge will be pumped into geotubes located in the disposal cell and allowed to dewater by gravity over time, with dewatering effluent being collected and conveyed using the decant and leachate collection systems.
   ii. Mechanically excavated sludge would be placed in a dump truck and end dumped into the disposal cell. End dumped sludge would be developed in lifts of approximately 1-3 m, followed by compaction to maximize disposal cell air space, and used to fill the gaps between the filled geotube bags. Leachate would be managed via the leachate collection system.
   iii. The waste disposal cell has the following available capacity (noting the total volume of waste is estimated to be approximately 550,000 m^3, including the existing 180,000 m^3 which is expected to consolidate to 116,000 m^3):

Table 4.1 Available Capacity

Cover Elevation	Total Capacity (m^3) Based on 10:1 Slope	Total Capacity (m^3) Based on 4:1 Slope
18 mAMSL	350,000	440,000
20 mAMSL	360,000	505,000
23 mAMSL	N/A	580,000
28 mAMSL	N/A	660,000

5. The bulk water management in Boat Harbour will be managed on site using low technology treatment system. A precipitation, coagulation, and adsorption based process is the most likely treatment method for bulk water management. Clarification process will accommodate a flow rate of 250 m^3/hr.

6. Dewatering effluent will be managed on site using low technology treatment system involving coagulation and precipitation coupled with geotube dewatering, the remainder of which will be treated through a GAC adsorption column.



7. The bridge "causeway" located along Highway 348 by the estuary will be demolished and replaced with a concrete girder single span bridge.

8. The sediments in the wetlands will be removed in the dry. Once excavated, sediment will be managed similarly to the sludge removed from the rest of the Site (will be excavated, but generally conveyed as a slurry into geotubes in the disposal cell). The wetlands will then be restored by planting or seeding of native aquatic and terrestrial vegetation.

9. The building on site and other miscellaneous surface infrastructure will be decommissioned and demolished. The waste resulting from the demolition process will be disposed of at the disposal cell.

Sludge disposal

The final disposal cell volume is 550,000 m^3, including the existing 180,000 m^3 of waste from the sludge containment cell.

The evaluation of potential LFG emissions from the project scenario was conducted in accordance with a Tier 1 approach described in the Ontario MOECC (1992) guideline: "Interim Guide to Estimate and Assess Landfill Air Impacts" (MOE Interim Guide). The Scholl Canyon model, a first-order decay model is accepted and recommended by both the MOE and United States Environmental Protection Agency (USEPA) to evaluate LFG production rates. Due to the relative uncertainty in the estimation LFG and based on the Site-specific conditions, consideration of the LFG production processes, and GHD's observation of conditions experienced at various landfills, it was considered appropriate to use the Scholl Canyon model to develop order of magnitude estimates.

Model input parameters were selected based on a literature review, the MOE Interim Guide, and USEPA (1996). The following model input parameters were selected:

- Landfill gas generation rate (k) of 0.05 $year^{-1}$ (upper) was selected based on the MOE Interim Guide and USEPA (1996)
- A methane generation potential rate (Lo) rate of 120 m^3 methane/tonne of volatile solid was selected for the pre-remediation scenario based on reported values for pulp and paper waste, as described in the baseline scenario above. (Mshandete et al. [2005])
- A methane generation potential rate (Lo) rate of 60 m^3 methane/tonne of volatile solid was selected for the post-remediation scenario, assuming that the methane production potential was reduced by 50% through exposure to oxygen and dewatering. (Mshandete et al. [2005])
- The model was run for 25 years assuming all sludge waste will be placed into the containment cell and no more disposals will be made after 2024. The waste density was assumed to be 0.5 tonnes/m^3. The containment cell will be capped after the remediation is complete, therefore, it was assumed that 50 percent of the methane produced is released post-rememdiation.

In order to provide a conservative analysis, the following assumptions were made:

- All dry matter in the sludge is composed of volatile solids; in reality, some portion of the solid matter will be composed of inorganic solids that will not readily decompose to methane. This is a highly conservative assumption that will over-predict the amount of LFG generated.

Diesel-fired Equipment

Based on the remediation schedule, a standard list of equipment with net horsepower ratings and brake specific fuel consumptions was used to estimate the total amount of diesel consumed over the course of the remediation. It was assumed that the equipment will run at full load for 4 hours per day and 40 percent of net horsepower while idling the remaining 4 hours per day. Based on this assumption, an 8-hour average horsepower rating was calculated and used to estimate the total fuel consumption.

The sludge will either be placed in the on-site containment cell or trucked off-site to the Colchester balefill, located 55 km from the site. There will be approximately 18,200 truckloads required to transport all of the sludge from the site. For the scenario where the sludge is transported off-site, a fuel economy of 39.5 L/100 km was assumed to calculate total diesel consumption for transportation.
(https://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/reports/7607)

Equation 5.2 from the document "Standards for Quantification, Reporting and Verification of Greenhouse Gas Emissions" was used to estimate the total CO_{2e} emissions from the diesel-fired equipment over the course of the remediation.

Purchased Electricity

Purchased electricity will be used to run the wastewater treatment pilot plant. The electricity is consumed by pumps, agitators and control systems for bulk wastewater treatment and dewatering effluent treatment. It was estimated that the annual electricity consumption will be 1,560,000 kWh/year for 3 years.

GHG Emissions

A summary of the GHG emissions for the baseline scenario from 2018 to 2043 are presented below. Supporting calculations are provided in Appendix B.

Table 4.2 Remediation Project Emissions

Emission Source	Consumption	Units	Emissions (tCO_2e)	Percentage of Total Emissions
Scope 1 - Direct Sources				
Diesel	2,250,165	L	6,111	11%
Sludge Transportation (Off-site disposal)	790,790	L	2,203	4%
Sludge Disposal Cell	NA		44,545	83%
		Scope 1 Subtotal	52,859	98%
Scope 2 - Energy Indirect Sources				
Electricity	957,000	kWh	641	1%
		Scope 2 Subtotal	641	1%
		Grand Total	**53,500**	**100%**

4.2 Operations & Maintenance

Operations and maintenance emissions are included in the above estimate. There will be no operations at the BHETF after the remediation is complete.

5. Estimated Net Increase or Reduction in Emissions

Over the 25 year period from 2018 to 2043, the baseline scenario GHG emissions were estimated to be 368,580 tonnes of CO_{2e}. Over the same time period, the emissions from the project scenario were estimated to be 53,500 tonnes of CO_{2e}, a net reduction of 315,080 tonnes of CO_{2e}.

6. Conclusions

The baseline scenario evaluated, as discussed in Section 3, was leaving the BHETF as is with no remediation. The BHETF could continue to accept and treat pulp and paper waste for 25 years. Emission sources from the baseline scenario included diesel-powered equipment, methane generation from the sludge containment cell, and purchased electricity to operate electrical aerators and pumps. The baseline emissions over a 25-year time period were estimated to be 368,580 tonnes of CO_{2e}.

The proposed remediation option is described in Section 4. Emission sources from the remediation project scenario included diesel-powered equipment used in the remediation process, methane generation from the sludge containment cell, and purchased electricity to operate the wastewater treatment pilot and full-scale plants during remediation. The project scenario emissions over a 25-year time period were estimated to be 53,500 tonnes of CO_{2e}.

The project would result in a net decrease of 315,080 tonnes of CO_{2e}, in addition to Boat Harbour being returned to its natural state.

All of Which is Respectfully Submitted,

GHD

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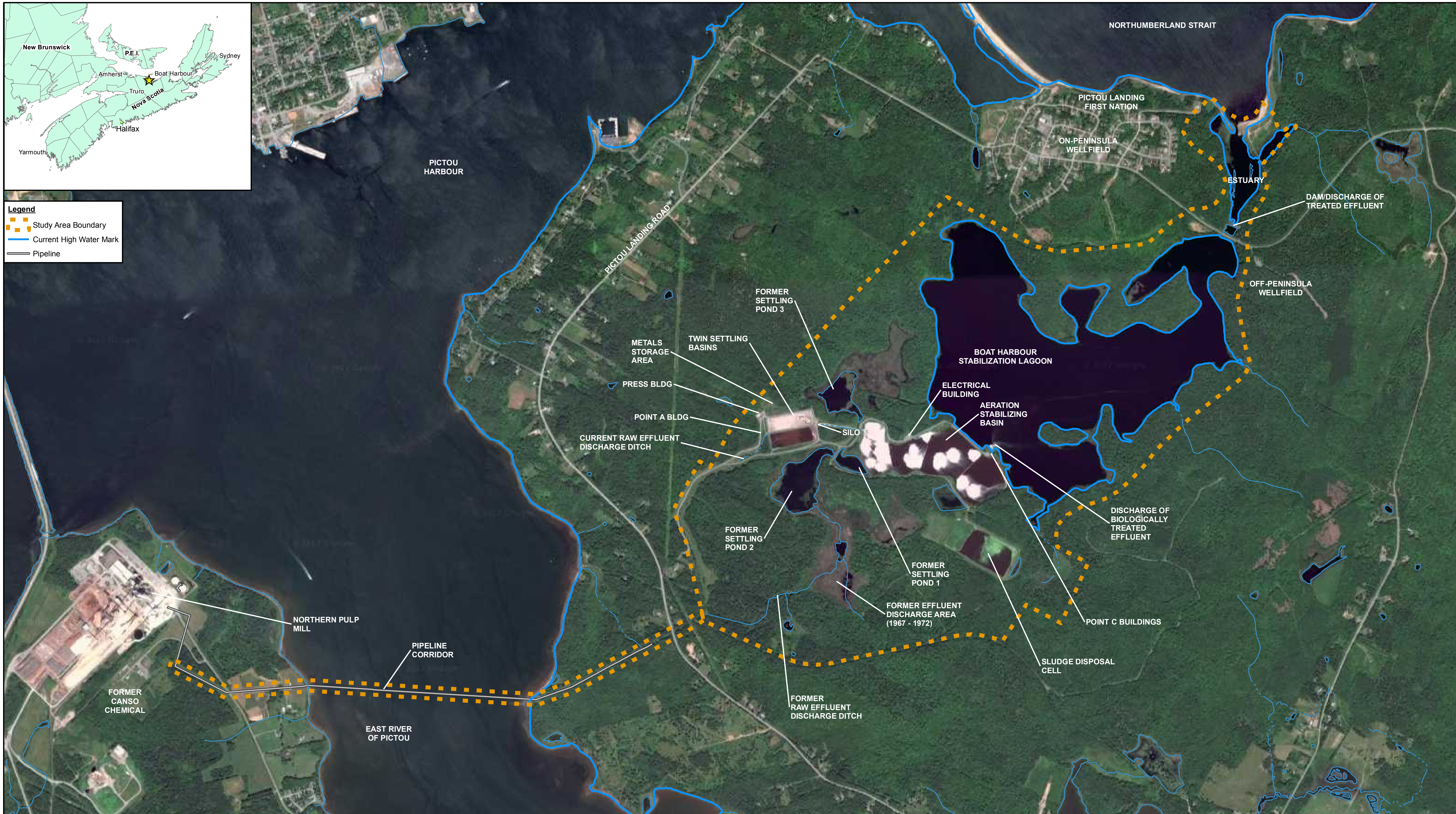

Source: Imagery @2017 Google CNES / Airbus, DigitalGlobe, Landsat / Copernicus

0 200 400 600
Meters

Coordinate System:
NAD 1983 CSRS UTM Zone 20N

N

NOVA SCOTIA LANDS INC
BOAT HARBOUR REMEDIATION PLANNING AND DESIGN, PICTOU LANDING, NS
CLIMATE CHANGE RESILIENCE ASSESSMENT

11148275-24
May 15, 2018

SITE STUDY AREA

FIGURE 1

GIS File: I:\GIS_DATA\Projects\8-chars\1114----\11148275 Boat Harbour\11148275-REPORTS\11148275-Rpt-14\11148275-24(014)GIS-DA001.mxd

Appendices

Appendix A
Supporting Calculations for Baseline GHG Emissions

Table A.1

Baseline Scenario - Electricity Consumption

Annual Electricity Consumption (kWh/year)	Emission Factor	Units	Source	CO2e (kg/year)
11,000,000	670	g CO2e/kWh	EC 2017	7,370,000.00

Table A.2

Baseline Scenario - Diesel

Equipment	Fuel Consumption (L/year)	CO_2 (kg/year)	CH_4 (kg/year)	N_2O (kg/year)	CO_2e (tonnes/year)
Backup Generator	2800	7456.4	0.3724	1.12	7.68747
Off-road vehicle	300	798.9	0.0399	0.12	0.8236575

CO_2	2.663	kg/L
CH_4	0.133	g/L
N_2O	0.4	g/L

Table A.3

Baseline Scenario - Annual Methane from Disposal Cell

Year	Methane Production (tonnes/year)	CO2e (tonnes/year)
2018	321	8014
2019	316	7908
2020	312	7807
2021	308	7711
2022	305	7620
2023	301	7534
2024	298	7451
2025	295	7373
2026	292	7298
2027	289	7227
2028	286	7160
2029	284	7096
2030	281	7035
2031	279	6976
2032	277	6921
2033	275	6869
2034	273	6819
2035	271	6771
2036	269	6726
2037	267	6683
2038	266	6642
2039	264	6603
2040	263	6566
2041	261	6531
2042	260	6497
2043	259	6465

Appendix B
Supporting Calculations for Project GHG Emissions

Table B.1

Remediation Scenario - Electricity Consumption

	Annual Electricity Consumption (kWh)	Emission Factor	Units	Source	CO2e (kg)
Pilot Plant	21,000	670	g CO2e/kWh	EC 2017	14,070.00
Full Scale Treatment Plant	936,000.00	670	g CO2e/kWh	EC 2017	627,120.00

Table B.2

Boat Harbour Remediation - Equipment List

Bit Item No	Description of Works	Duration (Total Calendar Days)	Duration (Working Days)	hours/day	Net hp	8-hr Average hp	BSFC (L/hp-hr)	Fuel Consumption (L)	CO2	CH4	N2O	CO2e
No1	Pipeline decomisssioning	183.0	130.7						(kg/year)	(kg/year)	(kg/year)	(tonnes)
	Cleaning	119.0	85.0									
	Inspecting	65.0	46.4									
	Surface infrastructure											
	30 Ton Excavator with Operator (CAT 330)	55.0	39.3	8.0	270.0	189.0	0.4	22,825.4	60,783.9	3.0	9.1	63.6
	30 Ton Truck for transport	55.0	39.3	8.0	328.0	229.6	0.4	26,915.7	71,676.5	3.6	10.8	75.0
No2	Remediation - Site Preparation	270.0	192.9									
	Site preparation											
	30 Ton Excavator with Operator (CAT 330)	270.0	192.9	8.0	270.0	189.0	0.4	112,051.8	298,393.8	14.9	44.8	312.1
	D7 Size Dozer with Operator	270.0	192.9	8.0	6 gal/hr diesel			35,042.1	93,317.1	4.7	14.0	97.6
	CAT 930G Loader	270.0	192.9	8.0	163.0	114.1	0.4	72,352.4	192,674.5	9.6	28.9	201.5
	30 Ton Truck for transport	270.0	192.9	8.0	328.0	229.6	0.4	132,131.5	351,866.2	17.6	52.9	368.1
	Mid size compactor	270.0	192.9	8.0	405.0	283.5	0.4	162,708.0	433,291.4	21.6	65.1	453.2
No3	Remediation - Active											
	Boat Harbour											
	MC 225 dredge or equivalent x 2	504.9	360.6	8.0	577,000m3/2,000 x 1.25		0.4					
	30 Ton Excavator with Operator (CAT 330)	504.9	360.6	8.0	270.0	189.0	0.4	209,526.4	557,968.8	27.9	83.8	583.6
	30 Ton Rock Truck with Operator	504.9	360.6	8.0	328.0	229.6	0.4	247,073.7	657,957.3	32.9	98.8	688.2
	ASB & Settling Basins											
	MC 225 dredge or equivalent x 2	135.6	96.9	8.0	155,000m3/2,000 x 1.25		0.4					
	30 Ton Excavator with Operator (CAT 330)	135.6	96.9	8.0	270.0	189.0	0.4	56,285.3	149,887.6	7.5	22.5	156.8
	30 Ton Rock Truck with Operator	135.6	96.9	8.0	328.0	229.6	0.4	66,371.6	176,747.6	8.8	26.5	184.9
	Estuary											
	MC 225 dredge or equivalent x 2	42.9	30.6	8.0	49,000m3/2,000 x 1.25		0.4					
	30 Ton Excavator with Operator (CAT 330)	42.9	30.6	8.0	270.0	189.0	0.4	17,793.4	47,383.8	2.4	7.1	49.6
	30 Ton Rock Truck with Operator	42.9	30.6	8.0	328.0	229.6	0.4	20,982.0	55,875.1	2.8	8.4	58.4
	Wetlands											
	30 Ton Excavator with Operator (CAT 330) x 2	230.1	164.4	8.0	270.0	189.0	0.4	95,503.4	254,325.5	12.7	38.2	266.0
	D7 Size Dozer with Operator	230.1	164.4	8.0	6 gal/hr diesel		0.0	29,866.9	79,535.5	4.0	11.9	83.2
	30 Ton Truck for transport x 2	230.1	164.4	8.0	656.0	459.2	0.4	225,235.3	599,801.6	30.0	90.1	627.4
	Overall											
	Slurry Pump (see example spec sheet)	1366.5	976.1	8.0	2.4 millions m3 of slurry				0.0			
No4	Building Decomissioning	46.0	32.9									
	Demolish											
	30 Ton Excavator with Operator (CAT 330)	46.0	32.9	8.0	270.0	189.0	0.4	19,090.3	50,837.5	2.5	7.6	53.2
	30 Ton Truck for transport	46.0	32.9	8.0	328.0	229.6	0.4	22,511.3	59,947.6	3.0	9.0	62.7
	Bobcat	46.0	32.9	8.0	46.0	32.2	0.2	1,413.5	3,764.1	0.2	0.6	3.9
			0.0									
No5	Dam Decomissioning	122.0	87.1	Includes building a cofferdam								
	Demolish											
	45 Ton Excavator with Operator	122.0	87.1	8.0	300.0	210.0	0.4	56,256.4				
	30 Ton Truck for transport	122.0	87.1	8.0	328.0	229.6	0.4	59,703.9	158,991.4	7.9	23.9	166.3
	Bobcat	122.0	87.1	8.0	46.0	32.2	0.2	3,748.8	9,983.1	0.5	1.5	10.4
No6	Bridge											
	Demolish and replace	183.0	130.7									
	30 Ton Excavator with Operator (CAT 330)	183.0	130.7	8.0	270.0	189.0	0.4	75,946.2	202,244.7	10.1	30.4	211.6
	30 Ton Truck for transport	183.0	130.7	8.0	328.0	229.6	0.4	89,555.8	238,487.1	11.9	35.8	249.5
	Bobcat	183.0	130.7	8.0	46.0	32.2	0.2	5,623.2	14,974.6	0.7	2.2	15.7
	D7 Size Dozer with Operator	183.0	183.0	8.0	6 gal/hr diesel		0.0	33,251.0	88,547.5	4.4	13.3	92.6
	Mid size compactor	183.0	183.0	8.0	405.0	283.5	0.4	154,391.8	411,145.4	20.5	61.8	430.1

Table B.2

Boat Harbour Remediation - Equipment List

Bit Item No	Description of Works	Duration (Total Calendar Days)	Duration (Working Days)	hours/day	Net hp	8-hr Average hp	BSFC (L/hp-hr)	Fuel Consumption (L)	CO2	CH4	N2O	CO2e
No7	**Disposal Cell Closure**											
	Waste management & Capping											
	30 Ton Excavator with Operator (CAT 330)	153.0	109.3	8.0	270.0	189.0	0.4	63,496.0	169,089.8	8.4	25.4	176.9
	D7 Size Dozer with Operator	153.0	109.3	8.0	6 gal/hr diesel		0.0	19,857.2	52,879.7	2.6	7.9	55.3
	30 Ton Rock Truck with Operator	153.0	109.3	8.0	328.0	229.6	0.4	74,874.5	199,390.9	10.0	29.9	208.6
	CAT 930G Loader	153.0	109.3	8.0	150.2	105.1	0.4	37,780.1	100,608.4	5.0	15.1	105.2
			Distance per trip	Total Trips	Average Fuel Economy (L/100 km)							**6,111.2**
	Trucking waste off-site		110.0	18200.0	39.5			790,790.0	2,105,873.8	105.2	316.3	2,202.8

CO2	2.663	kg/L
CH4	0.133	g/L
N2O	0.4	g/L

Table B.3

Baseline Scenario - Annual Methane from Disposal Cell

Year	Methane Production (tonnes/year)	CO_2e (tonnes/year)
2020	280	6993
2021	266	6652
2022	253	6328
2023	241	6019
2024	57	1431
2025	54	1362
2026	52	1295
2027	49	1232
2028	47	1172
2029	45	1115
2030	42	1060
2031	40	1009
2032	38	959
2033	37	913
2034	35	868
2035	33	826
2036	31	786
2037	30	747
2038	28	711
2039	27	676
2040	26	643
2041	24	612
2042	23	582
2043	22	554

about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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Climate Change Resilience Assessment (GHD 2018)

Climate Change Resilience Assessment

Boat Harbour Remediation
Planning and Design
Pictou County, Nova Scotia

Nova Scotia Lands Inc.

GHD | 45 Akerley Boulevard, Dartmouth, Nova Scotia B3B 1J7 Canada | 11148275 | Report No 14 | May 22 2018

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1. Introduction

This document has been completed for the purposes of undertaking a qualitative climate risk and vulnerability assessment (a Climate Lens assessment) for the Boat Harbour Remediation Project (the Project), located in Pictou County, Nova Scotia. This report will be used for federal funding applications and is of value to the environmental permitting process.

This document is intended to meet the requirements of the Draft General Guidance – Climate Lens discussion document issued by Infrastructure Canada's Investing in Canada Infrastructure Program (ICIP) and has been prepared in keeping with Federal and Provincial guidance on considering climate change in the context of environmental assessments. This document contains the climate change resilience assessment, employing a risk management approach to anticipate, prevent, withstand, respond to, and recover from a climate change related disruption or impact.

This document has been compiled employing the ISO 31000 Risk Management Standard.

The Project requires the consideration of potential effects of the Project on climate change (i.e., predicted emissions of greenhouse gases from the proposed Project and/or sequestration of existing greenhouse gas sources), and potential effects of future climate change on the Project (i.e., the effects of existing and future climate on the proposed activities and infrastructure). This document summarizes the findings of the Climate Change Resilience Assessment prepared as part of Boat Harbour Remediation Planning and Design.

Boat Harbour, formerly known as A'se'k in Mi'kmaq, was originally a tidal estuary[1] connected to the Northumberland Strait in Nova Scotia. The Province of Nova Scotia (the Province) constructed the Boat Harbour Effluent Treatment Facility (BHETF) in 1967 to treat effluent from industrial sources including a chlor-alkali plant and a kraft bleached pulp mill. Its construction included reconstructing the natural tidal estuary into a closed effluent stabilization lagoon. The Kraft Mill owner is currently responsible for operating the facility under a lease agreement with the Province. The Province has committed to ceasing the reception and treatment of new effluent to the BHETF by January 31, 2020 in accordance with the Boat Harbour Act. Once operations have ceased, the Province will remediate Boat Harbour and lands associated with the BHETF and restore Boat Harbour to a tidal estuary. As part of the restoration work, the existing causeway along Highway 348 and the dam will be removed and replaced with a bridge that will permit boat access to Boat Harbour.

The main components of the BHETF include: the wastewater effluent pipeline (over 3 km in length) that runs from the Kraft Mill and extends eastward, below the East River of Pictou (East River), to the BHETF property; twin settling basins and an Aeration Stabilization Basin (ASB) west-southwest of Boat Harbour; and the Boat Harbour stabilization lagoon (BH or Boat Harbour). Effluent from Boat Harbour discharges through a dam (northeast of Boat Harbour) into an estuary before being released to the Northumberland Strait. Prior to the construction of the twin settling basins and ASB in 1972, effluent was routed by open ditch from the pipeline on the east side of Highway 348 to a natural wetland area (Former Ponds 1, 2, and 3) before being discharged into the stabilization lagoon.

1 Partially enclosed coastal body of water, having an open connection with the ocean, where freshwater from inland is mixed with saltwater from the sea

The Study Area (or Site) for this Project spans from the effluent pipeline, described above, from the first standpipe on the Kraft Mill property, existing and historic BHETF lands, and Boat Harbour and its banks to the dam. The Study area also extends beyond the BHETF to Northumberland Strait and on to adjacent lands including a portion of Pictou Landing First Nation (PLFN) IR 24, 24G and 37 Lands. The total Site area is approximately 546 hectares (ha) of which 141 ha is Boat Harbour. A plan showing the Study Area is provided on Figure 1.

The remedial solution for BHETF requires the following:

- Management of residual mill effluent within the BHETF
- Risk management and/or removal, treatment, and disposal of impacted sediments/sludge and dewatering effluent from former effluent ditch and natural wetlands, twin settling basins, ASB, Boat Harbour, and the estuary
- Remediation of impacted surface water and potentially groundwater and soil
- Use and closure of the existing sludge disposal cell, or transportation and disposal at an approved off-Site facility
- Decommissioning of BHETF infrastructure including the pipeline, causeway, dam, and support facilities
- Restoration of Highway 348 including construction of a bridge in the location of the existing causeway

The remediation project is anticipated to commence in mid-2020 and is anticipated to be completed within 5 to 7 years.

2. Climate Review

Following is a brief summary of the historic and predicted future climate in the project area.

2.1 Historic Climate Assessment

Environment Canada reports Canadian Climate Normals over 30-year periods, and updates them on a decadal basis (such that the most recent climate normal periods are: the 1981 to 2010 period, the 1971 to 2000 period, and the 1961 to 1990 period). For the purposes of this review and assessment, the reported climate normals for the 1981 to 2010 period have been reviewed for the following locations:

Table 2.1 Climate Normals Data Sources (1981 – 2010)

Station ID	Station ID	Latitude	Longitude	Elevation (mASL)	Distance from Site (km)
Lyons Brook, NS	8203230	45°39' N	62°47' W	29	12
Collegeville, NS	8201000	45°29' N	62°01' W	76	54
Upper Stewiacke, NS	8206200	45°13' N	63°00' W	23	56
Truro, NS	8205990	45°22' N	63°15' W	40	58
Debert, NS	8201380	45°25' N	63°06' W	38	66

Table 2.1 Climate Normals Data Sources (1981 – 2010)

Station ID	Station ID	Latitude	Longitude	Elevation (mASL)	Distance from Site (km)
Note: From http://climate.weather.gc.ca/climate_normals/ accessed 26 March, 2018.					

Boat Harbour is located at approximately 45°39'N, 62°39'W at 2 m above sea level. Lyons Brook is the nearest station geographically, is the station at the closest elevation to the project site, and is also located in immediate proximity to the Northumberland Strait, making it the most appropriate station for comparison of climate to the BHETF.

For the Lyons Brook NS climate station, the following values and qualitative trends have been identified. Lyons Brook has only been in operation since 1984, and as such averages for the 1971 to 2000 period are based on 17 years of data, while the 1981 to 2010 period is based on the full 30 years of data. There are no climate normal data available for this location for the 1961 to 1990 period as only 7 years of data were available for that period, which is an insufficient set to generate accurate normal data.

Table 2.2 Lyons Brook Climate Indices

Climate Indices	1981 – 2010 Averages	1971 – 2000 Averages(1)	Trend
Total Precipitation (mm equiv.)	1232.2	1232.9	Steady
Spring Precipitation (mm equiv.)	277.9	278.0	Steady
Summer Precipitation (mm equiv.)	247.7	255.4	Possibly decreasing
Autumn Precipitation (mm equiv.)	381.8	370.1	Possibly increasing
Winter Precipitation (mm equiv.)	325.5	329.4	Possibly decreasing
Annual Average Temperature (°C)	6.6	6.5	Steady
Spring Average Temperature (°C)	4.2	4.3	Steady
Summer Average Temperature (°C)	17.9	17.9	Steady
Autumn Average Temperature (°C)	9.2	9.0	Steady
Winter Average Temperature (°C)	-4.9	-5.0	Steady
Note: (1)1971 to 2000 Canadian Climate Normals were reported for 17 years of data (1984 to 2000)			

2.2 Future Climate Assessment

With the release in 2013 of the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5, IPCC 2013), there are updated models, emissions scenarios, and modelled projections for global climate from the 2020s through 2100.

Global Climate Models (GCM) data is typically presented on a monthly basis, and represents the mean temperature and total precipitation. Information on extreme values is not directly available and cannot be inferred from such a broad time scale. For this reason, the climate factor trends must be developed to fully assess the impacts of the projected climate on the Project infrastructure components.

The climate factors assessed include changes to rainfall, temperature, extreme events (e.g., storms), and sea level rise. These factors are further subdivided into specific event type factors that describe long term changes such as increasing winter temperatures, or extreme events such as increased drought. These climate factors are a combination of the general trends of the GCM data and qualitative assessments from literature.

Current climate factors are based on historic climate analyses from (data sources), as summarized in Section 3.1. The future trends of the climate factors have been based on existing literature, research, and data and do not represent new calculations, assessments or analyses. Any climate indices not available in the historic record have been discussed in terms of trends identified in the literature.

The justification for the direction of each of the future climate factor trends is provided in Table 2.3 - Climate Risk Matrix below.

Table 2.3 Climate Risk Matrix

Climate Factor	Trend	Justification	Other Comments on Future Trends
Precipitation			
Frequency of Drought	Unknown		Tendency towards reduced aridity in winter and increased aridity in summer over large areas of Canada (Warren and Lemmen, 2014).
Heavy Rain	Increasing	Increase predicted based on higher rainfall volumes in the summer season.	An increase is projected for the amount of rain (Warren and Lemmen, 2014). Total annual precipitation will increase, but precipitation in the key seasons may decrease and the intensity of rain may increase (Warren and Lemmen, 2014).
Total Rainfall	Increasing	Slight increase based on higher rainfall in the spring and fall.	An increase is projected for the annual amount of rain (Warren and Lemmen, 2014). Total annual precipitation may increase but there is a decrease predicted for the summer season, and an increase in the spring and fall (Warren and Lemmen, 2014).
Total Snowfall	Decreasing	Decrease in amount of precipitation falling as snow and duration of the snow seasons decreases.	There has been a slight decrease in the amount of total precipitation falling as snow (Warren and Lemmen, 2014). Duration of the winter season is projected to continue to decrease, resulting in continued decrease in precipitation falling as snow (Warren and Lemmen, 2014).

Table 2.3 Climate Risk Matrix

Climate Factor	Trend	Justification	Other Comments on Future Trends
Snow Accumulation	Qualitative	Further assessment of trend would be required due to uncertainties in precipitation distribution.	There has been a slight decrease in the amount of total precipitation falling as snow (Warren and Lemmen, 2014).
Snowmelt	Qualitative	Further assessment of trend would be required due to uncertainties in precipitation distribution.	Reduced snow cover is expected, with the largest changes in maritime mountain regions, i.e., Canada's west coast (Warren and Lemmen, 2014).
Ice Storms/Freezing Rain	Unknown	Slight increase in temperature will create a vertical temperature profile that is conducive to freezing rain events.	An increase in the frequency and duration of freezing rain events has been observed and is predicted to increase in Ontario, the trend in the Atlantic region is uncertain (Berry et al, 2014).
Rain on Snow Events	Increasing	Increase in winter temperatures increasing the frequency of freeze-thaw events.	Increasing temperatures in winter may lead to increased incidence of winter precipitation as rain (CCME, 2003).
Temperature			
Freeze-Thaw Cycles	Increasing	Increase in winter temperatures increasing the frequency of freeze-thaw events.	Preliminary studies indicate that in much of Canada, freeze-thaw cycles are occurring more often, likely in response to increasing winter average temperatures. Trend strongest in southern Ontario and weakest in British Columbia (CCME, 2003).
Flash Freeze Events (Rain/Freeze-Thaw)	Increasing	Further assessment of trend would be required due to uncertainties in precipitation distribution.	Freeze-thaw events are projected to increase for much of Canada (Audrey et al., 2014).
Snowmelt	Qualitative	Further assessment of trend would be required due to uncertainties in precipitation distribution.	Reduced snow cover is anticipated, with the largest changes in maritime mountain regions (Warren and Lemmen, 2014).

Table 2.3 Climate Risk Matrix

Climate Factor	Trend	Justification	Other Comments on Future Trends
Extreme Heat	Increasing	Increase based on increase in average summer temperatures.	Rare hot extremes are currently projected to become more frequent, such that a 1-in-20 year extreme hot day is projected to become about a 1-in-5 year event by mid-century (Warren and Lemmen, 2014).
Extreme Cold	Decreasing	Decrease based on increase in average winter temperatures.	Decrease in frequency and magnitude of unusually cold days and nights (Warren and Lemmen, 2014).
Cooling Degree Days	Increasing	Increase based on increasing average summer temperatures.	Increases in cooling degree days have been smaller and less widespread than the decreases in heating degree days (CCME, 2003).
Heating Degree Days	Decreasing	Decrease based on increasing average winter temperatures.	Warmer winters are projected (Bush et al., 2014). Increases in cooling degree days have been smaller and less widespread than the decreases in heating degree days (CCME, 2003).
Average Temperature	Increasing	General warning trend in Canada has been observed since the 1950s.	Magnitude of project warming varies substantially with emissions scenario, but warming trend will be most noticeable in winter (Warren and Lemmen, 2014).
Frequency of Extreme Temperatures	Unknown	Possible increase in extreme temperatures, but strength of trend is unknown.	Any increase in the length and/or frequency of heat waves has not been found (Bush, et al., 2014).
Sea Surface Temperature	Increasing	Warming trend measured over past 60-80 years off Canada's Atlantic and Pacific coasts	Warming trend not consistent over all regions, and may be related to increasing air temperatures. Widespread warming of upper ocean around Canada predicted during the 21st century, with significant seasonal and spatial variability (Bush, et al., 2014).

Table 2.3 Climate Risk Matrix

Climate Factor	Trend	Justification	Other Comments on Future Trends
Other			
Sea Level	Increasing	Observed increase in mean sea level of 21 cm from 1880 to 2012.	Projected global sea-level rise for the 21st century, with estimates ranging from 20 to 80 cm or more by year 2100, depending on emissions scenario due to a combination of land subsidence in the Maritimes, and increase in sea volume (Warren and Lemmen, 2014).
Extreme Water Levels	Increasing	Likely to increase as a result of increasing sea level.	An increase in extreme high water levels is projected, corresponding to an increase in sea level and sea ice changes, although tides, storm surge, and waves will continue to play prominent roles (Warren and Lemmen, 2014).
Extreme Weather Events	Increasing	Increase in predicted extreme weather (storm events).	Extreme wind events are projected to increase with continued climate change, including the increasing incidence of extreme weather (e.g., thunderstorms, lightning, tornadoes, hailstorms, hurricanes, storm surge) (Warren and Lemmen, 2014).
High Humidity Periods	Increasing	Slight increase based on increasing precipitation and increase in temperature	Projected increases in temperature and precipitation will increase evaporation (Bush et al., 2014).
High Winds	Increasing	Increase in predicted extreme weather (storm events), including high winds.	Extreme wind events are projected to increase with continued climate change, including the increasing incidence of extreme weather (e.g., storms), such as Atlantic hurricanes (Warren and Lemmen, 2014).

3. Potential Climate Infrastructure Interactions

In keeping with the Federal-Provincial Guidance for Considering Climate Change in Environmental Assessment (FPTCCCEA 2003) and Nova Scotia Environment's Guide to Considering Climate Change in Environmental Assessments in Nova Scotia (Nova Scotia Environment 2011), GHD has examined the potential effects of a changing climate on the Boat Harbour Remediation Project, and the infrastructure which will remain following the completion of the remediation plan. Potential climate-infrastructure interactions have been identified below, and interactions have been analyzed for significance. The potential future climate is described using climate factors that are based on potential changes to climate normal and extreme events for sea level rise, extreme weather events, wind, temperature, and precipitation that have the greatest potential to impact the Project or permanent future infrastructure.

The effects of climate change on infrastructure are typically noticed over a climate normal period (typically 30 years), if not longer. With the exception of the infrastructure that may remain on site and require long term management following the remediation and closure of the Boat Harbour treatment facility (e.g., the bridge passing over the tidal estuary; the pipeline to be cleaned, filled in some sections and abandoned; and the sludge disposal area), most facilities and infrastructure in the Project area are anticipated to be removed, or allowed to be naturally reclaimed over a period of about 5 years, therefore, climate change is likely not to have significant effect on infrastructure during the remediation process. Through Remediation Planning and Design of the Project, the remaining infrastructure will be stabilized or built such that effects due to climate change will not be significant.

The detailed design of the infrastructure to remain on-site will be based on established guidelines and engineering practice, and will consider extreme meteorological events. For example the bridge has been designed taking into consideration the current 1-in-100 year storm surge high high water, and the anticipated sea level for the year 2100. It is not anticipated that additional measures or adjustments will be required to address predicted climate change over the lifetime of the infrastructure (approximately 75 years). Over periods of less than 20 years, the inter-seasonal variability in weather is much greater than the decadal shifts in temperature, precipitation trends, or likely extreme weather events. Due to the short time frame of the remediation phase of the project, the potential effects of climate change on infrastructure or operations during this phase is considered to be negligible.

A qualitative assessment of potential climate-infrastructure interactions that may affect the effectiveness or performance of specific facility/infrastructure is provided in Table 3.1, for general climate factors (temperature, rain, snow, mixed events, and sea level rise). In this table, interactions that require further assessment for the infrastructure component are indicated by boxes containing a "Y". All other interactions are not discussed further.

Table 3.1 Climate Matrix

Infrastructure Component	Sea Level	Extreme Weather Events (e.g., Storms)	High Winds	Temperature	Precipitation
During Remediation					
Pipeline removal and/or filling	N	N	N	N	N
Sludge removal from settling and stabilization basins	N	N	N	N	N
Sludge disposal area construction	N	N	N	N	N
Bridge construction	N	N	N	N	N
Dam removal	N	N	N	N	N

Table 3.1 Climate Matrix

Infrastructure Component	Sea Level	Extreme Weather Events (e.g., Storms)	High Winds	Temperature	Precipitation
After Remediation					
Bridge	**Y**	**Y**	N	N	N
Roads	**Y**	**Y**	N	N	N
Buildings	N	N	N	N	N
Abandoned pipeline(s)	N	N	N	N	N
Sludge disposal facility	N	**Y**	N	N	**Y**
Estuary biodiversity/vegetation	**Y**	**Y**	N	**Y**	**Y**

Climate/infrastructure interactions following the completion of remediation has more potential to be significant as long-term trends are likely to influence remaining infrastructure and activities, such as leachate generation at the sludge disposal facility, and the use of the bridge and remaining roads. These potential interactions have been considered by water and waste management, and bridge design engineers and experts, to assess the potential impact, and to determine if additional mitigation or design may be required.

The remedial works required for BHETF are summarized in Section 2, including the planned removal and management of the sediments and sludge from the settling, stabilization basins and wetlands, the pipeline, causeway, and dam, and the addition of a bridge for Highway 348.

The remediation plan is still currently under review. Detailed design for infrastructure will be approved and administered through appropriate Provincial channels according to best engineering practices and taking into account the future predicted high water levels in the area, and 1-in-100 year precipitation events. A summary of the current future climate-infrastructure assessment is provided in Table 3.2 below.

Table 3.2 Climate Resilience Assessment

Climate Factor	Project Resilience Assessment
Sea Level	• The bridge across the estuary has been designed using the predicted sea level for the year 2100, including the current 1-in-100 year storm surge and precipitation intensity-duration-frequency (IDF) allowing existing and future small craft access to the estuary. • The bridge will connect existing Highway 348 sections, which are all significantly above existing and future 1-in-100 year storm surge and predicted high high water level. • Potential effects of rising sea level on bridge maintenance are being modelled and will be addressed through armoring. • The sludge disposal facility is located at a point approximately 8 m higher above sea level than the current high water mark at the nearest point in the Boat Harbour estuary, it is unlikely that sea level rise will be a factor for this facility.

Table 3.2 Climate Resilience Assessment

Climate Factor	Project Resilience Assessment
	• The dredged estuary will be allowed to return to a natural state, rising sea levels will raise water levels in the estuary. There will be no Facility infrastructure built along the edges of the estuary to be affected by rising sea levels.
Extreme Weather Events (e.g., Storms)	• The bridge across the estuary has been designed using the predicted sea level for the year 2100, including the current 1-in-100 year storm surge and IDF allowing existing and future small craft access to the estuary. • The bridge will connect existing Highway 348 sections, which are all significantly above existing and future 1-in-100 year storm surge and predicted high high water level. • Potential effects of increased storm surge on bridge foundation is being modelled and impacts will be mitigated using through armoring. • Stormwater runoff at the sludge disposal facility will be managed in accordance with Provincial regulations for similar waste management facilities, the stormwater management system has been designed based on the current 1-in-100 year storm IDF. • The dredged estuary will be allowed to return to a natural state, rising sea levels will raise water levels in the estuary. There will be no Facility infrastructure built along the edges of the estuary to be affected by storm water surge.
Temperature	• Plant biodiversity in the area may be affected by increasing temperatures, the lengthening of the growing season, and the shortening of the winter senescence season. The dredged estuary will be allowed to return to a natural state, including the revegetation process.
Precipitation	• The sludge disposal facility has been designed including a low-permeability liner to prevent the movement of potentially contaminated leachate into the groundwater. This liner has been designed to meet current best practices. There is an existing monitoring well network to test groundwater quality and monitoring will continue post-remediation. • Stormwater runoff at the sludge disposal facility will be managed in accordance with Provincial regulations for similar waste management facilities. The stormwater management system includes stormwater runoff ditches, sized to accommodate a 1-in-25 year storm event (under post-closure/capping conditions), and a stormwater management pond, sized to accommodate a 1-in-100 year storm event. • Plant biodiversity in the area may be affected by changing precipitation patterns. The dredged estuary will be allowed to return to a natural state, including the revegetation process.

4. Conclusions

The climate trends for the region indicate that the region is very likely to experience significant sea level rise and an increase in extreme high water levels as a combination of increasing sea level, increasing extreme weather and high winds and the resulting storm surge. Precipitation is also likely to be increasing, and the trend is toward more precipitation falling as rain than as snow. In the future, less frequent but more intense precipitation events (compared to current conditions) are reasonably expected. Temperatures are also generally increasing, more noticeably in the winter months.

During the remediation phase of the Project, climate facility-infrastructure interactions do not require further consideration of the potential effects of a changing climate, beyond those measures incorporated in the planning and design process, due to the short timeline for this phase.

The climate-infrastructure interactions where a changing climate may require further consideration are projected to take place post-remediation. The design height of the bridge already takes into account the predicted sea level for the year 2100, current 1-in-100 year storm surge, and high high water levels assuring small craft access to the estuary under existing and future climate conditions, however the potential effects of increasing sea levels and added storm surge on bridge maintenance and upkeep are currently unknown. Changes in overall precipitation are unlikely to significantly influence the generation and concentrations of contaminants in the leachate from the sludge disposal facility, which will continue to be monitored through the post-closure phase. Changes in climate may affect the growth of vegetation in the area, potentially impacting naturalization of the remediated lands, which will be allowed to proceed naturally. Rising sea levels will likely create more saltwater wetlands in the area than exist currently.

Based on this assessment, it can be concluded that the effects of a potentially changing climate on the remediation of Boat Harbour are being suitably addressed through detailed engineering design and construction standards.

5. References

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All of Which is Respectfully Submitted,

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Source: Imagery @2017 Google CNES / Airbus, DigitalGlobe, Landsat / Copernicus

0 200 400 600
Meters

Coordinate System:
NAD 1983 CSRS UTM Zone 20N

N

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NOVA SCOTIA LANDS INC
BOAT HARBOUR REMEDIATION PLANNING AND DESIGN, PICTOU LANDING, NS
CLIMATE CHANGE RESILIENCE ASSESSMENT

11148275-24
May 15, 2018

SITE STUDY AREA

FIGURE 1

GIS File: I:\GIS_DATA\Projects\8-chars\1114----\11148275 Boat Harbour\11148275-REPORTS\11148275-Rpt-14\11148275-24(014)GIS-DA001.mxd

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